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GEOLOGICAL SURVEY BULLETIN

No. 21

The South Heemskirk Tin Field

BY

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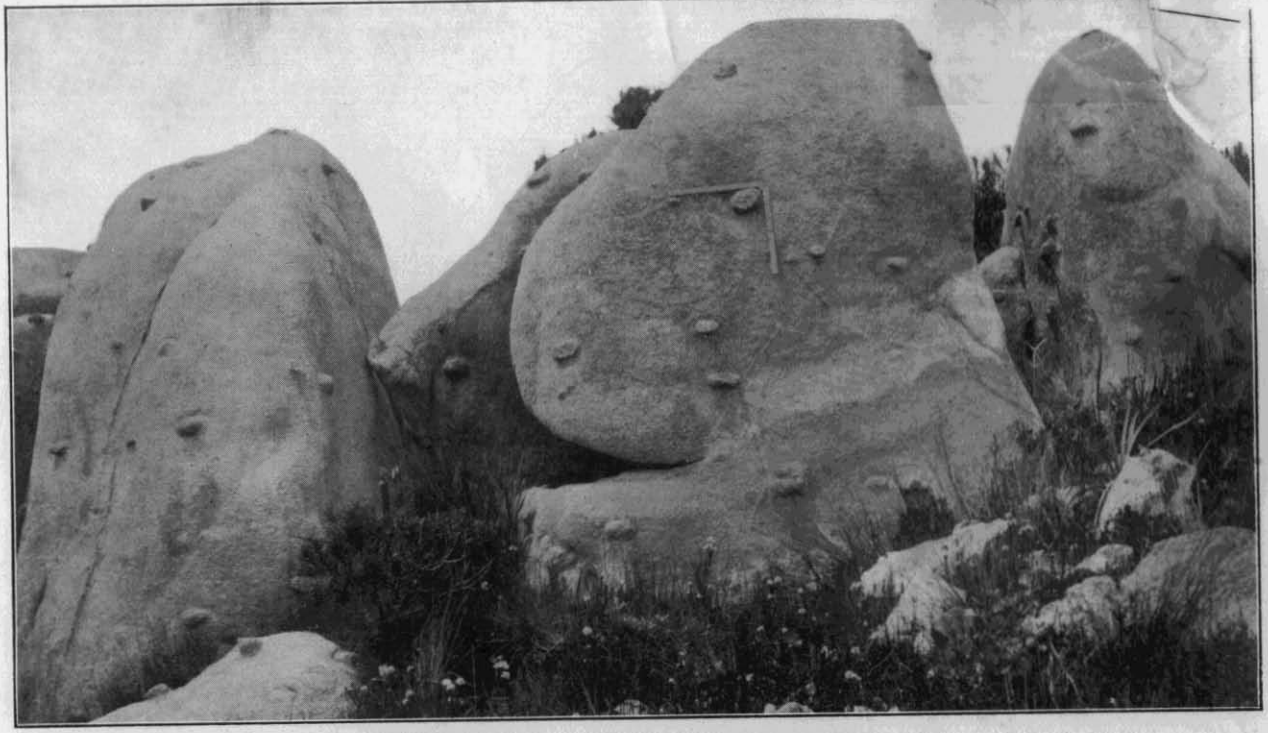


PHOTO. 1—NODULAR GRANITE. QUARTZ-TOURMALINE NODULES STANDING OUT IN RELIEF FROM WEATHERED SURFACE OF "WHITE" GRANITE.

[L. Lawry Waterhouse, Photo.

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LOCALITY MAP

Photo Mcgraphed by John Vail, Government Printer Hobart Tasmania

The South Heemskirk Tinfield.

I.—INTRODUCTION.

(*a*) *General.*

Tin was discovered in the Heemskirk district nearly 40 years ago, but, considering the time which has elapsed since mining operations were commenced, a surprisingly small amount of work has been done. In the earlier period of its history the field was boomed, and many thousands of pounds were spent, a large number of men being employed. An attempt is made in the course of this bulletin to investigate the resources of the district, to try and determine what grounds existed for the earlier boom, and to enquire into the causes of the present inactivity. In conducting such an investigation, it is essential that the geological structure of the district should be understood, as also the structure of the ore-bodies, their relationships to each other and to the various rock-types, and these problems are discussed in the course of this report.

The district to the north, comprising the North Heemskirk mining properties, has been dealt with by the writer in a separate publication, to which the reader is referred.(1)

(*b*) *Geographical Position and Access.*

The district under review, as will be seen by reference to the accompanying locality map (Plate I.), is situated on the extreme west coast of the island, and comprises a strip of country extending from the Little Henty River on the south to a stream known as Granite Creek on the north, with a width of 5 to 6 miles. The northern and eastern boundaries are not well defined, for the field adjoins the North Heemskirk field on the one hand, and the Comstock on the east, the latter merging into the Zeehan field; consequently, it will be seen that the boundaries are defined largely as a matter of convenience for descriptive purposes, although on the east the mineralogical composition of the lode formations forms an additional reason for the division.

(1) *Vide* Geol. Surv. Tas. Report 6: "Reconnaissance of the North Heemskirk Tinfield," by L. Lawry Waterhouse, 1915.

With reference to the other mineral fields, Zeehan is about 7 miles distant by air-line to the east, the Stanley River field about 15 miles to the north, and Mt. Lyell about 20 miles to the south-east.

The inaccessibility of the district in the early days of its exploitation proved one of the most serious drawbacks to its active development, and has hampered progress right up to the present time. It must be borne in mind that at the time of the discovery and early working of the Heemskirk field, Zeehan was still unknown, and consequently there was no railway connecting the West Coast with the rest of the State. Access was obtained by way of Trial Harbour, an open roadstead exposed to the full force of the weather from south to north-west. The coast in the vicinity is treacherous, with long rocky points running out seawards, in some instances covered only at high tide. Between two of these points a jetty was erected, which carried a travelling crane; in favourable weather the steamer anchored some distance out. The cargo was unloaded on to lighters, and brought alongside the jetty; being transferred to carts, it was taken to its destination. Frequently boats would approach, but be unable to land their cargo for several days. It will readily be understood, then, that the inaccessibility of the field in the early days must have been a serious drawback to its advancement. Later on, when Zeehan was established, all necessaries were brought to that town by rail, and carted thence. The road is very rough at its best, and the grade steep in places, the distance from Zeehan to the Federation Mine being about 14 miles. Consequently the weight of machinery which can be carted is limited, and the expense of carting high. These factors have certainly had some influence in retarding the progress of the district.

At this time Remine (as the settlement at Trial Harbour was called) boasted two hotels and a post-office, being connected with Waratah (*via* Corinna) by telegraph, and was considered quite a flourishing little township. At the present time desolation reigns supreme. No house remains standing, and the site of the township is practically obliterated by the dense scrub which has sprung up and spread in every direction. The reason for this is apparent. When the Zeehan field was discovered Remine was doomed. A road was constructed at a cost of £32,000, according to official figures, connecting Trial Harbour with Zeehan, and this road has since served the Heemskirk field, for although in Zeehan's early history all necessaries were landed at Trial Harbour and carted to Zeehan, and there were 100 teams engaged at one time in this work, yet when the railway was

brought through, first from Strahan to Zeehan, and later from Burnie to Zeehan, Trial Harbour, having no merits of its own, fell into disuse, and Remine disappeared. In the early days Remine was also connected with Corinna, and this old road served the Heemskirk field.

The present condition of the road connecting South Heemskirk with Zeehan is far from satisfactory. The grade on the whole is good, although deviations at several points are required, and would have to be constructed if continuous heavy carting were required. When the road was originally constructed, little provision was made for carrying off the surface-water, which is considerable, as the rainfall approaches 100 inches per year. The effect of such a heavy rainfall on a road-surface on which there is not much traffic will be obvious. Gutters have formed, particularly in the wheel-tracks, and with continued scour combined with want of attention these have deepened until in some places the gutters are from 2 to 3 feet deep. In many places the whole of the macadam has been sluiced away, leaving the bare bed-rock. Under these circumstances it is not surprising that carting is a rather expensive item. The distance by road from Zeehan naturally varies for the different properties, being about 12 miles to the turn-off of the Trial Harbour Road; the distance is about 1 mile from here to the site of the old township of Remine.

Although necessaries are at the present time carted by road from Zeehan, there is a steel tram-line of 2-feet gauge constructed to Comstock, between 6 and 7 miles, which could be utilised if necessary for this distance. A continuation from the present terminus does not appear practicable, and connection would have to be made at a point nearer Zeehan than the terminus.

The want of better facilities has had its effect in retarding the progress of the district.

II.—PREVIOUS LITERATURE.

Several official reports have been issued in the past dealing with the whole or portions of the South Heemskirk Tinfield.

The list includes the following:—

(1) Reports on the Mineral Districts of the West Coast of Tasmania—No. 1, Pieman River Goldfield; No. 2, Mt. Heemskirk—June, 1881, by Mr. G. Thureau.

(2) An Interim Report on the Stanniferous Deposits at Mt. Heemskirk, August, 1882, by Mr. G. Thureau.

(3) Parliament of Tasmania, No. 89, June, 1884, Western Mining Districts, by Mr. G. Thureau.

(4) Interim Report on the Progress of the Mineral Fields of the County of Montagu, April, 1893, by Mr. A. Montgomery, M.A.

(5) Report on the Progress of the Mineral Fields of the County of Montagu, May, 1893, by Mr. A. Montgomery, M.A.

(6) Report on the Progress of the Mineral Fields in the Neighbourhood of Zeehan, May, 1895, by Mr. A. Montgomery, M.A.

(7) Report on the Mineral Districts of Zeehan and Neighbourhood, October, 1900, by Mr. W. H. Twelvetrees.

(8) Report on the Tin-ore Deposits of Mt. Heemskirk, September, 1902, by Mr. G. A. Waller.

Of the above reports, No. 1, by Mr. G. Thureau, in 1881, is out of print, and no copy was available even for reference. The lastnamed, No. 8, by Mr. G. A. Waller, is the most valuable, dealing with the geology of the district in a more detailed manner than any of the others. It is accompanied by four useful plans of mining properties. In some cases no work of any description has been done on mining properties since Mr. Waller's inspection of the field, and his report still holds good.

III.—PHYSIOGRAPHY.

(1)—Topography.

(*a*) *General Description.*

The general topographical features of the district under review are distinct and easily recognisable, and as such may conveniently be dealt with separately.

Briefly described, there are two physiographical units; the Heemskirk Range occupies the eastern portion of the area, while the western and southern portions are occupied by the coastal peneplain, which also extends a considerable distance to the north of the area dealt with in this publication.

The Heemskirk Range rises abruptly above the level of the plain to a considerable height, and is striking when viewed from the sea-coast.

The eastern drainage is divided between the Pieman and Little Henty Rivers, but belongs mainly to the former. The Little Henty and its tributaries drain the southern and south-western area, while the western and part of the northern drainage is carried direct to the sea by a number of short consequent streams. Tributaries of the Pieman River drain most of the northern portion of the district.

The coast-line, which forms the western boundary of the area, is rocky, with numerous jutting reefs exposed at low tide, but regarded as a whole the coast-line is regular. There are no true harbours, although Trial Harbour (so-called) is an open roadstead which acted as a port for the district in the earlier portion of its history.

Further comments on the various features will be made under separate headings.

(*b*) *Mountains.*

The mountains of the district belong to one physiographical unit, the Heemskirk Range. Speaking broadly, the range is simple, with few important spurs. To the north it is more irregular, but its general features in this area have recently been described by the writer.[2] The most important spur to the north is the North Heemskirk Spur, of which the culminating peak to the south is Gap Peak. The Spur is connected with the main range by a

[2] *Vide* Geol. Surv. Tas. Report 6, pp. 1-2.

saddle, known as " The Gap," which aneroid readings indicate has an elevation of about 1200 feet above sea-level, or 650 feet above the creek at its base (the aneroid reading at Granite Creek indicating 550 feet). Gap Peak is about 1400 feet above sea-level.

The main range is about 5 miles in length, and has a general bearing of north-west. It runs approximately parallel to the coast. As viewed from a distance, it is seen to have a generally level crest, broken by a few rounded peaks rising from 100 to 200 feet above the general level of the range, which is about 2600 feet. The main peaks of the range are Mts. Agnew and Heemskirk, the southern and northern culminating peaks, and rising to 2800 and 2700 feet above sea-level respectively. Between these are several other peaks which have received no names. Mt. Agnew, 2800 feet, appears to be the highest point of the range. Although a distant view indicates that the crest of the range is comparatively level, a closer acquaintance very soon dispels the illusion, and shows that the " simple ridge " cannot be scaled with impunity. The body of the range is rugged, and is found to be cut up into gorges by the various watercourses, and most of these gorges are filled with almost impenetrable timber and scrub. The main range slopes steeply to the east and west.

Mt. Agnew itself is a rounded conical peak, connected by a saddle with another peak a short distance to the north, but otherwise isolated. It forms a prominent landmark for many miles around. Its summit is rounded in the manner so typical of granite peaks. It may be well to call attention at this juncture to an apparent anomaly which has crept in with regard to the naming of this peak. This matter was suggested to the writer by Mr. A. Yates. It is a matter of history that two prominent peaks were sighted by Tasman in 1642 when sailing along this portion of the coast, and were named by him Mts. Zeehan and Heemskirk respectively. Mt. Zeehan is an isolated peak standing out so prominently that it could scarcely be mistaken, but the peak now called Heemskirk is at the north end of the field, and cannot really be called prominent. It consists rather of a ridge with several smaller peaks, and the highest point appears to be approximately 100 feet lower than Mt. Agnew. Again, when the range is viewed from the west, the latter certainly is the prominent peak. From its shape, too, it would command attention rather than the northern peak. It seems feasible, then, that the peak now known as Mt. Agnew was the original Mt. Heemskirk of Tasman. Some confirmation of this view is afforded by the Admiralty



PHOTO. 2—THE CUMBERLAND DAM, LOOKING SOUTH-EAST.

[L. Lawry Waterhouse, Photo.

chart, on which the peak shown as " Mt. Heemskirk " corresponds as regards bearings and distances with that now known as Mt. Agnew. It is interesting to notice that on this chart the peak is described as being visible for 30 miles. No change from the established usage is even suggested, as no useful purpose could be served, and only confusion would result.

It is worthy of note that the Heemskirk Range is approximately the same height as the Parson's Hood Range, a few miles to the north,[3] and that between the two the country is comparatively low-lying. Reference is made to this fact and its significance elsewhere.[4]

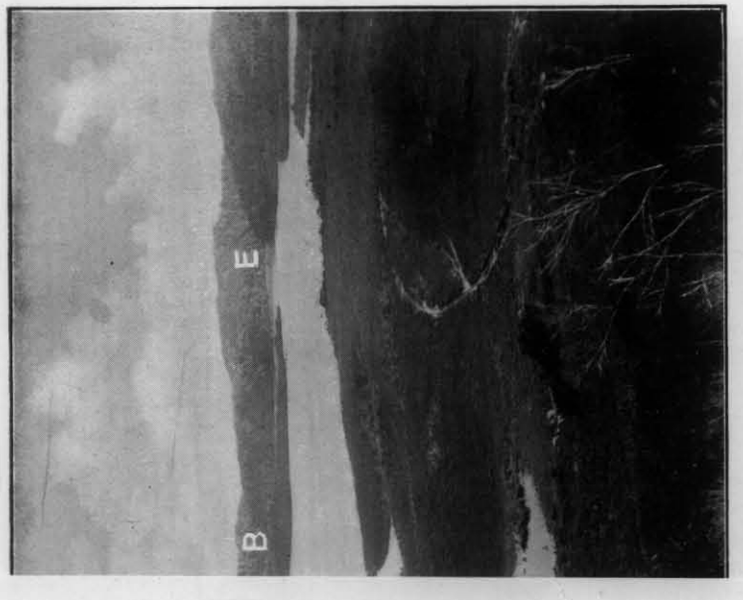
The Heemskirk Range is composed entirely of granite, and its rounded peaks owe their form to the characteristic weathering of this rock. It is possible that the outline of the range may have been somewhat modified by ice action. The evidence for this assumption is not very strong, but mention must be made of a peculiar, but economically very important, feature, *i.e.*, the development of a hanging valley at a considerable elevation above sea-level. The hanging valley referred to is that in the bed of the Cumberland Creek, now occupied by the artificially-formed Cumberland Dam. It is situated at the foot of Mt. Agnew, at an elevation of about 1350 feet above sea-level. Mt. Agnew slopes steeply and, generally speaking, regularly from the summit to the valley of the Cumberland Creek. To the north and north-west the range rises steeply, forming an amphitheatre. Packer's Creek has cut back into the range, but not far enough to capture the head waters of the Cumberland Creek, and here the divide between the elevated drainage of the Cumberland Creek and that westward into the ocean is lower. It rises again to 1750 feet on the highest part of the Federation property in the vicinity of Munro's shaft, and then falls again, averaging about 1550 feet (or 200 feet above the dam) on the south-west and south. From this watershed the slope eastward to the creek is gradual. To the south there are several gorges, nearly at the same level along the divide, but one of these formed the natural outlet for the water of the Cumberland Creek. When a barrier was built across this creek to dam back the water,[5] a race but a few feet deep allowed the overflow from the dam to escape by another creek-channel, showing the difference of level was small. The fall of the Cumberland Creek to the

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(3) *Vide* Plate II., Geol. Surv. Tas. Bulletin 15.

(4) *Vide infra*, pp. 17–19.

(5) For description of Cumberland Dam, see pp. 24–26.



[L. Lawry Waterhouse, Photo.

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(3) *Vide* Plate II., Geol. Surv. Tas. Bulletin 15.
(4) *Vide infra*, pp. 17–19.
(5) For description of Cumberland Dam, see pp. 24–26.

south, a few chains below the present embankment, is precipitous. Above the embankment the grade is small, not more than 25 feet per mile. It extends gradually in this way northwards to the foot of the hills which rise steeply to the summit of the main range, from which it is fed. Not only to the south of the dam, but also to the west, the range falls away steeply from the " rim " of the hanging valley. This description of the valley is necessary to make clear the following discussion. The actual form of the valley is far more striking than a mere description can be. In seeking for an explanation of the particular form of the valley, the writer came to the conclusion that it represents a glacial cirque, or hanging valley, which has at one time been occupied by a valley glacier. There is practically no evidence to support this theory. The rounded form of some of the hillocks on the eastern slope is suggestive, but inconclusive, evidence of *roches moutonnées*. It must be borne in mind that weathering agencies have been at work for so long, and degradational forces so active, that all positive traces on the rock surfaces would have been destroyed in the case of such a rock as granite. There is one other feature which should be noted. On the Federation lease, No. 3917M, and on the southern slope of the hill a few chains west of the Long Tunnel, is a curious heap of quartz-tourmaline stone, at about 80 feet above the level of the dam. The stones are obviously from different points, and do not resemble the quartz-tourmaline outcrops immediately at hand. A good deal of the material resembles that from the vicinity of the Black Face on the opposite slope of the hill. The boulders are angular and sub-angular, inclined to be flat, and are roughly graded. There is practically no very fine material, but a good deal about 3 or 4 inches, and many boulders from 8 to 10 inches across and up to 18 inches. The heap is, perhaps, a chain in length, 15 feet in width, and 3 to 4 feet in depth.

A somewhat similar heap occurs about a quarter of a mile to the west, just over the western fall of the hill, and higher than the heap just described. This heap consists of similar material throughout, being sub-angular quartz-tourmaline stone with quartz and green tourmaline. This material is similar to a quartz-tourmaline outcrop about 2 chains up the slope of the hill. The heap is about 1 chain long, 10 feet wide, and 3 feet deep. There is no fine material, but the boulders appear to have been sorted, one heap consisting of stones from about 2 to 6 inches, the other from 6 to 18 inches.

In the case of both heaps there are bushes of some size growing about and through the heaps in such a way as to

indicate clearly that they must have been in position for many years. They may possibly be artificial, the stones being collected and stored for some purpose at the spots noted, but no information is available concerning them, and it is difficult to imagine that they could have been collected in such positions away from any track or tramway, as no useful purpose could possibly be served, and the material for the heap near the Long Tunnel must have been carried a considerable distance. They are not in any watercourses, and a striking feature is that similar material is not found in any quantity lying about in the vicinity. No other such heaps were noticed, although most of the country round the northern end of the dam is very heavily timbered, and could not be examined.

Can these heaps be remnants of morainal deposits? There is much against such a theory, and it cannot be insisted on. Larger heaps would be expected, with larger and more irregular boulders. If denudation had removed more extensive portions of such deposits, remnants would be exposed in the lower part of the catchment; also other remnants at about the same level would be expected.

However, from the form of the valley the writer is inclined to assume that it has been formed by glacial action.

With regard to the mountain range as a whole, a remarkable feature is its lineal extension in a direction parallel to the coast-line. The geological structure of the range is dealt with elsewhere, and it is shown that the range is composed of granite which has been forced up into the overlying strata, along a plane of crustal weakness. As described elsewhere, the present coast-line is due to faulting, although at a much later period than that at which the granitic intrusion took place, indicating that the forces acting at different periods set up strains in the rock-mass which were relieved by parallel fracturing.

The Heemskirk Range is composed almost entirely of granite.

(c) *Coastal Peneplain.*

From any point on the Heemskirk Range from which a panoramic view of the surrounding country is obtainable, the observer is struck by the remarkable appearance of the country to the west, south, and east. The same applies to the country to the north, but a description of this area does not come within the scope of this report. The striking feature of this country when viewed from a distance is its remarkably even surface. Mention has already been

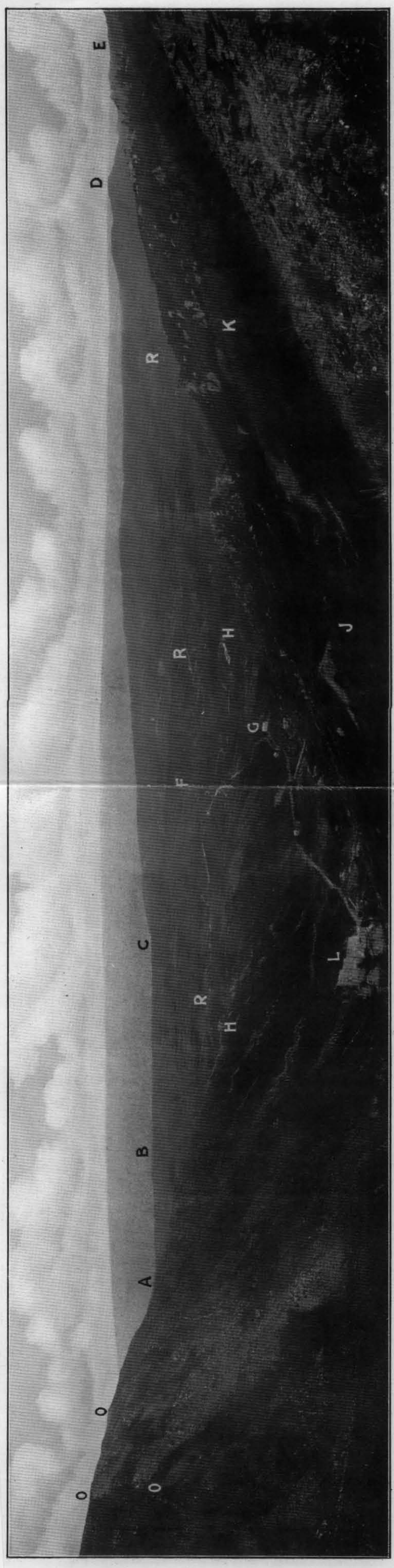


PHOTO. 3—PART OF COASTAL PENEPLAIN, LOOKING WEST FROM TOP OF FEDERATION HAULAGE. FEDERATION BATTERY IN FOREGROUND. [L. Lawry Waterhouse, Photo.

made of the generally level appearance of the Heemskirk Range when viewed from a distance: the low country, however, appears to form an extensive plain, stretching westwards to the coast, southwards for many miles beyond the Henty River, eastwards to the foothills of Mt. Zeehan and Mt. Dundas, and northwards beyond the Pieman River.

The general appearance of this country has been described as being that of a continuous plain, when viewed from an elevation such as the summit of Mt. Agnew, or any of the higher peaks or spurs of the Heemskirk Range. In reality, however, in travelling over it, the observer sees little resembling a plain, as the actual surface is very uneven, being divided into steep ridges and narrow valleys (towards its western extension) by the various streams: at close range it is probably the extremely uneven nature of the country which most impresses one. In reality, the level appearance of the country is due to the various ridges being of sensibly equal height. These ridges in fact represent remnants of an old peneplain, which has been dissected by various streams owing to an uplift of the land surface relative to sea-level.

At this stage it is proposed to deal with the portion of the old peneplain lying between the Heemskirk Range and the coast, and its extension to the south and south-west of the range, to the Little Henty River.

This coastal plain was recognised by Messrs. Twelvetrees and Ward, and referred to in their bulletin on the Zeehan Field.(6)

The general height of the peneplain at the base of the range is 700 feet above sea-level, and the average height near the coastal cliffs (which varies from point to point) may be taken as 500 feet. Thus the average slope seawards would be about 100 feet per mile. The variation at different points is considerable, some recorded readings indicating a slope of as much as 80 feet, others 150 feet, per mile. The figure given above, however, is in the writer's opinion about an average value for the gradient. The variation is caused by the difficulty in determining (*a*) the extension of the peneplain eastwards, *i.e.*, deciding just where the plain begins and the foothills of the mountain range end, and (*b*) the extension of the peneplain westwards towards the coast, on account of the more rapid wearing down of the coastal cliffs than of the general level of the peneplain.

(6) Geol. Surv. Tas. Bulletin 8, pp. 10–13.



PHOTO. 4—VIEW OF PART OF THE LITTLE HENTY PENEPLAIN, LOOKING SOUTH FROM HEEMSKIRK RANGE.

[L. Lawry Waterhouse, Photo.

The width of the coastal plain varies slightly, but averages about 2 miles. West of the Gap Peak, however, the width of the true plain is practically negligible, as a spur of that peak runs down to the coast, and although it does not rise much above the general level of the plain, it is quite appreciable, and formed a ridge when the plain under consideration formed an area of low relief.

At a few points on the ridges which mark the remnants of the old peneplain, small accumulations of well-rounded pebbles were noticed: these are never extensive, sometimes loose pebbles only remaining to mark the presence of former beds of gravel. These pebbles are probably remnants of beds of alluvial material which has been deposited by the old streams when the grade of their beds became too shallow for the material brought down by the streams to be carried to the ocean. There is nothing to indicate the extent of such deposits, which have been almost entirely removed since the uplift, by the rejuvenated streams. Thus the evidence of these residual deposits of gravel on the ridges is important, as it indicates that the grade of the streams had become very flat, and that the area had been reduced almost to base level. The fact that the peneplain near the coast is about 500 feet above sea-level, as indicated by aneroid readings, shows that an elevation (relative to sea-level) of at least this amount must have taken place. It must be borne in mind that points now on the coast may have been some distance inland at the time of the peneplanation of the area. Again, denudation has lowered the height of the old surface since its uplift, and so the actual amount calculated for the uplift, from observed heights, should be increased.

The form of the coast-line is dealt with below, and it is pointed out that along the coastal cliffs it would be expected the denudation would proceed more rapidly, and the level along the cliffs would be below that of the old peneplain, as actually is the case.

(*d*) *Rivers.*

The drainage of the area is divided between the Little Henty River (for the southern portion of the district), the Pieman (for the eastern portion), and several short consequent streams flowing direct to the ocean (for the western portion). The Little Henty River drains a considerable area of country, of which the southern portion of this district is but a small area. It rises in the spurs of Mt.

Dundas, and drains the country immediately surrounding Zeehan. It drains a considerable extent of the peneplaned surface to the south-east, east, and west of Mt. Agnew, the southern extension of the same surface being drained by the Henty River. The more mature condition of the upper portion of the Little Henty River system, as compared with the lower portion, has been described by Mr. L. K. Ward,(7) and attributed by him to the controlling influence exerted by the West Coast Range conglomerate through which the river passes. In the lower part of its course, the river is seen to be immature. The banks usually slope steeply and are heavily timbered. For about a mile from the mouth the grade is flat, but then it commences to rise, and at various points (as, for instance, near the point of confluence of Burnt Bridge Creek) the rocky bed forms shallow cascades, the rate of erosion being partly determined by the nature of the bedrock. The beds of the tributary streams in this part of its course are also steeply graded as a rule. In some instances hard rock bars retard the progress of the degradation of the creek beds, with the result that alluvial deposits of small extent may be formed above these hard bars. In the case of the main river, deposits of limited extent may be formed in the same way at certain spots, but on account of the nature of the country only isolated points were visited. In the course of the last mile, where the grade is flat, small deposits of alluvium have been formed at favourable spots, as, for instance, in the bends of the river. In the vicinity of Mt. Zeehan the river was not visited, but a fine view of the shape of the valley in cross-section at different points is available from Mt. Agnew and its spurs. The river here has a typically young valley, with steeply sloping sides, and in places is a canyon excavated in the old peneplain.

The Little Henty River enters the South Pacific Ocean at the northern end of Ocean Beach. The periodical shifting of the exact point of emergence of the river deserves notice. The beach here is from 200 to 300 yards wide, and is composed at its northern end largely of fairly coarse, well-rounded, gritty sand grains. Normally the river does not cut direct through the sand beach to the ocean, but turns sharply to the south-west, and flows along the beach parallel to the actual shore-line for a considerable distance (the distance varying up to several miles) before entering the ocean. A fresh-water or brackish lagoon is sometimes formed on the beach. Another striking feature is that

(7) *Vide* Geol. Surv. Tas. Bulletin 8, pp. 12, 13.

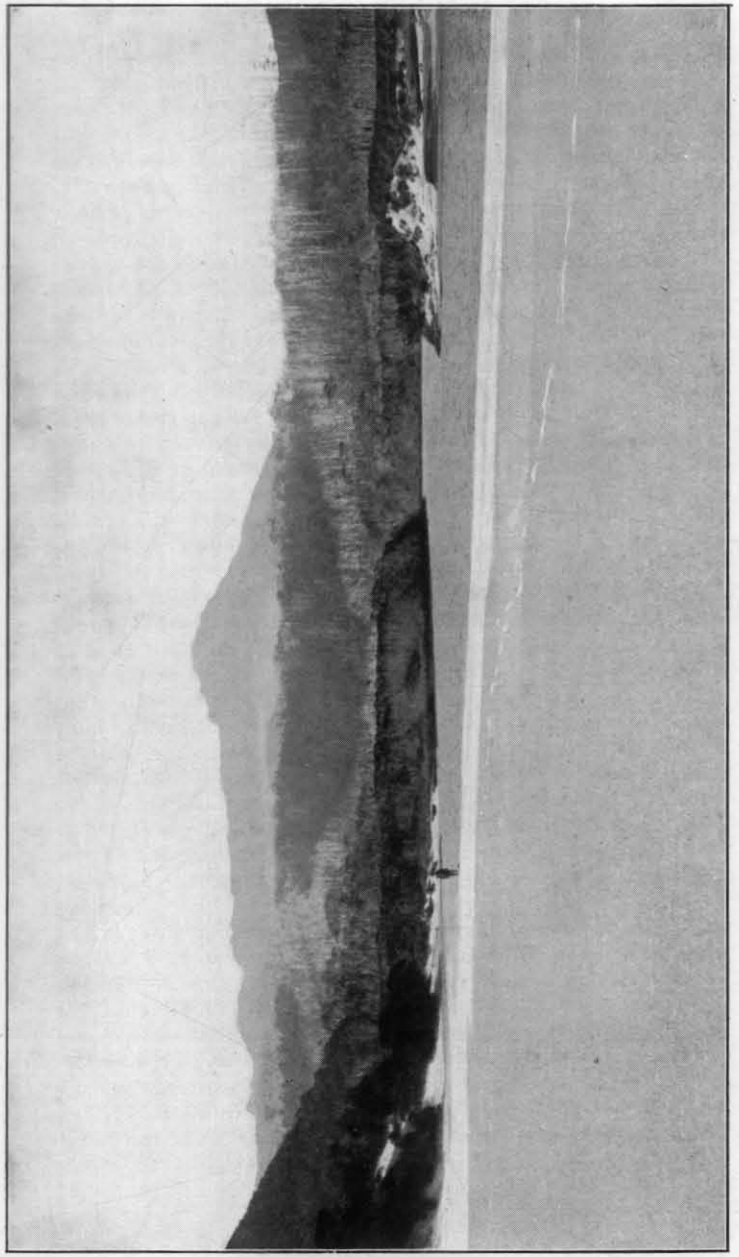


Photo. 5—Mouth of Little Henty River, showing Edge of Coastal Peneplain in Foreground, and Mt. Agnew in Background.

[L. Lawry Waterhouse, Photo.

the Henty River sometimes bends north-east and travels along the sand in a similar manner before entering the ocean: the waters of the two rivers were not seen to actually unite on the sand, although they sometimes approached to within short distances of each other. The sandbank between the river and the actual shore-line is but a few feet (average about 10 feet) above the river level, although local dunes may somewhat increase this amount at different points. At certain seasons, however, the Little Henty River behaves in a normal fashion and cuts through the sandbank at its mouth, entering the sea directly, without wandering along the beach.

The behaviour of the river at its mouth is determined essentially by (*a*) the low sand-dunes which may be banked up by prevailing winds, other determining factors being (*b*) the volume of water in the river, and (*c*) the calm or rough state of the ocean, assisted by tidal effects. The rather unusually broad beach assists in diverting the river water from entering the ocean direct.

The remaining streams of the field require little detailed notice. The western slopes of the mountain range and the coastal peneplain are drained by consequent streams, which are usually short and carry a fluctuating (but usually small) volume of water. None deserve the name of rivers. The largest of the streams are Packer's Creek (draining the country in the vicinity of the Federation Mine) and Granite Creek (draining part of the western slopes of Mt. Heemskirk and of Gap Peak). The creeks have a general westerly course to the ocean. Rising in and flowing through granite country, which is at best covered with an open sandy soil, which usually supports a growth of peaty button-grass, it is not surprising to find that the volume of water carried by most of the creeks fluctuates considerably. The soil drains fairly rapidly after rain. Where timber occurs (and thick clumps are not uncommon in the more sheltered valleys of the mountain slopes), the moisture is retained longer by these "reservoirs," and given out to the creeks more gradually.

The valleys of these consequent streams are usually more or less V-shaped in section, some showing signs of greater maturity than others. There is a striking tendency for the northern banks to slope much more steeply than the southern. The explanation of this feature is not quite clear, unless it be that a slight crustal tilting caused a raising of the southern or a lowering of the northern portion.

In most instances, while the ridges are covered with button-grass, the valleys carry more or less scrub, which,

although stunted, may be thick enough to considerably hamper the wayfarer.

The coastal cliffs are described elsewhere. As the streams reach these cliffs they plunge over as falls, the height varying with the depth to which the creeks have eroded their beds below the level of the old peneplain. The amount of erosion is usually less than 200 feet. In the case of some of the smaller creeks it is considerably less.

The coincidence of the falls with the vertical cliff face, or the distance inland they occur, also varies considerably, and depends largely on the volume of the stream and its eroding power. In the case of the larger creeks the amount which the stream has cut back into the cliff face is usually several hundred feet. This action may in certain instances be assisted by the ocean, as described below under the heading of " Coast-line."

It is clear that the streams have been rejuvenated by the recent uplift of the land subsequent to the peneplanation of the old land surface. In view of the fact that particulars are not available with regard to the course of the old streams on the coastal peneplain before its uplift, no deductions can be made from the observed amount of erosion of the beds, or the height of the streams at the coast above sea-level, as to the actual amount of erosion since the uplift of the surface. The height of the creek-beds at the top of the falls is, in the case of larger creeks, about 300 feet above sea-level, or about 200 feet below the normal level of the remnants of the peneplain at the present time.

No alluvial deposits have been formed in these streams, as the rock-waste which finds its way into the creek-beds is carried seawards since the beds are not yet graded. Alluvial deposits of small extent have been located, and in a few cases profitably worked, on the old peneplain remnants, but these represent deposits formed by the streams of the old base-levelled surface, when the grade became too flat to allow of their being carried to the sea.

(*e*) *Coast-line.*

On the whole, the coast-line is very regular, without any very marked projections (certainly none which can be definitely named), and without any really important indentations, although two (Granville Harbour and Trial Harbour) have been utilised at times commercially. The general aspect is that of a barren, wild, inhospitable, rock-



PHOTO. 6.—TYPICAL COASTAL SCENE SHOWING GRANITE CLIFFS AND EDGE OF COASTAL PENEPLAIN: LOOKING NORTH FROM CLIFF MINE.

[L. Lawry Waterhouse, Photo.

bound coast. Photo. No. 6 shows a typical peep of the coast-line of this region.

The general regularity of the coast-line is not surprising when it is realised that it has been formed by the faulting of an already peneplaned surface. It does not necessarily follow that the strand-line at the present day represents the old fault-line, and it is in fact unlikely that it does so, since marine erosion has been active, and must to some extent have modified the form of the strand-line. This modification has been assisted by the character of the rocks, and also by their structural features. The granite is usually hard and resistant, and often the contact-rocks form small projecting rocky points along the coast, owing to their hardness and resistance to the attacks of chemical agencies. The serpentine has been worn down with comparative ease. The way the structural features of the rocks may modify the sculpturing of the coast-line, and assist the ocean in its work, is well illustrated by Photo. No. 8, which shows how the parallel fissuring of granite on the coast assists the sea in its inroads.

The streams are not of sufficient magnitude to have any very marked effect, but still the effect is noticeable, and slowly but surely the tendency is to form indentations in the coast-line where the streams empty from the raised land surface.

At different points along the coast-line are isolated rocks separated from the land, but no islands occur.

Flat jutting reefs occur at several points, particularly at Trial Harbour; the "harbour" is, in fact, formed by two such reefs. The southern is the more prominent, and extends seawards for several chains; it is uncovered at low tide, but always covered at high water, when it forms a dangerous point. It is really a flat ledge of serpentine which has been worn down by wave-action. The northern reef of the "harbour" is not so prominent, and is covered even at low water, although here, as at several other points along the coast, the presence of the rocky ledge at no great depth is made evident by the breaking surf. These jutting reefs are illustrated in Photo. No. 7, which gives a good idea of the southern portion of the coast-line. Its nature further north is far less hospitable, cliffs often rising precipitously within a few yards of the water's edge. The general nature of this portion of the coast is illustrated in Photo. No. 6.

In the early days of mining on the Heemskirk field, and on the Zeehan field, Trial Harbour was largely used for landing men, machinery, and supplies. The reefs afforded

scanty protection, and vessels could only approach in fine weather, and even then it was necessary for them to anchor some distance off-shore, a landing being effected by means of boats and lighters on to a jetty which was erected on the beach. Thus the so-called "harbour" is merely an open roadstead, exposed to the full force of the weather from the north-west, west, or south-west.

Granville Harbour has certainly a better claim to the name, although it is not of large size. It belongs in reality to the North Heemskirk field. No other indentations of note occur.

The coast-line has a general north-westerly trend.

Sand-dunes occur to the south, towards the mouth of the Little Henty River, but are not very extensive; their effect in deflecting the mouth of the river is noted elsewhere.

The coastal cliffs have modified the topography in an interesting way, viz., in causing the more rapid wearing down of the edge of the coastal peneplain. It is not suggested that this action has really any causal connection with the sea coast, for it would have taken place where any such scarp as that formed by these cliffs was exposed. Where an edge such as that presented by the top of the coastal cliffs is exposed to weathering agencies, it must be denuded and worn down more rapidly than similar rocks outcropping on a level surface, owing to the additional area exposed to the weathering action, and to the assistance afforded by gravity and by surface-waters in rapidly removing the products of disintegration. The process is hastened by another factor: at short intervals along the edge of the scarp streams are engaged in cutting V-shaped valley openings, thus giving an increased surface for wearing agencies to act upon, and this must result in the ridges between consecutive valleys being eroded much more rapidly than would otherwise be the case. The net result of these processes will be that the level of the coastal cliffs will be lowered more rapidly than that of the peneplain further back from the shore, and therefore the slope of the surface in this vicinity does not represent the true slope of the old peneplain.

It is interesting to note from the Admiralty Chart of Tasmania that at a distance of 15½ miles due west of Remine the sounding is given as 85 fathoms, at 31 miles west of the same point 91 fathoms. In both cases shells were recorded. At 6½ miles north of the latter sounding the depth recorded was 95 fathoms. At Ocean Beach the recorded depth is 12 and 13 fathoms at 1¼ mile from the shore.

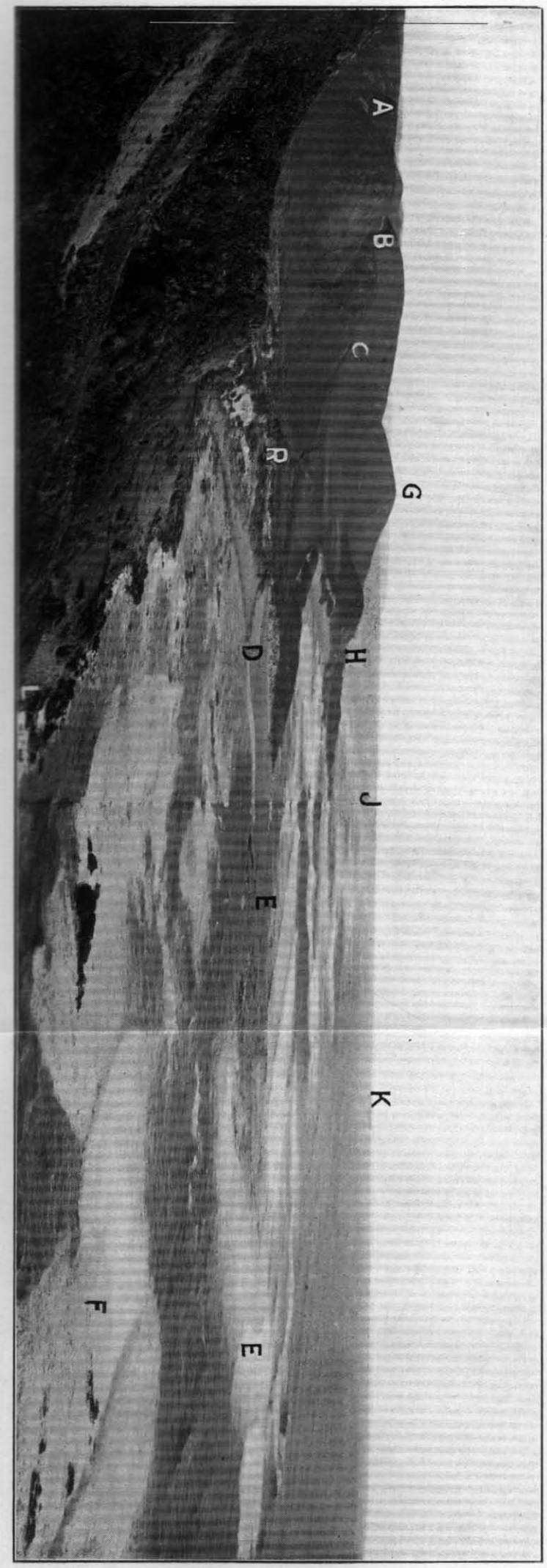


PLATE I.—TRIAL HARBOUR AND VICINITY, SHOWING SITE OF OLD TOWNSHIP OF REMINE, AND NICKEL REWARD MINE; LOOKING SOUTH.

(L. Lawry Waterhouse, Photo.

(2)—The Relation of the Topography to that of Adjacent Regions.

No discussion of the topography of the district can be regarded as complete without some reference to adjacent regions, especially when several of the physiographical units are distinctly comparable.

The coastal peneplain which has been described immediately suggests a comparison with the remnants of the old peneplains which exist in adjacent districts, and such a comparison serves to confirm the conclusions which have been arrived at for explaining the mode of origin of the coastal plain described in this report.

Such a comparison as that suggested has previously been made by Mr. L. K. Ward,[8] who correlates this coastal peneplain with that of the Balfour field, and concludes that both belong to the same physiographical unit as the old flood plain of the Pieman River and its tributaries between Mt. Black and Parson's Hood, and Brown's Plains on the Corinna-Waratah Road. The extensive peneplanation of the old land surface is assumed by Mr. Ward as belonging probably to Pleistocene time,[9] on the evidence supplied by the occurrence of huge glacial erratics of West Coast conglomerate and porphyroid in the old river gravels in the North Dundas district. The writer has recently examined portion of the north-western extension of the old Pieman peneplain,[10] and is quite in accord with Mr. Ward's correlation of this area with the coastal peneplain of Mts. Balfour and Heemskirk.

Further to the south, the coastal plain is seen to be continuous for many miles, and to extend back to the base of the West Coast Range. The portion of the plain to the south of that described is drained by the Henty River, but is undoubtedly portion of the same old peneplaned surface. This has been recognised by Mr. Hills,[11] who also agrees in correlating the plains, and who states that the coastal peneplain extends southwards "to beyond Point Hibbs and apparently to the foot of the Junction Range."

Immediately to the north of the area described in this report, *i.e.*, the North Heemskirk-Pieman district,

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([8]) *Vide* Geol. Surv. Tas. Bulletin 10, pp. 14, 15.
([9]) *Vide* Geol Surv. Tas. Bulletin 6, p. 36.
([10]) *Vide* Geol. Surv. Tas. Bulletin 15, pp. 4, 5.
([11]) *Vide* Geol. Surv. Tas. Bulletin 16, p. 23.

the country has not been examined in detail, but undoubtedly belongs to the same old peneplain, which is being dissected at the present day owing to the rejuvenation of the streams by a comparatively recent uplift of the old base-levelled surface. This area is actually continuous with that of the Balfour district further north, forming here really part of the Pieman River component of the unit.

The area surrounding Zeehan, to the immediate west of the Heemskirk Range, has been described in detail by Mr. Ward,([12]) and forms part of the Little Henty peneplain.

The average height of the Heemskirk component of the Little Henty peneplain is 600 feet above sea-level and its slope seawards about 100 feet per mile; these figures agree fairly well with those established for other portions of the physiographical unit.

As more detailed information becomes available with the extension of the work of the Geological Survey, it becomes more and more certain that the correlation of various areas of peneplanation is justifiable, and in fact essential to explain adequately the structural features. The importance of this correlation has been pointed out by Mr. L. K. Ward, who remarks([13]) that if a close comparison of the Little Henty and Pieman peneplains can be made, the remarkable uniformity of heights indicates that "the crustal deformation which has revived the river systems and started the dissection of the peneplains has caused a simple negative movement of the strand-line such that a considerable area remained at an approximately equal height above sea-level."

The writer quoted above has in another publication([14]) called attention to the striking fact that several peaks of the west coast, although widely separated, "rise to approximately the same altitude, as if they constituted residual fragments of a former base-levelled surface." The peaks referred to are Mts. Heemskirk and Agnew of the Heemskirk Range; Mt. Zeehan, Mt. Livingstone, and the Parson's Hood of the Meredith Range; Mt. Ramsay, Mt. Bischoff, and various peaks of the Norfolk Range. The appearance of these eminences when viewed from any one of them is very striking, and the suggestion is an attractive and interesting one, but in view of the tremendous amount of denudation which has taken place since the formation of the hypothetical peneplain, the remnants cannot, in light of the information available, be correlated for certain. As the abovementioned writer has pointed out, if such a peneplain as that suggested was developed, it must have been in the period between the irruption of the Devonian granite, and the formation of the basal Permo-Carboniferous beds. Obviously, then, the topography must have been intensely modified since the base-levelled surface was developed.

([12]) *Vide* Geol. Surv. Tas. Bulletin 8, pp. 9–13.
([13]) *Vide* Geol. Surv. Tas. Bulletin 8, p. 12.
([14]) *Vide* Geol. Surv. Tas. Bulletin 10, p. 15.

(3)—Relation of Topography to Geology.

In the South Heemskirk district the relation of topography to geology is not marked. The bulk of the mountain range is granite, the coastal peneplain is granite, serpentine, gabbro-amphibolite, and slate and sandstone. Thus it will be seen that in general the main topographical features have not been determined by the geological formations.

The structure of the granite *massif* is dealt with elsewhere([15]): the huge mass of granite has been forced up along a line of weakness into the overlying strata. The surface of the mass as it consolidated was approximately dome-shaped, the igneous rock doubtless rising to a much greater elevation along the line of the present mountain range than near the sea-coast. In the long cycle of denudation which followed, the whole of the overlying cover of sedimentary rocks was removed, and the western extension suffered peneplanation with the surrounding rocks. Harder and softer rocks alike were worn down to a common level in this area. The streams cut their way back into the mountain range, and the form of the massive dome was modified, but the original inequality of the igneous rock surface was too great to allow of its reduction to general base level in the time during which degradational forces were active. Had the rock been less stable, and more readily attacked by weathering agencies, the range would have been much reduced in elevation. Thus the formation of the mountain range is due primarily to the geological structure, and its elevation is greater than it would otherwise be owing to the resistance of the particular rock-type to weathering.

In the development of the coastal peneplain, as mentioned above, all geological formations have suffered

([15]) *Vide infra*, p. 95.

degradation, and granite, slate, sandstone, serpentine, and gabbro-amphibolite have been worn down to a common level, giving another indication that the period of denudation must have been of long duration.

Since the uplift of the old plain the action of weathering on the different rock-types has been effectual in carving them to a different extent. This is noticeable along the coast, where the granite cliffs always are near the water's edge and slope steeply, while the serpentine hills are back some distance from the shore, with a plain of varying width from their base to the shore, and only a few feet above sea-level. The valleys cut in the serpentine, too, are wider and shallower than those carved in the granite or contact sedimentaries.

The hardness of the rock-type has in some cases materially influenced the rate at which the streams have cut back their channels. This is well illustrated by Serpentine Creek, which has cut back with comparative ease and rapidity through the softer serpentine near the coast, until reaching a band of very hard diopside rock, which has retarded the progress of the erosion. Thus falls exist here, caused by the hard rock encountered. It is noticeable in this locality that as the stream has cut back more rapidly, the surrounding rcoks have been more quickly eroded and removed, and a comparatively broad valley formed. Somewhat similar effects are noticeable in several of the other creeks where hard contact rocks are developed.

The hardness of the rock-type has also modified the sculpture of the coast-line, the resistant contact sedimentaries forming rocky points. Calcareous bands have acted in an opposite way, and have caused a very marked honeycombed weathering.

The influence of the coastal sand-dunes on the positions of the debouchures of the rivers has already been noted.

On the hill slopes, and to a less extent on the old peneplaned surface, the quartz-tourmaline veins and dykes stand out in marked relief from the weathered surface of the granite, sometimes standing out in bold relief for 6 or 8 feet. These dykes do not influence to any great extent the development of the main physiographical units.

Reference has been made to the possibility of the summit of the Heemskirk Range representing a remnant of a very old peneplaned surface: it is worthy of note that this surface is granite, similar to that occupying a considerable area of the coastal peneplain. Again, the rock in the creek beds and at sea-level along the whole of the northern portion of the old plain is granite. Thus the degradational



PHOTO. 8—GRANITE ROCKS AT CLIFF MINE, ILLUSTRATING EFFECT OF PARALLEL FISSURING ON CONFIGURATION OF COAST-LINE.

[L. Lawry Waterhouse, Photo.

processes at work during the three cycles of erosion of which records are preserved have acted largely on the same rock-types.

(4)—The Relation of Topography to Mining.

It is important to consider the economic bearings which the topography may have upon the development of the field. This may conveniently be done under different headings, considering the topography from different points of view. The aspects of the question to be dealt with will include (*a*) transportation facilities, (*b*) prospecting and exploitation, (*c*) water-supply, (*d*) power.

(*a*) *Transportation Facilities.*

Little need be said under this heading, as the question of access has already been dealt with.

The topography has on the whole been favourable to communication and transport. From the description given above of the physiographical units, it will be clear that one unit (the Heemskirk Range) would have proved a serious obstacle, but fortunately the presence of the other main unit (the Little Henty peneplain) has provided a comparatively easy route of access from the nearest town and railway-station—Zeehan. The main road has been described; the grade on the whole is good, as the ridges of the old peneplaned surface have been followed where possible. In some places minor deviations could have been made advantageously. No serious obstacles were encountered, but as is to be expected, the dissection of the peneplain by the rejuvenated streams has placed minor difficulties in the way. As the valleys of these streams are mostly youthful, the sides slope steeply, and side-cuttings have been necessary, although no bridges (apart from culverts) have been required.

In considering a tram route for the South Heemskirk field, the same dissected peneplain will necessarily have to be traversed, and the broken nature of the surface presents obstacles which will probably prove on a close examination to be much less formidable than they appear at first sight. No attempt was made to prepare a detailed contour map of the district in the time available, but from his general examination of the country which would be traversed the writer believes that a practicable tram route could be selected, to enable the field to be connected with Zeehan.

The influence of the topography has been to lengthen the route between the Federation and adjacent properties, by which heavier pieces of machinery could be taken out from Zeehan, or tin-oxide taken in, since it has been necessary to follow the old peneplain and wind round the end of the mountain range. The foothills of the range have somewhat increased the difficulty. A pack-track constructed over the southern end of the range has shortened the distance between the Federation Mine and Zeehan by about 2 miles, but the grade is so steep when rising from the plain on the southern side of the range, and descending again on the western side, that the utility of the track is limited.

Several foot-tracks cross the button-grass plains to various properties. The fact of these plains being free of timber tends to facilitate transportation to properties which are not connected with the road with well-formed tracks.

(*b*) *Prospecting and Exploitation.*

On the whole the topography of the district is favourable to prospecting and exploitation of the mining properties; in particular cases it is distinctly unfavourable to exploitation.

The existence of the old peneplaned surface free of timber, the dissection of this surface by present-day streams, and the cutting back of these streams into the mountain range are factors which have distinctly aided prospecting. Outcrops are located with comparative ease, and they may frequently be traced on the surface for considerable distances with a minimum of work and expense. The streams are usually steeply graded, and do not offer many facilities for the lodgment of detrital ore derived from the deposits.

Properties on the coastal plain (excepting those at the edge thereof) are not as a rule helped very much by the topographical features, as the streams have not yet cut down their channels to a sufficient depth to allow of deep level adits being driven. Shallow adits have sometimes been driven to exploit ore-bodies exposed on the surface, in some cases without justification, owing to the shallow depth available. Shafts will in most cases be necessary when permanent work is undertaken on these mines.

Properties such as the Cliff Mine, on the sea-coast, benefit considerably from the topography, as adits may be driven from the cliff face with advantage.

Where properties such as the Federation Mine are situated on the slopes of the range, they derive immense advantages from the topographical features. The occurrence of outcrops on the hill-slopes, and their dissection by the gorges

of the creeks, enables the ore-bodies in certain cases to be tested at considerable differences of level without any exploitation work. In the case of the property mentioned above, the locality is particularly favourable for the development of various ore-bodies from adits, which may be driven, (*a*) from the general westerly slope of the hillside, (*b*) from either side of two creeks which have cut deep valleys in the hillside, (*c*) from the eastern slope of the hill towards the Cumberland dam. The machinery may be brought by the comparatively level plain, and erected at the foot of the hill-slope, from which the ore may be lowered to it by self-acting inclined tramways. There is unlimited tipping-space for waste material, and water troubles are reduced to a minimum.

In the case of the higher portions of the mountain range, the country is rugged and often precipitous, dissected by various streams, and often overgrown with heavy timber and thick scrub, and thus serious obstacles are presented by topographical features to the prospecting and exploitation of this little-known locality.

(*c*) *Water-supply.*

The question of rainfall is considered independently in the section on " Meteorology," which should be read in this connection: it is shown that the average rainfall is about 100 inches per annum in the district, and that at no season of the year is the rainfall negligible, the average for the driest month (February) being over 4 inches.

The question of water-supply is important to the mining companies interested in the district.

The influence of the mountain range is in the direction of increasing the amount of precipitation, but the water is rapidly conveyed to the sea by the various members of the drainage system. On account of the nature of the soil, the tendency is for the water to drain off comparatively quickly after the cessation of rainfall, although the areas of timber and scrub tend to act as reservoirs to some extent.

On the whole, the question of water-supply is not one which need cause serious anxiety to the mining companies on the field, as the supply is in most cases sufficient for present purposes.

The question of power is dealt with elsewhere, and in this respect the field is seen to be favourably situated.

For dressing purposes, the supply of water has proved sufficient in all properties worked up to the present. If more water for this purpose be needed in the case of the Federation Mine, an additional supply may be obtained

from Packer's Creek by means of a race following the general course of the old West Cumberland Company's race, but situated higher up the hill.

In sluicing some of the detrital material on the higher ground at the Federation Mine, the question of water-supply becomes important, but is best dealt with when describing that property.([16])

Small patches of alluvial material have been sluiced from time to time in different parts of the district, but the water-supply has in most localities proved sufficient for the work to be done. In one locality particularly, however (the flats near the Agnew Creek, south of Mt. Agnew), the scarcity of water has hampered operations considerably, but it is doubtful whether the grade of the deposits would justify the cutting of fairly long races through heavily-timbered country to bring water on to the ground.

Although in the North Heemskirk district the alluvial deposits are of great economic importance,([17]) in the South Heemskirk district they are small in extent and of minor importance, and the question of water-supply for working them is not so urgent.

(*d*) *Power.*

The topography of the district has an exceedingly important bearing on the question of power, and some at least of the mining companies concerned are exceptionally well situated.

In a region where the rainfall is variable, although high at certain seasons of the year, where the streams do not carry a large volume of water, and more particularly where the volume is liable to fluctuate considerably owing to the fairly rapid draining of the precipitated moisture, the question of storage becomes paramount in the consideration of water-supply; in considering power, an additional factor demands attention, viz., the storage of the water at as great an elevation as possible, with a practicable means of exit from this storage basin. These conditions are satisfied in the district under review in an exceptional way.

The Cumberland Creek was of comparatively small volume and varied with the rainfall, but flowed through a wide valley (believed to be of glacial origin) at a high elevation, the outlet to which was a narrow gorge, below which were falls several hundred feet in height. This outlet of the creek was dammed by an embankment about a chain in length, and about 25 feet in height, with the

([16]) *Vide infra*, pp. 291–295.
([17]) *Vide* Geol. Surv. Tas. Report 6.

result that the water of the creek was thrown back over a mile, and a large body of water impounded at a considerable height, the storage basin being so situated that water could be delivered on the plain below without difficulty. Thus the Cumberland Dam was formed. It has been estimated that about 100,000,000 gallons of water are impounded in the present dam. An accurate contoured survey of the catchment area was not made, but a general examination was made, and it is certain that the height of the embankment could be raised without difficulty, and that if this were done (with a corresponding increase in the height of the by-wash, by which the surplus water escapes by an adjacent gorge) the storage capacity of the dam would be enormously increased. By such an increase several mines could be provided with power, and as the catchment area is about 1600 acres (which could be slightly increased by cutting short races from the head-waters of other creeks), such an increase in storage would be advisable if the dam were to be largely drawn upon for supplies.

The dam is situated at an elevation of 500 feet above the coastal plain, and so provides excellent facilities for the generation of power.

From the description given of the rainfall in another section of this report, it is clear that at no season of the year is the rainfall negligible. In such a case as the present, where mines may be depending on the dam for power, it is important that a constant supply of water should be maintained throughout the year. As the amount of water flowing into the reservoir depends directly on the rainfall, it is essential that as much as possible of the surplus rainfall of the wet season should be stored to maintain the supply over any exceptionally dry season which may be encountered: this has already been shown to be possible by increasing the height of the embankment and by-wash.

In this connection the heavy timber on the slopes of the catchment area of the dam is an advantage, for it means that after a period of heavy rainfall the water is retained longer in the soil; as it drains off more slowly into the dam it may consequently be utilised to far better advantage than if it ran off rapidly.

Reference has been made above to the possibility of slightly increasing the catchment. The head-waters of the Cumberland Creek are separated from those of Packer's Creek by a high, narrow ridge: it is possible that by means of a comparatively short race the head-waters of the latter creek may be diverted into the Cumberland Creek and so into the dam.

Thus it will be seen that the Cumberland Dam offers the combined advantages of—

(*a*) Elevation, resulting in maximum power from a given volume of water;

(*b*) Catchment in an area of high rainfall during the major portion of the year;

(*c*) Facilities for enormously increasing the storage capacity at a very low cost;

(*d*) Proximity to several mining properties on both southern and western slopes of the range, meaning short races and pipe columns.

An interesting point with reference to the drainage of the area is raised if water from the Cumberland Dam be used for power purposes at, say, the Federation Mine. Naturally the Cumberland Creek flows into Pyke's Creek, and thence to the ocean by the Little Henty River. From the Federation plant, however, the spent water would empty into Packer's Creek, and would be conveyed by this creek direct to the ocean, entering at a point about $3\frac{1}{4}$ miles north-west of the mouth of the Little Henty.

With regard to the embankment of the Cumberland Dam, it is worthy of note that it has been constructed and faced with granite quarried from the immediate vicinity. The granite is the normal coarse pink granite of the district, fully described elsewhere, the granite here containing black tourmaline as well as a small amount of biotite. The embankment appears to be substantially built, and the height could be increased without any rebuilding of the present wall.

Apart from the Cumberland Dam, the steep slope of the mountain range has been utilised in a small way on several properties for creating a head of water to generate power on a small scale.

Descending from the mountain range, it is noteworthy that on the dissected coastal peneplain also attempts have been made to utilise water for the generation of power. Water-wheels have been favoured in several cases: in one instance water has been brought by a short race and utilised for a breast-wheel; in another the water has been brought in by a race, a certain head obtained, and not really utilised, as the water merely drives an overshot water-wheel. On the plain, however, the streams have not cut their valleys deep enough to allow of more than a merely nominal head being developed.

When the relation of the coastal plain to the strandline is considered, it is evident that there is opened up a potential source of power, for the coastal cliffs slope steeply to the shore, and although the streams have cut their way

down to varying extents into these cliffs, there is frequently from 200 to 300 feet of pressure available from the creeks. Unfortunately few of the properties are so situated that they can take advantage of these natural facilities, and in no instance, up to the present, has power been utilised in this way. The plant of the old Cornwall Company was situated on the shore, but a water-wheel was installed, which did not make use of the available pressure. In the case of the Cliff Mine, however, instead of working the battery on top of the cliffs by means of a water-wheel, the plant should unquestionably be transferred to the base of the cliffs, and power generated by means of a Pelton wheel which would utilise the available head of water. Doubtless with this end in view, the present owners have diverted the water from one or two smaller creeks, and a site certainly exists which could be used for the storage of water in a comparatively wide and shallow creek bed on the plain.

(5)—Meteorology.

No accurate figures are available with regard to the rainfall in the Heemskirk district, as no records have been kept, so far as the writer is aware. The amount of precipitation is undoubtedly heavy, and approximates closely to that recorded for Zeehan, which, as will be seen by reference to the accompanying map of the district (Plate II.) is only about 9 miles distant in a direct line, about east-north-east. It is likely that the rainfall on the Heemskirk Range is somewhat heavier than that recorded at Zeehan, on account of the much greater elevation of the range, which is about 2000 feet above the town.

The accompanying tables, compiled from the monthly rain maps supplied by the Commonwealth Meteorologist, give an idea of the annual rainfall for several years, and also of the annual distribution of this rainfall.

Table I.

Average Annual Rainfall in Inches at Zeehan.

1907	101·40
1908	96·78
1909	108·30
1910	116·14
1911	95·97
1912	90·52
1913	104·17
1914	80·94
Average annual	97·89

TABLE II.

Annual Distribution of Rainfall in Inches at Zeehan.

	1907.	1908.	1909.	1910.	1911.	1912.	1913.	1914.	Average.
January	3·04	3·74	4·99	2·27	3·85	5·50	7·27	6·19	5·94
February	2·71	5·11	1·61	4·09	5·02	0·64	4·52	1·96	4·24
March	6·18	11·15	9·17	2·32	8·54	5·38	7·35	4·62	6·09
April	11·14	5·74	17·15	11·00	11·66	7·46	3·90	14·81	9·02
May	5·87	14·74	10·63	20·03	6 32	9·34	7·82	8·72	9·40
June	5·30	9·96	9·53	12·20	13·55	8·11	6·42	8·17	9·70
July	13·72	8·99	8·37	4·48	6·45	4·89	13·02	10·70	10·15
August	12·89	9·53	12·92	17·87	6·61	9·45	13·42	8·46	9·78
September	16·73	7·55	4·43	12·35	5·07	13·28	12·38	6·73	9·18
October	10·02	8·71	10·56	9·82	9·29	9·25	6·95	2·66	9·40
November	2·63	4·80	7·86	8·52	5·90	8·57	14·07	4·39	7·71
December	11·17	6·76	11·08	11·19	13·71	8·65	7·05	3·53	7·28

It will be seen that the average annual rainfall for Zeehan is 97·89 inches. At Heemskirk the average is likely to be somewhat higher, and would approximate 100 inches per annum.

Table II. shows the annual distribution of this rainfall, and makes it clear that at no period of the year is the rainfall negligible. February is the driest month of the year, with an average of 4·24 inches, while July is the wettest month, with a record of 10·15 inches. It is seen that for seven months in the year (April to October) the average rainfall is very high, being 9·52 inches. With such a high rainfall at one period of the year, it would obviously be a simple matter, if a storage area were available, to conserve sufficient water to tide over the summer months, in the case of mining companies depending on water for mining operations. Attention is called elsewhere to the fact that a magnificent storage area is available on the South Heemskirk Tinfield which can be utilised for the purpose mentioned

Hail is not uncommon in the winter months, and snow sometimes falls on the higher ground, where frosts are frequent and severe in the fine weather. The district is subject to very boisterous weather, wind from the west and south-west being very severe, and often continuous for comparatively long periods.

With the exception of the Little Henty River, draining the southern part of the field and much of the country to the west, the streams are short, and comparatively unimportant, rising in the mountain range and flowing westwards into the ocean. Much of the western slope of the range is covered with button-grass, and has little depth of soil. Even this soil is very open, containing much quartz gravel derived from the decomposition of the granite, and, in consequence, does not retain moisture for any length of time after a fall of rain. In some of the more sheltered valleys are belts of timber and thick scrub, and such localities would favour the retention of moisture for a rather longer time; *i.e.*, they would, to some extent, act as reservoirs for the creeks after a fall of rain. Most of the streams, however, rapidly show the effects after a few days' dry weather. Fortunately, the existence of an excellent high-level storage basin (the Cumberland dam) places several of the properties on an excellent footing with regard to water-supply, and renders them quite independent of the inevitable fluctuation of the smaller streams in the summer time.

(6)—Timber and Vegetation.

Brief reference must be made to the vegetation occurring in the district.

The coastal peneplain is generally covered with button-grass, through which the underlying granite outcrops at frequent intervals. The depth of soil is usually small, and sometimes considerable areas of practically bare granite are exposed. In the creek beds, however, thick scrub and stunted shrubs are usually met with. No timber of any consequence occurs on the peneplain to the north of the Trial Harbour Road; on the final descent to the old township there is fairly thick scrub on the northern side of the road, on the southern slope of the spur along which the road winds. South of the road, towards the Little Henty River, timber and scrub are abundant. It is a striking fact that the change in the nature of the vegetation coincides with the change of soil, resulting from the decomposition of different rock-types. The Pre-Silurian slates series yields a clayey soil, which supports a luxuriant growth of timber and undergrowth, not only in the valleys, but also on the sides and summits of the ridges. This tangled undergrowth is quite impenetrable in most places. The timbers noticed included myrtle, sassafras, leatherwood, horizontal, musk, and dogwood; sometimes groups of gum and blackwood were noticed (although comparatively few of the latter). An agreeable change from the thick undergrowth (with abundant bauera in places), is an occasional patch of open myrtle forest, with "man" and "cat-head" fern.

This class of heavily-timbered country continues along the valley of the Little Henty River and its tributary streams, as far eastwards as they were examined.

The serpentine and gabbro-amphibolite, on the other hand, support rather stunted timber, although in favourable localities, such as sheltered flats, the scrub is thick.

In most of this country the scrub and undergrowth become more tangled and impenetrable after a fire has been through and destroyed the original growth, and under these circumstances the abundance of a shrub known as "prickly wattle" makes travelling difficult and unpleasant.

Mention has been made of the fact that the coastal peneplain is practically bare of timber in the northern portion of the area examined. This is partly owing to the poor soil, but not entirely so, as is clear from the fact

that on exactly similar granite soil in certain protected spots on the mountain slopes are clumps of heavy timber. The scarcity on the plains and on the more exposed hill-sides is partly owing to the heavy winds, which are almost continuous in the district. The prevailing winds are from south-west to north-west, so that there is no protection on the plain, and none on many of the hill-slopes. Back in the range, however, and on practically all hill-slopes protected from the quarters mentioned, belts of excellent timber are to be found. It is to be regretted that fires have been allowed into some of these belts, with the result that where trees have not been killed outright, many of the main branches have died, and numerous shoots have made their appearance practically from ground-level. Thus trees (gums) which were formerly perfectly sound, and rose to 40 feet or more without a branch, are useless as a source of first-class timber. It certainly is advisable that these timber areas be preserved from fire if possible.

Several timbered areas have been reserved by the Government. These are shown on the accompanying map of the district (Plate II.).

The question of timber in relation to mining cannot be said to have become acute in the district. In the case of properties like the Cliff Mine, on the coast, suitable timber would have to be transported some distance, but if the need arose, light tramways could be run into the timber belts. Other properties, like the Montagu, on the old peneplain, have no timber immediately at hand, but it could be secured within reasonable distance. The Federation Mine is rather fortunately situated, as a line of limited length would open up an excellent belt of timber which clothes the western slopes of Mt. Agnew and the surrounding peaks and spurs.

The scarcity of timber of any description on the button-grass plains becomes very evident when camps are erected, when firewood has to be carried long distances in many cases. The obvious solution of this difficulty is to pitch camp near a timber belt; but this is not always practicable if the camp is to be at the same time near particular workings.

Reference may be made in passing to the timbered country in the valley of the Little Henty, to the east of the district examined, and between the Little Henty and Henty Rivers. There are thick belts of timber, which do not appear to have been exploited, in this locality.

IV.—GENERAL GEOLOGY.

(1)—The Rock-types Represented on the Field.

Before proceeding to deal in detail with the geology of the district, it seems advisable to summarise in a general statement the relations of the various groups to each other, to enable the reader to more readily understand the following discussion.

Into a series of previously-consolidated sediments, consisting of slates, sandstones, and tuffs, a mass of basic igneous rock was intruded. Closely following its consolidation, a huge mass of acid igneous rock, which had been derived from the same magma as the basic rock, was forced up along a line of weakness in the crust, but consolidated deep below the surface. Long-continued denudation removed much of the overlying cover of sedimentary rocks, and cut deeply into the underlying basic and acid igneous rocks. Consideration will therefore be given in this chapter to the igneous rocks, basic and acid, and then to the sedimentary rocks and their modifications Finally, the general sequence of events which has led to the present geological structure will be described and summarised.

Basic Group.

The oldest known igneous rocks of the district occur in the south-east of the area mapped, and in the extreme southern portion. These form two distinct areas, the former (near Comstock) being gabbro-amphibolite, and the latter (near Trial Harbour) serpentine. Although these rocks are believed to be closely related, and of similar age, they may, for the sake of convenience, be dealt with separately.

Gabbro-amphibolite.—On proceeding from Zeehan westwards along the Trial Harbour Road, these rocks are first encountered in a road-cutting at Comstock, about 6 chains beyond the spot where the Comstock Creek crosses the road. On the Comstock side the slates are much contorted near the junction, frequently dipping at a low angle to the north-east. At one spot there appear to be several intrusive sheets of decomposed basic rock in the slate series, within a short distance of the contact. At the actual contact, and for some little distance beyond it, the greenish basic rock is a good deal decomposed, and cannot be determined with certainty in hand specimens.

From this point onwards for about ¾-mile is a development of altered slates, very difficult to distinguish from the fine-grained varieties of gabbro-amphibolite, and impossible to determine definitely without microscopical aid. The rocks are described elsewhere.([18]) They are usually very much decomposed, and it is not easy to obtain fresh specimens. The soil yielded by the slates is very much ironstained, being reddish-brown in colour, of a clayey nature, and supporting a very luxuriant growth of vegetation, rendering accurate field work difficult. The rocks are andalusite slates. They are exposed along the side cutting of the Trial Harbour Road to within about 2 chains of McIvor's north-east corner, when fine-grained gabbro-amphibolites make their appearance.

Although the area of gabbro near the Comstock, and that near McIvor's, are shown as almost separate areas on the accompanying map,([19]) if the country is ever made accessible, even by good bush fires, it may prove that there is a wider surface connection. This could not be determined on this occasion with accuracy.

The gabbro-amphibolite is seen to vary a good deal in texture from point to point as exposed along the road.

Probably the rock is most typically developed below a hut known as McIvor's on a hill of the same name, which is also locally known as " The Red Hill," on account of the high iron content of the soil imparting to it a rich red-brown colour. Below this hill is an extensive marshy flat (see Plate II.), and on this flat are abundant outcrops of gabbro-amphibolite.

The rock is of a general greenish colour when fresh, weathered specimens showing a reddish-brown crust, which in the coarser varieties is pitted, owing to the decomposition of the felspars. Much of the rock is coarse-grained, and is seen to be composed of abundant greenish-black prismatic crystals of hornblende, which were observed in exceptional cases as much as 3 inches in length and ½-inch in breadth, with varying amounts of light-greenish felspar forming the groundmass of the rock, and sometimes penetrating the hornblende crystals. Owing to the difference in colour of these two main constituents, the coarser varieties of the rock are strikingly mottled in appearance. In many instances radiating aggregates of fine, needle-like crystals of dark-green amphibole are abundant throughout the rock. The coarser prisms tend sometimes to take a

([18]) *Vide infra*, p. 121. ([19]) Plate II.

radiating habit. Magnetite is not uncommon, in masses up to ½-inch in diameter. Sporadic crystals of pyrrhotite are present throughout the rock, and occasionally tufts of a soft greenish mineral resembling chlorite are noticeable.

The texture of the rock varies from very coarse to very fine; in the latter the component minerals sometimes cannot be determined in hand specimens, although this is rather exceptional.

Towards its western extremity the rock appears as a compact dark-green rock, with pale-greenish veinlets. In this locality a noticeable feature at several points is the abundant iron ore scattered about on the surface. This is frequently nodular limonite, or consists of grains of magnetite cemented together by limonite. It appears to be several feet thick in places. It is secondary iron ore, derived from the decomposition of iron-bearing minerals in the gabbro-amphibolite, the included magnetite being primary, and set free from the body of the rock as it weathers. The nature of this iron ore appears to have been misunderstood, and the material mistaken for the gossan capping of a lode-formation, for several shafts have been sunk to shallow depths.

The northern and eastern boundaries of the basic mass were not traversed, as they belong in reality to the Comstock district, which is not dealt with in this bulletin. Part of the northern and the western boundaries are, however, approximately mapped on the accompanying general map of the district. Several attempts were made to trace the south-western and southern boundaries, but this was found impossible to accomplish in detail, owing to the dense undergrowth, through which there are no tracks and few rock outcrops. A passage was forced through the scrub along several lines, and sufficient was seen to satisfy the writer that no unbroken connection exists on the surface between the main gabbro-amphibolite mass, and the Trial Harbour serpentine. It would appear, however, that there is a connection at no great depth below the surface. In at least one locality an intrusive mass of igneous rock was observed which merits special notice. The general nature of the occurrence, and a description of the surrounding rocks, is given in another place.([20]). The small outcrop exposed indicates dyke form for the igneous rock, but its structure suggests Plutonic affinities. The rock is green in colour, and varies some-

([20]) *Vide infra*, p. 103.

what in texture, from close-grained to medium. In the former variety are fairly abundant inclusions of light-coloured cherty fragments of very irregular shape, up to about 1 inch across. The groundmass is pale-green, but cannot be definitely resolved. In the medium-grained variety, however, three minerals are distinguishable in hand specimens—a pale-green pyroxene or amphibole, abundant grey felspars, and scattered grains and aggregates of pyrrhotite. Microscopically, further information is gleaned as to the nature of the rock, leaving little doubt as to its mode of origin. It is seen to consist of irregular pale-green masses composed of minute sheaf-like and radiating pleochroic crystals, and of partially-clouded crystal forms which frequently have a tabular habit. The green masses are composed of crystals of actinolite, and the colourless crystal forms are undoubtedly partially decomposed felspars. The outlines of the aggregates of actinolite are not usually sharply defined. Projecting from them and penetrating the adjacent felspars are frequently to be seen minute needles of actinolite. In general habit, however, the aggregates of actinolite partially surround, and are moulded on, distinguishable felspars. The latter sometimes show idiomorphic outlines, although at times they are penetrated by actinolite needles, as described above. Although in some cases the original felspars are represented by cloudy masses resulting from the decomposition of the original mineral, in others the crystals clearly show multiple twinning after the albite law The twin lamellæ are broad, and extinction angles measured on sections approximately perpendicular to albite twins, show that the plagioclase present is the basic lime-soda felspar labradorite. A little scattered magnetite is visible throughout the slide, and it is noticeable that a little sphene is present in aggregates of small, rounded, semi-opaque aggregates. Apatite is present in small quantities in scattered clear crystals. The rock is evidently a gabbro-amphibolite, and is to be correlated with the large mass of this rock exposed about 2 miles to the north-east.

Several thin sections of rocks collected from various points were examined, and a slight variation was noticed in the structure of the rock in different localities. This, however, is only to be expected in such an area of rocks, and it will be seen that the variations are really of minor importance, the rock retaining its general characteristics throughout the area. A specimen collected from the cutting on the Trial Harbour Road, just beyond the Com-

stock, appears in hand specimens dark-green in colour, with scattered darker-coloured lath-shaped crystals. In thin section the rock is seen to be composed essentially of felspar and hornblende. In addition, a small amount of quartz is developed, but its habit suggests that it may be secondary. Ilmenite is fairly abundant, but is largely converted to leucoxene. Scattered grains of magnetite are also noticeable through the slide. In places, granular epidote is developed as a secondary mineral at the expense of the felspar. In light-green fibres, actinolite is also fairly abundant, and is obviously a secondary mineral, the fibres often penetrating or developing along cracks in the felspar crystals. Although the felspars usually retain their crystal form, they are too clouded by decomposition products to be determined. The crystals are usually hypidiomorphic; their relation to the hornblende is particularly interesting. They frequently penetrate, and are sometimes almost entirely included in, crystals of amphibole. In some cases, however, the form of the felspar is evidently determined by that of the amphibole. The latter mineral itself is light-green in colour, and strongly pleochroic. It occurs in broad prismatic crystals, which sometimes show signs of twinning. These crystals have the typical hornblende cleavages in longitudinal and cross sections. Although the optical properties are certainly those of hornblende the form of the crystals and the ophitic structure exhibited by the felspar and hornblende are strongly suggestive of monoclinic pyroxene, so often present in gabbros. In this slide portion of the amphibole has been converted to a bright-green chlorite.

About three-quarters of a mile on the Remine side of Comstock is a sharp elbow in the road, and the rocks here are seen to be light greenish-grey in colour. A thin section of a rock collected from this point indicates that the rock has originally been a gabbro. It consists now of a thoroughly chloritised and actinolitised groundmass, with abundant granular aggregates of epidote with some zoisite. There appears to be also a little dolomite in the groundmass. Although at first sight the slide appears to show simply an aggregate structure, close examination reveals the general outlines of felspar crystals in the areas now occupied mainly by epidote. The relation of these pseudomorphs after felspar to the surrounding masses of chlorite and actinolite, and the general shape of these masses, suggests that amphibole or pyroxene (probably the latter) has been replaced. The rock appears to be a thoroughly saussuritised gabbro.

This rock apparently represents an extreme type of alteration. Bands of rock in the same vicinity are of a darker green colour, and are seen microscopically to be altered, but not to the same extent as that previously described. Some of the felspars have undergone a good deal of alteration, while in others broad twinning lamellæ are faintly discernible, but are not distinct enough for the exact plagioclase to be determined. The crystals are usually lath-shaped, and show hypidiomorphic outlines. Abundant green pleochroic amphibole is present, some crystals frequently surrounding the felspars on three sides, and sometimes completely enclosing them, thus exhibiting typical ophitic structure. The amphibole has quite irregular outlines determined by adjacent crystals of the same mineral or of felspar; in places it is partly chloritised. The slide is traversed by veinlets of appreciable width, filled with radiating tufts of light-green pleochroic actinolite. About 1 mile further along the road towards Remine, near a hut known as McIvor's, the rock is fine-grained, but still of the prevailing greenish tint. In thin section this rock is seen to be composed almost entirely of green amphibole and lath-shaped felspars. The latter are sometimes idiomorphic, usually hypidiomorphic, and where the extinction angles can be measured are seen to be labradorite, a lime-soda felspar. Here, as in previous cases, the structure is ophitic, the amphibole being allotriomorphic. Abundant grains of magnetite are scattered through the slide, with a small amount of ilmenite. The amphibole is slightly chloritised in places.

Some of the rock exposed in a quarry on the roadside opposite McIvor's hut is extremely fine-grained, and resembles some of the contact-metamorphic slates which occur in the district near the granite contact. It is dark-green in colour, but no constituents can be determined in hand specimens. This rock is intersected by numerous veinlets of quartz, from mere threads up to 1½ inch in thickness. These are evidently fissure fillings, with sharply-defined walls, and a tendency towards crustification. The metallic minerals present are magnetite, chalcopyrite, and pyrite. Sometimes there are several veinlets parallel and adjacent to each other, with veinlets extending from one to the other, and enclosing masses of country-rock. In one instance where a segregation of granular magnetite occurred in the igneous rock, this was intersected by quartz veinlets. In some of the veins were disseminated grains of a fairly soft honey-yellow translucent mineral, with almost an adamantine lustre, which proves to be siderite. A

striking fact is the presence of abundant tourmaline in some of the narrow fissures. On breaking off a specimen along a fissure the black tourmaline was seen to occur in fine, needle-like crystals, usually with a radiating structure, some of the needles attaining 1 inch in length. Associated with the tourmaline is a little quartz, and chalcopyrite is noticeable between some of the tourmaline needles, having evidently crystallised later than that mineral. A thin section cut through one of these veinlets shows that in addition to hypidiomorphic quartz, which forms the bulk of the slide, there are present irregular fragments of felspar, a good deal kaolinised. From the indefinite extinction angles observed, it appears that some at least of the felspar present is microcline. The siderite is moulded on the quartz crystals; in one or two cases it is slightly discoloured by limonite, but is usually very fresh. There are scattered aggregates of chlorite, and a few shreds of actinolite present in the slide.

In some of the veins small aggregates of a yellowish-green mineral are present, which is apparently epidote. None was present in the slide examined.

The gabbro-amphibolite is so fine-grained at this point that it cannot be distinguished in hand specimens from contact-metamorphic slates which occur in the neighbourhood. A thin section, however, shows the true nature of the rock. It consists of abundant minute lath-shaped felspars, with abundant interstitial pleochroic green amphibole. Several phenocrysts of clear simply-twinned orthoclase felspar are present, and other crystals appear to be albite-oligoclase. Scattered through the slide are bright-green chloritic aggregates. In one part of the slide is noticed a granular aggregate of epidote crystals, and a veinlet adjacent is filled with the same mineral.

Another section from a slightly coarser-grained rock from the same quarry also shows some orthoclase as well as plagioclase felspar. These minerals are intimately associated with strongly pleochroic green amphibole, which is abundant and quite irregular in shape. The amphibole is largely moulded on the felspars, but in many instances the two minerals are intergrown in such a way as to give striking "graphic" effects, recalling to mind the graphic intergrowth of quartz and felspar in certain granites. A slight variation of the same structure is shown by the development of an imperfect radial structure in the amphibole, different portions of the aggregate being optically continuous, and enclosing clear fragments of felspar. This structure is common in the series, giving some portions of the rockmass a

typically poikilitic texture. Crystals of clear secondary albite felspar are not uncommon, and occasional grains of epidote are distinguishable. Chlorite is developed in places at the expense of the amphibole, and magnetite is abundantly scattered through the slide in irregular grains and granular aggregates. No apatite was noticed.

On the extensive marshy flat below McIvor's the basic rocks under discussion are well developed. The rocks are fresher here than at some of the previously-mentioned localities, but an examination of several thin sections shows that the features are similar to those already described. No pyroxene is to be seen, but green amphibole with characteristic cleavage and optical properties is abundant. Here, again, the habit suggests that of pyroxene. Labradorite felspar is present, and in one slide a little chalcedony was noticed, but this is probably secondary, as the felspars are partially saussuritised. Skeleton crystals of magnetite occur in this slide, as well as grains of ilmenite with leucoxene.

A rather extreme type occurs on the roadside towards the western edge of the marshy flat referred to above. This is about the western limit of the area of basic rocks in this vicinity. The dark-green rock is seen to be traversed by veinlets of greenish-grey mineral. In this section it is seen that felspars, although present, are scarce, and a good deal decomposed. Crystals of green amphibole are abundant, while the groundmass is thoroughly actinolitised, a little secondary silica being noticeable in places. Veinlets traverse the slide crowded with hypidiomorphic crystals of the light-coloured monoclinic pyroxene diopside. Aggregates of chlorite are present, and a few scattered grains of magnetite.

At one point an occurrence was noticed which is of importance in throwing light on the relation of the acid to the basic rocks. South of Section 6667M, 80 acres, charted in the name of H. D. Marsh, and between the southern boundary of that section and the Trial Harbour Road, the gabbro-amphibolite outcrops at intervals in a marshy flat. On the edge of this flat at one point several veins of quartz were observed, up to 2 inches in width, cutting through the basic rock. The veins could not be traced far, but apparently had an approximately east and west strike. The white outcrops showed very distinctly in the dark-coloured basic rock. From this point the granite contact is distant between 20 and 25 chains, being hidden by dense scrub. Within about 1 chain of the quartz-veins a black vein was noticed, varying in width from one-half to 2 inches. The vein-filling appar-

ently consists of one mineral, which seems to form a granular mass. On close examination abundant minute needle-like crystals are distinguishable. The mineral proves to be black tourmaline. In the immediate vicinity of the tourmaline vein the wall-rock (gabbro-amphibolite) is slightly silicified, and some diopside is developed.

Even were the quartz veins connected with the basic magma, and expelled as a result of the " after-action " during the final stages of consolidation, such a mode of origin cannot be assigned to the tourmaline, and there can be little doubt that this is connected with the acid magma, and it is very probable that the quartz also has been derived from a similar source. Clearly, then, the gabbro-amphibolite had consolidated before the final stages of consolidation of the granite.

Serpentine.—This rock is believed to occur at Comstock,([21]) but was not detected on this occasion, as no detailed examination was made of the Comstock district.

There is, however, a development in the vicinity of Trial Harbour, which merits a detailed description.

Throughout the area, at no point visited was any outcrop noticed of any unaltered basic igneous rock, to give a clue as to the nature of the rock from which the serpentine was derived. Microscopical sections, however, give some valuable information.

Round the borders of the serpentine the rocks are usually much altered, but it must be borne in mind that the borders of the granite *massif* are never far from the edge of the serpentine, and the intrusion of this huge mass of acid igneous rock has undoubtedly caused intense metamorphic effects on the adjacent rocks.

The rock itself varies in colour a good deal from point to point. Weathered surfaces are usually grey to brown, and the rock near the surface is generally greenish-gray to brownish. The fresh serpentine appears normally to be dark-blue or black. Some specimens collected show interesting gradations from weathered to fresh rock: the outer crust is brown, grading into a greenish rock for about 2 inches, the central portion being very dark-blue.

The serpentine is not as handsome as some of the green varieties occurring in other parts of the State. It is usually dense and close-grained, but almost all varieties show magnetite in streaks and irregular scattered aggregates—partly secondary magnetite set free in the ser-

([21]) *Vide* Geol. Surv. Tas. Bulletin 8, p. 21

pentinisation of the original igneous rock, and partly primary.

A very interesting form of magnetite occurs in the serpentine at several points, viz., radiating magnetite. Irregular masses occur, up to about 12 inches across, and 2 to 3 feet in length. The radiating habit of the mineral is rather unusual, and is described below as it occurs at various localities. Perhaps the most typical specimens were obtained from the Nickel Reward Mine (Section 892-M), where rosette-like masses of radiating fibres up to $2\frac{1}{2}$ inches in length occur. The mineral is brownish-black in colour, highly magnetic and polar. Filling interstices between fibres and radial aggregates are masses of white crystalline arragonite. It is not certain whether the magnetite is primary or secondary: it may have crystallised out as a primary mineral from the cooling basic magma, or have been set free in the serpentinisation of the basic rock, and thus have been formed by secondary agencies. The accompanying arragonite certainly is secondary. Various other secondary minerals occur in the serpentine which may conveniently be described at this stage. In using the word " secondary " it must be understood that the minerals are regarded as secondary with relation to the serpentine, itself strictly speaking a secondary rock: the minerals referred to, however, have ben formed subsequently to the serpentine.

Arragonite.—This mineral is fairly abundant in certain localities: it was noticed particularly in the serpentine forming the long reef on the southern side of Trial Harbour, and in the workings at the Nickel Reward Mine on the hill overlooking the harbour. In the former locality it is sometimes associated with oolitic calcite, and occurs in minute, sharply-pointed, transparent, prismatic crystals: these crystals are usually in radiating aggregates, sometimes at right angles to the walls of the fissures, sometimes (in the case of narrow fissures) parallel to the walls. Cavities in some instances are lined with prismatic crystals projecting at all angles. The arragonite crystals occur in all sizes from microscopic size up to one-quarter inch in length: in all cases they appear to terminate in acute, needle-like points. At the Nickel Mine the serpentine is traversed by abundant veinlets of this mineral, with a habit generally similar to that described above. Crystals are usually transparent and occur in radiating aggregates, individual crystals attaining a length of 1 inch and diameter of one-eighth inch. These arragonite veinlets

attain a width of 1 inch: in the wider veinlets the crystals are more or less perpendicular to the walls. Closely associated in some cases with the arragonite are veinlets of the green deweylite described below.

Calcite.—Although not as common as arragonite, calcite is present in irregular masses and in veinlets in the serpentine. The only locality where it was noticed was at the Nickel Mine. It appears usually to be associated with the brown deweylite described below, and good specimens were collected from the No. 3 Adit. In one instance calcite and arragonite occur in the one veinlet, the latter occupying the central portion of the fissure: in this case the minerals clearly belong to two generations.

Calcite was noticed at one spot as an oolitic encrustation on the walls of fissures and small geodes. These opaline translucent oolites are sometimes encrusted with minute needles of arragonite.

Dolomite.—This mineral was noticed in small quantity, filling a fissure in the serpentine at the No. 2 Adit of the Nickel Mine. The width of the vein of dolomite is about 2 inches.

Magnesite.—Although of good quality the magnesite is not present in sufficient quantity to be of commercial value. It occurs in the serpentine both in narrow veins and irregular masses, up to 6 inches in width and a few feet in length. It frequently shows slight stains of pyrolusite, and the dendritic habit of this black mineral shows out distinctly in the white magnesite. The magnesite is sometimes traversed by narrow veinlets of a mineral resembling opal in appearance: it is flesh-pink in colour, of a pearly lustre, hardness about 3·5, and is probably allied to the magnesium silicates described below.

The magnesite is always massive, and tends to break with a conchoidal fracture. The specific gravity is 2·44: it is not completely soluble in acids, a residue of gelatinous silica remaining.

Brucite.—This mineral (magnesium hydroxide) occurs in a rather unusual form. It is fairly abundant on the brow of the hill overlooking Trial Harbour, near the collar of the shaft connecting with No. 1 Adit of the Nickel Mine,([22]) and a little lower down the hill in a small open-cut about 1 chain north of the No. 1 Adit. The mineral occurs in masses apparently of quite irregular shape, included in the serpentine, measuring sometimes several

([22]) *Vide infra*, p. 415 *et seq.*

feet across. On freshly broken surfaces the mineral presents a striking appearance, for it occurs in radiating aggregates of fine fibres, these fibres varying in length from almost microscopic size to 1 inch in length. These aggregates are usually circular in section, although the shape is to some extent determined by adjoining aggregates, and the resulting rock is white with a very faint greenish tint in places. The lustre is pearly, hardness 2, streak white, specific gravity 2·42. It is not, however, completely soluble in acids. Before the blowpipe it is infusible and shows a pink colouration with cobalt nitrate. Included in masses of radiating aggregates are disseminated tabular hexagonal crystals of a light greenish colour, up to 1 inch across. These crystals have a perfect basal cleavage, and resemble in physical characteristics the radiating white brucite described. Although somewhat resembling mica in appearance these crystals are of brucite, the mineral thus occurring in two distinct forms.

The brucite is partly converted to hydromagnesite.

Associated with the brucite are granular aggregates of magnetite, slight stains of pyrolusite and of limonite, a little opal, and veinlets filled with a brown to black mineral resembling opal in appearance, but apparently consisting of a silicate of magnesium similar to those described below. In some specimens stains of apple-green garnierite are noticeable.

Several specimens were obtained on the dump-heap at the mouth of the No. 1 Adit of the Nickel Mine, and others at the No. 3 Adit, of a mineral which is probably a form of brucite which has not been exposed to weathering agencies to the same extent as the white variety described above. The radiating habit of the mineral is similar to that of the white brucite described, and the association in one specimen of greenish hexagonal tabular plates with the radiating aggregates, is suggestive. The colour is greenish-grey, streak white, hardness 3, specific gravity 2·48. Although not very hard, the mineral is tough. Before the blowpipe it is very slightly fusible on thinnest edges: heated with cobalt nitrate the colour is pink: it yields water in closed tube. Although it does not exactly correspond in some particulars with the mineral described in text-books, it appears to be brucite, and the white variety described above has been bleached by weathering agencies. The green brucite from the No. 1 Adit is associated with arragonite (which has crystallised later), and that from the No. 3 Adit with calcite (also a later formed mineral) and aggregates of magnetite.

Brucite is also present in the serpentine, as disclosed by the microscopical examination of thin sections of the rock: these are described below.

Opal.—Veins of opaline silica are noticeable in a few localities: one occurrence of this mineral is described in some detail elsewhere,[23] as in this locality the silica cements fragments of rock on the surface. Little need be said at this stage concerning the occurrence.

Chalcedony.—Chalcedonic veins in the serpentine are not uncommon, and these are believed by the writer to be due to the extrusion of siliceous solutions during the final stages of consolidation of the basic magma: this question has been discussed elsewhere.[24]

Deweylite.—Under this heading will be described secondary minerals which occur fairly abundantly in the serpentine exposed in the workings of the Nickel Reward Mine overlooking Trial Harbour. They were noticed in varying quantities in Nos. 1, 2, and 3 Adits, but most abundantly in the No. 1 adit.

Further investigation is necessary before the minerals can be positively named. There are two varieties which have certain features in common, but which may, upon a more minute examination, prove to be distinct minerals, although preliminary tests indicate that the colour is the main distinction, one (the more common) being green and the other brown. The writer believes they are varieties of deweylite (hydrous basic silicate of magnesium).

Deweylite (Green).—This green mineral occurs in veins in the serpentine in such a way as to indicate that it is certainly a secondary mineral. The veins sometimes attain a width of one-half inch, though they are usually narrower. The width may vary from point to point. In some places several veins of approximately parallel strike may approach each other, forming a vein-like mass 5 or 6 inches in width. In such cases the interstitial spaces between individual veinlets of the green mineral are filled with crystalline arragonite. Arragonite is a very common associate of the mineral, and is a later-formed mineral, transparent prismatic crystals, usually radiating from a centre, frequently occupying cracks. Dendritic markings of black manganese minerals are also frequently noticed, extending outwards from cracks in the earlier-formed mineral. Veins are not simple, but branching forms are sometimes noticed, with included masses of serpentine. In one specimen collected the green

(23) *Vide infra*, p. 110. (24) *Vide infra*, p. 57.

mineral occurs in rather irregular blebs and aggregates through the serpentine, and not in definite veins. It is replacing the serpentine in this specimen. As described elsewhere (25), the mineral is much stained with garnierite in the No. 1 Adit of the Nickel Mine, and it appears to be almost invariably present in the pentlandite-bearing serpentine; in addition, occasional fragments of pentlandite are noticed included in it. These facts suggest a possible connection between these veins and the nickel ore, but, as noted elsewhere, the writer is of opinion that the connection is rather accidental than essential, and that there is in fact no genetic connection between them. The colour of the mineral varies slightly through shades of pale-green and greenish-grey. It is amorphous and brittle, and has a wax-like lustre; hardness about 3 to 3·5; streak white. The specific gravity is 2·44. Before the blowpipe it decrepitates, and is only very slightly fusible on thinnest edges, when it changes colour to a dirty-brown. This colour rather masks the colour resulting from an intense heating with cobalt nitrate, but this colouration is a dirty-pink. When powdered and heated in a closed tube, water is given off. Acids have little effect, there being a slight action (perhaps due to impurities), with hot hydrochloric acid. A quantitative analysis could not be undertaken on account of lack of apparatus, but some of the mineral was selected as carefully as possible, and a qualitative analysis made by the writer to determine the elements present. These were found to be silica, magnesium, iron, aluminium, and traces of manganese and nickel; no calcium was present. The manganese and nickel are evidently impurities, and iron and aluminium are present in comparatively small quantities, suggesting that they may be impurities or replacing elements. Apparently the mineral is essentially a hydrous silicate of magnesium. Although it does not correspond in all particulars with the usual forms of that mineral, it appears to be a variety of deweylite.

Deweylite (Brown).—A brown mineral which occurs under similar conditions to the green deweylite described above, may be a variety of the same mineral. Veinlets occur in close association with those of the green mineral, which are sometimes so dark as to be almost black in colour. The two varieties alternate in some specimens. On the dump at the mouth of No. 3 Adit of the Nickel Mine, itself inaccessible, some specimens were obtained which show this mineral very abundantly. It occurs with calcite in veins in

(25) *Vide infra*, p. 417.

the serpentine. The two minerals are closely associated, although the calcite appears to be a later-formed mineral, the veins being between 3 and 4 inches in width. The mineral varies in colour from pale-green through shades of brown to almost black. Some of the dark amber-coloured varieties are translucent; it was this variety which was selected for the qualitative analysis described below. The mineral has a dull to wax-like lustre, although some fragments are more typically resinous. The physical characters correspond closely with those described above for the green mineral. There is a magnesium reaction before the blowpipe, and the powdered mineral yields abundant water in closed tube. Unfortunately a quantitative analysis of the mineral was not possible with the apparatus available, but the writer made a careful qualitative analysis of the mineral, which showed the presence of abundant silica and magnesium, with small amounts of iron, aluminium, and manganese, and a trace of calcium; nickel was absent. Although the mineral was separated from calcite as well as possible by mechanical means, the trace of lime found is almost certainly due to an impurity in the shape of calcite. It is questionable whether the iron, aluminium, and manganese are not also present either as impurities or as replacing elements, and whether the mineral is not essentially a hydrous silicate of magnesium. Pending further investigation, the mineral may be regarded as deweylite, a hydrous basic silicate of magnesium. In the writer's opinion there is no essential difference between this mineral and the green mineral previously described.

Pyrolusite.—Manganese dioxide is not abundant, and does not call for detailed description. It occurs in small quantities as an encrusting deposit in open fissures, and forming dendritic markings on the earlier-formed minerals.

Limonite.—Limonite is abundant on the surface of the serpentine, derived from the decomposition of the ferriferous minerals. It is described elsewhere as a secondary iron ore.([26]) It is also present in small amount in the serpentine exposed in the workings at the Nickel Reward Mine, where it is derived from the oxidation of pyritic minerals.

Selenite.—This mineral is not abundant, but it does occur in the serpentine. Although not observed *in situ*, crystal plates of transparent selenite about 1 inch across and one-eighth inch in thickness were found on the dump

([26]) *Vide infra*, p.p. 215–217.

at the mouth of the No. 1 Adit of the Nickel Mine. Apparently it occurs as a vein in the serpentine. The sulphur necessary for the formation of the mineral has probably been derived from the decomposition of the pyritic minerals.

Chrysotile.—Fibrous serpentine, chrysotile (frequently called asbestos), is not common in the serpentine area. At several points near Trial Harbour narrow veins of the mineral were observed, not more than one-half inch in width. Sometimes veinlets were noticed traversing the serpentine, when examining thin sections under the microscope, which were invisible to the naked eye. The mineral is of no economic value in this area.

Garnierite.—The silicate of nickel and magnesium is developed at two localities, but as an ore of nickel it is described elsewhere.([27])

It is not easy to trace with any degree of accuracy the boundaries of this serpentine mass. Over the greater part of the area is a thick cover of vegetation, low scrub and button-grass to the west, and very thick scrub along the eastern extension, so thick as to be quite impenetrable in most places. Several attempts were made to break through in this vicinity, without success. At Trial Harbour itself the beach sand covers the outcrop; on the southern side of the harbour the long jutting reef, which is bare only at low tide, is composed of serpentine, which is here brown in colour, and, as one would expect, very soft.

To the north-west, along the coast towards the granite contact, the rocks are so highly metamorphosed that the junction of the original sedimentaries is difficult to determine. The characters of these rocks are referred to elsewhere.([28]) To the south-east the serpentine is bounded by sedimentaries, and this also is the case on the east.

From a few chains south of the granite-slate contact, and just north of Trial Harbour, the serpentine contact runs east for about a mile, then bends south for less than half a mile, and west again to the ocean, the approximate width along the coast being three-quarters of a mile. At several points it extends to within a few chains of the granite, but at no point was an actual contact observed.

The serpentine mass does not appear to be connected on the surface with the area of gabbro-amphibolite further to the north-east. The country between the two areas is practically inaccessible, being rough and covered with dense

([27]) *Vide infra*, p.p. 209, 214, 215. ([28]) *Vide infra*, pp. 114–117.

scrub. By two different routes, however, the writer reached the Little Henty River from the Trial Harbour Road, and, although no outcrops were visible for some distance, nothing was seen to indicate the presence of a continuous belt of igneous rock.

To the south-east is a development of lime silicate rocks, referred to elsewhere in this report.([29])

Up to the present a mineral deposit of possible economic value has been discovered at one locality in the serpentine. Nickel ore has been located, and some work done, in the vicinity of Trial Harbour; this is described elsewhere.([30]) Magnetite is present throughout the mass, but not in sufficient quantity to be of economic value. Secondary iron ores also occur, and some work has been done on them,([31]) but they are of no value. Some of the effects of weathering are described in another part of this report. The weathering has been responsible for the setting free of certain compounds which have been carried in solution to form new compounds. Thus, secondary iron ores have been formed on the surface from the iron set free, and iron, lime, and silica have assisted in the cementing of unconsolidated sediments.

Little information with regard to the true nature of the serpentine and its mode of origin can be learned from an examination of hand-specimens. No crystalline structure is noticeable, and the original igneous rock seems to have altered completely. With the aid of the microscope, however, some important information is gleaned, and the mode of origin of the rock becomes clear. Where it is first met *in situ* on the coast to the north of Trial Harbour, in contact with a light-coloured lime-silicate hornstone described elsewhere ([32]) (*i.e.*, at its furthest extension north along the coast), the rock is dark bluish-black in colour on freshly broken faces, and black on weathered surfaces. The weight of the rock is at once noticeable, and an examination shows that it carries abundant magnetite in streaks and segregations through the rockmass. The rock strongly affects the magnetic needle, and fragments carry so much magnetite that they are themselves magnetic.

In thin section but two minerals are seen to be present—serpentine and magnetite. The serpentine, however, is not massive, but throughout the slide shows the forms of more or less rounded grains separated by serpentine-filled veinlets producing what is known as "mesh structure." Many

([29]) *Vide infra*, p. 127.
([30]) *Vide infra*, pp. 185–188, 415–421.
([31]) *Vide infra*, p. 216.
([32]) *Vide infra*, pp. 125–126.

of the rounded grains are surrounded, or partially surrounded, by masses of finely granular magnetite. In some instances the forms of crystals resembling olivine are brought into relief by these magnetite rims. Magnetite is also present in irregular aggregates and in the form of irregular streaks. Beyond the form of crystal grains suggested by the magnetite and by the structure of the serpentine, there is nothing to show definitely the nature of the primary igneous rock.

Included in this serpentine are apparent lenses of a rock quite distinct in appearance, being yellowish on weathered surfaces, and greenish-yellow on freshly-broken faces. This rock proves to be a lime-silicate hornstone, composed essentially of diopside and magnetite. It is described in detail elsewhere.([33]) Occurrences of a similar rock occur at different points in the vicinity.

Near its northern extremity, as exposed on the coast, the serpentine has been described as enclosing masses of this yellow diopside rock. What appears to be a well-defined band of sedimentary rocks 3 feet wide is noticeable in these rocks, striking a little north of west. An examination of freshly-broken specimens of this rock shows that it is an intensely altered sedimentary, with peculiar reddish and greenish bands. Garnet, biotite, and actinolite are recognisable in the groundmass, but the rock was not examined microscopically.

Southwards very dark-coloured serpentine continues, carrying very abundant magnetite. In many places the amount of serpentine present in the rock is subordinate to the magnetite. Greenish flakes of phlogopite mica up to 1 inch in diameter occur with masses of magnetite, which frequently stand out in relief from the weathered rock surfaces. The magnetite is frequently crystallised, the dodecahedron being the form usually developed. Crystals occur up to one-quarter inch across. This magnetite-serpentine gradually merges into the more normal variety of grey-blue serpentine, which is a deeper bluish tint below the weathered crust. The rock is still traversed by veinlets of magnetite, which stand out in relief, and as the softer rock weathers away give the rock surface a peculiar appearance. The rock here is cut through in places by veinlets of chalcedonic and opaline silica, which also sometimes stand out in relief. Occurring in geodes, the silica sometimes takes botryoidal forms. Nodular masses of magnetite with phlogopite are still to be seen, cut through by veins of chalcedony. The

([33]) *Vide infra*, pp. 125–126.

magnetite here sometimes occurs in long radiating fibres, which form masses up to about 12 inches in diameter. The radiating magnetite is not only highly magnetic, but also polar. Fibres which form the radiating aggregates are sometimes several inches in length, aggregates crossing and recrossing at various angles. Granular magnetite is also present, phlogopite is common, and irregular veinlets filled with clear radiating crystals of arragonite are common. Masses of a white kaolinised mineral frequently occur with magnetite, sometimes forming interstitial material between the fibres.

The serpentine here appears normal. It is a dense rock of a very dark-bluish colour, almost black in places, and very soft, showing a white streak. Near the surface the weathered crust is sometimes light-brown.

A thin section of this serpentine was examined microscopically, and gave some interesting information. In ordinary light the serpentine is of a light-greenish colour; studded throughout the groundmass are abundant more or less rounded grains of olivine. A small quantity of fine magnetite and idiomorphic octahedral crystals of the same mineral are present. The fine magnetite sometimes occurs in irregular veinlets traversing the rock; several of these veinlets, in addition to carrying magnetite, contain fibrous chrysotile, the fibres being at right angles to the walls of the fissures. A small quantity of pyrrhotite is sporadically distributed through the rock. A close examination of the structure of the serpentine shows that most of the olivine grains are surrounded by patches of serpentine, which are either slightly more transparent than the immediately surrounding material, or differ from it sufficiently to indicate definite crystal forms. In other words, the olivine grains still unaltered are but kernels of original grains whose periphery has been changed to serpentine. Examination between crossed nicols shows that frequently several adjacent grains extinguish simultaneously, and from their relation to each other it is quite clear that many of the groups of grains represent original olivine crystals which have suffered serpentinisation along cracks; in fact, some of the larger grains are actually traversed by cracks, showing incipient serpentinisation. As a result of this action, mesh-structure is developed. No indication is given by the section of the presence of any other mineral than olivine (excepting the pyrrhotite and part of the magnetite) in the original igneous rock; the latter therefore appears to have been an ultra-basic rock, peridotite.

Continuing the coastal section southwards towards Trial Harbour, the serpentine for a few chains does not vary essentially. Nodules of radiating magnetite still occur at intervals, and in places a few irregular veins up to 3 inches in width, containing fibrous chrysotile with phlogopite and magnetite. The chrysotile is readily divisible into extremely fine silky fibres, but no veins carrying fibres of any length were seen. Nodular masses also occur containing talc in addition to the other minerals.

This belt of what may be regarded as fairly normal serpentine is succeeded by a well-defined belt of rock, apparently consisting of an intersecting network of vein-like masses of a very dense black rock in a groundmass of a light-yellowish rock. Close examination shows that the black masses are composed of dark serpentine, thickly impregnated with granular magnetite, which forms the bulk of the rock. Occasional veinlets of fibrous chrysotile cut through the rock. The lighter-coloured rock proves to be granular yellow diopside rock. A description is given below of the microscopic structure of this rock.([34]) It contains abundant magnetite, and occasional inclusions of a dense black rock, apparently the black serpentine described above. The rock varies in colour from greenish-yellow, the typical colour, to greenish-grey.

These rocks mark the junction with a belt of highly metamorphosed sedimentaries again. The rocks are extremely hard and flinty, of a general dark-blue colour, and contain aggregates of crystals of greenish-black pyroxene or amphibole, and also aggregates of, and irregular fissures filled with, white tremolite. Occasional irregular light-coloured siliceous patches occur in these rocks, with included magnetite. There are also apparently intrusive masses of black serpentine with very abundant magnetite. The rocks were not examined microscopically, but certainly have the appearance of being highly altered slates. They are banded, and these bands strike about north-west.

Shingle and talus cover the outcrop for a few yards, but the rocks described appear to merge into a series of highly contorted schistose rocks, which are very siliceous, and contain a little fine disseminated pyrite. The rocks are apparently schistose quartzites. They continue for several chains along the coast, past the mouth of Montagu Creek, and are very schistose in places. Here and there are large angular boulders of a striking white rock, and the same rock appears to be *in situ* at the base of the cliffs a little north of

([34]) *Vide infra*, p. 125–126.

Montagu Creek. The rock is quite white near the surface, but is not homogeneous. The groundmass of the rock is a finely granular white mass, with fairly abundant octahedral crystals and grains of magnetite. This groundmass is intersected in all directions by veins of white silica. Occasionally small geodes are to be seen lined with minute transparent crystals of quartz, but more usually such linings are of botryoidal silica which has taken the chalcedonic form; the vein-fillings are usually chalcedonic. The microscopical examination of a thin section gives some further interesting information concerning the original nature of the rock, and the alteration it has undergone. The general structure of a large portion of the groundmass closely resembles that of the normal serpentine described above.[35] Crystal forms resembling olivine, sometimes divided into meshes by fine cracks, stand out clearly. Many of these crystal forms are partly or wholly surrounded by a very narrow rim of finely-divided magnetite. This mineral also occurs in sporadic octahedral crystals. While the general structure of the slide is so suggestive of the structure of serpentine when viewed in ordinary light, between crossed nicols, it is seen that (with the exception of the magnetite) the rock is completely replaced by silica. In the groundmass the silica takes the form of opal, which shows minute dark crosses whose arms do not rotate with the rotation of the stage. From this opaline groundmass the forms of the olivine crystals stand out clearly; these, too, are replaced by opal, but the structure of the material is in some almost indefinable way different. It appears to be of finer texture. The apparent cracks in some of these crystals are traversed by opal similar to that forming the groundmass of the slide. The slide itself is traversed by veinlets which are filled partly with opal, partly with chalcedony. There can be little doubt that the rock is an opaline serpentine; it would appear that the original peridotite has first suffered serpentinisation, and that subsequently the serpentine has been replaced by silica.

The schistose rocks referred to above are followed near the end of the Trial Harbour Road, a few chains above the site of the old township, by very dense blue rocks, extremely hard, and showing disseminated pyrite; these rocks also are metamorphic slates. Their southern extension is a band of weathered greenish-brown rock, which may be a decomposed diopside rock, as the greenish diopside rock with magnetite, similar to that occurring further north and

(35) *Vide supra*, p. 50.

described above, makes its appearance again at the northern end of the old township site, near the foot of the road.

As the road is on a fairly steep grade up the hillside, side cuttings for the road have been necessary for some distance, affording fine sections of the rocks at the surface. A close examination of these rocks reveals a similar succession to that on the beach. At the base of the cliffs and near the bottom of the road is a soft yellow to brown rock, apparently a thoroughly decomposed serpentine: the rock shows a little magnetite in scattered grains and streaks. This merges into undoubted serpentine, greenish when partly weathered, dark greenish-blue when fresh. For several chains a red iron-stained soil covers the surface, but it is probable that serpentine exists below, as the succeeding rocks are of very dark-coloured (almost black) serpentine, with very abundant magnetite; the latter mineral sometimes occupies the bulk of the rock. In places patches of the serpentine are lighter-coloured, being yellowish, but are always streaked with magnetite. On the whole, this dense magnetite-serpentine corresponds closely with that already described on the coast below.

The serpentine is succeeded by an exposure for about 5 chains of metamorphosed blue slates and reddish quartzites, much hardened and altered.

The road here takes a bend about north-east, and at this bend is some massive magnetite, in decomposed rocks, apparently diopside rocks. The magnetite occurs both granular and radiating: the granular variety is usually of medium texture, while in the radiating magnetite the fibres are fine, and sometimes several inches in length. The radial aggregates tend to form flat laminæ: in some cases the structure is typically plumose. Granular magnetite is usually scattered through the radiating masses.

The magnetite occurs in lenses, the width varying up to about 12 inches. Greenish stains, apparently due to a trace of nickel, are visible on some specimens. Magnetite is not sufficiently abundant to be of economic value.

For the following 6 chains along the road, the cutting exposes yellowish-green diopside rocks described in detail elsewhere.[36] Although they vary a little from point to point, the essential features of these rocks are similar to those occurring near the northern extension of the serpentine along the coast.

These rocks are apparently in contact with sedimentaries, which are exposed on the roadside near the falls on Ser-

(36) *Vide infra*, p. 126.

pentine Creek. The rocks are extremely hard and flinty, of a general light-greenish to reddish colour. They are intensely altered, and continue to the granite contact, which here approaches within a few chains. Abundant pink garnet is developed in these contact rocks, sometimes in irregular veins. Diopside and actinolite aggregates are also noticeable. Serpentine is not exposed in the road further north.

Returning to the site of the old township of Remine, at the northern end of the town site, at the foot of the road, the greenish-yellow diopside rocks give place to serpentine, which is exposed on the shore. The rock is light greenish-grey on weathered surfaces, and very dark blue, almost black, in fresh specimens. The rock is soft, as usual, but beyond magnetite in streaks and veinlets through the rock, no constituents of the serpentine can be determined in hand specimens.

Serpentine forms the bedrock at Trial Harbour itself. Adjoining the diopside rocks at the foot of the road, it is cut through by numerous chalcedonic veins. The long reef on the south side is exposed at low tide, and is seen to be composed of the same rock. As is to be expected with a rock in such a position, the serpentine is a good deal softened: the freshest specimens obtainable are light-brown in colour, and are intersected by numerous veinlets filled with arragonite, frequently in radiating aggregates of minute, needle-like prisms. The serpentine is exposed along the coast southwards for about three-quarters of a mile, where it junctions with altered sedimentary rocks: the latter continue to the southern limit of the area examined, the mouth of the Little Henty River. These rocks are described elsewhere.

Inland, the serpentine where exposed is normally a dark blue-grey rock, when fresh, with no distinguishable constituent minerals macroscopically except magnetite, and corresponding with the rocks already described from the coast.

A specimen of serpentine collected from the upper (No. 1) adit of the Nickel Mine on the hill overlooking Trial Harbour, appears dark bluish-green in hand specimen and shows darker patches of magnetite at intervals through the rock. In thin section the rock is pale-green by transmitted light, and is seen to contain very abundant magnetite; part of this is evidently primary, as it shows idiomorphic outlines, but a good deal is secondary. In the thoroughly serpentinised groundmass are residual grains of olivine

quite similar to those occurring in a slide previously described([37]) from the beach north of Trial Harbour. Occurring rather abundantly through the slide, in clear crystal plates distinctly moulded on olivine crystals, and in foliated masses, is the mineral brucite. Associated with the brucite is a little colourless hydromagnesite; this rock also appears to represent a serpentinised peridotite.

One other section of serpentine was examined microscopically, and the examination confirmed the observations previously made. This section was prepared from a specimen collected from the Serpentine Creek near the head of the falls in the vicinity of Trial Harbour. The rock is grey on weathered surfaces, but a dark blue-grey colour on freshly broken surfaces. It is seen to be traversed by abundant minute veinlets of magnetite. No further information as to the structure of the rock can be obtained from a macroscopic examination. Microscopically it is seen that olivine fragments are abundant right throughout the slide in a thoroughly serpentinised groundmass. Magnetite is very abundant in veinlets, irregular aggregates and thread-like veinlets surrounding and forming the skeleton crystals of the partially serpentinised olivine crystals. No other minerals are present, and, excepting in minor details (as, for instance, the amount of magnetite present), the rock is quite similar to those described from other parts of the area, and is to be regarded as a serpentinised peridotite.

In places the serpentine from this locality is traversed by chalcedonic veins striking north-west: the rock itself is frequently much decomposed, and is usually covered by a crust of limonite. The serpentine here appears to merge into a yellowish-green diopside rock with magnetite, which is very hard; this rock occurs *in situ* at the head of the Serpentine Creek Falls, and probably accounts largely for the formation of these falls.

Towards the eastern extremity of the serpentine, on the high ground forming the Little Henty divide, but on the slope towards that river, is fairly thick scrub concealing many details of the rocks below. Between the serpentine and slates there is at several points a development of lime-silicate rocks. At one point on the borders of the serpentine is an occurrence worthy of note: the rock outcrops on the summit of the divide, but its extent could not be determined. It is pure white in colour, and consequently

([37]) *Vide supra*, p. 50.

the detrital material lying on the surface can be traced to its source with comparative ease. The rock is rather cellular at the surface, owing to the effects of weathering, but is thoroughly silicified: in texture it is granular, and it carries fairly abundant crystals of magnetite. Cutting through this rock are abundant veins of chalcedony and sometimes quartz. Clear prismatic quartz crystals of small size are sometimes noticed lining small geodes. At intervals the rock is seen to be encrusted with amorphous emerald-green garnierite (hydrous silicate of nickel and magnesium): a more detailed description of this mineral is given elsewhere.[38] The rock is identical in essentials with that described[39] from the beach north of Trial Harbour, and is opaline serpentine. Normal serpentine appears a few chains to the north-west.

Summary.—It appears advisable to summarise the foregoing description of the serpentine area, and the rocks closely associated with it.

The bulk of the rock classed as serpentine is really a serpentinised peridotite, the unaltered grains of fresh olivine occurring throughout the rocks, with the characteristic structure of the serpentine and secondary magnetite, giving a clear indication as to the nature of the primary igneous rock. Since its formation, secondary lime and magnesia minerals have been developed in the serpentine. Part of the serpentine has been completely silicified since its derivation from the peridotite. The significance of this observation is important as throwing light on the cause of the serpentinisation of the peridotite. The structure of the silicified rock makes it clear that it is the secondary serpentine, and not the primary peridotite, which has been replaced. Since the chalcedonic and opaline silica is apparently derived from hot solutions traversing fissures in the rock-mass, it is clear that the original olivine must have been hydrated (serpentinised), at least in part, before the introduction of the silica. The source of the silica must be connected with (*a*) the weathering of the crust of the rocks freeing silica from the decomposed rock-forming minerals, which has been introduced in solution into the still undecomposed rock below, (*b*) the intrusion of the acid rocks, or (*c*) the intrusion of the basic rocks themselves.

(*a*) The introduction by descending solutions of silica freed in the process of weathering does not appear likely. A cementing action has taken place in another part of the

[38] *Vide infra*, p. 214. [39] *Vide supra*, p. 52.

area, by silica freed in this way,[40] but the effect is merely local, and does not appreciably affect the rock more than a few inches below the surface. In that locality there are no veins apparent, and the silica has taken the form of opal, no chalcedony being seen: also, although at the surface the rock is to some extent impregnated, no complete replacement has taken place.

(*b*) It is possible that the silica-bearing solutions may have been derived from the acid magma which gave rise to the granite, during its final stages of consolidation. The chalcedony-filled fissures cannot be traced beyond the serpentine into the sedimentaries which exist between the serpentine and the granite: at one point at the serpentine contact the sedimentaries are silicified.[41] Where siliceous veins do occur in this zone, they are of quartz, and not of chalcedony. No minerals are present to indicate granitic affinities.

(*c*) It appears to the writer most probable that the solutions have been derived from the magma which gave rise to the basic rocks, being expelled from the cooling mass during the final stages of consolidation, and traversing fissures caused by contraction of the cooled crust. The presence of scattered idiomorphic crystals of magnetite, and of nickel stains (garnierite) in chalcedonic veins from towards the eastern extension of the serpentine belt, certainly indicates affinities with the basic rather than the acid magma.

It seems clear that the silicification is due to magmatic waters. If these waters were derived, as suggested, from the basic magma, the serpentinisation of the rock-mass must obviously have been caused by magmatic waters, *during* the latest stages of the consolidation of the magma, but *before* the final consolidation, which was marked by the extrusion of siliceous solutions. Thus the serpentinisation of the peridotite is not a weathering effect.

A precisely similar conclusion was arrived at by Mr. W. H. Twelvetrees for the Bald Hill serpentine, where veins of chalcedony and opaline silica also occur. After discussing the question of serpentinisation Mr. Twelvetrees[42] states: "There are good reasons for supposing serpentinisation to be a deep-seated thermal process. On this hypothesis, the Bald Hill serpentine is a product of the after-action of the gabbro-peridotite consolidations; and the opalisation and chalcedonisation of the rock may be attributed to the same cause, but later than the serpentinising process."

[40] *Vide infra*, p. 110. [41] *Vide infra*, p. 112.
[42] Geol. Surv. Tas. Bulletin 17, p. 8.

Mr. L. K. Ward also concluded([43]) that serpentinisation of the basic rocks was not due to the action of surface waters, attributing it (on evidence supplied by the alteration of a mica-gabbro dyke in the summit cutting on the Comstock Tramway) " to the influence of the magmatic emanations given off from the whole surface of the cooling acidic magma of later date."

Relationships of the Basic Rocks.—A description has been given above of the basic rocks, but it remains to briefly discuss the relation of the gabbro-amphibolite to the serpentine.

As described above, the rocks on the surface occupy distinct areas, the former south-west of the Comstock, the latter near Trial Harbour. The country between the two areas is mostly heavily timbered, and carries abundant thick scrub and undergrowth, rendering a detailed examination of the area impossible, but at one point at least (in the Burnt Bridge Creek) gabbro-amphibolite outcrops. Most of this area is occupied by sedimentary rocks—slates and sandstones of Pre-Silurian age. There is no surface connection between the two rock types.

It is unfortunate that analyses of the rocks are not available for comparison, but in their absence the microscope has been requisitioned to disclose the mineralogical composition of the rocks. The results of the microscopical examination of thin sections have been recorded elsewhere. It appears that the gabbro-amphibolite has been originally pyroxene-bearing, the pyroxene having been converted to amphibole probably as a result of the pressure exerted by the somewhat later granitic intrusion. The rock carries fairly abundant felspar, and represents an altered basic rock—a gabbro. The serpentine, on the other hand, shows abundant olivine remnants, but no felspar, and represents an altered ultra-basic rock—a peridotite.

The presence of an outcrop of gabbro at one intermediate point implies connection with an underlying reservoir of basic rock. There can be little doubt of the connection of the two rock-masses at a depth. The difference noted in the exact rock type is not surprising, and can be explained by the phenomena of differentiation. That such an assumption is justified is shown by the occurrences of basic rocks elsewhere in the State.

At North Dundas ([44]) similar rocks to those described are developed, and the structure is in general similar.

([43]) "The Origin of Certain Contact Rocks with a High Content of Lime and Magnesia:" Proc. Sect on C, A.A.A.S. Vol. XIII., p. 186.
([44]) *Vide* Geol. Surv. Tas. Bulletin 6, pp. 18–24.

In the Wilson River district ([45]) a large area of basic and ultra-basic rocks is exposed, the latter rocks forming the marginal development of the mass, formed by magmatic differentiation.

In the vicinity of the Bald Hill similar rocks are known to occur again, and from the description given of them ([46]) it would appear that here also differentiation accounts for the different rock types.

In the South Heemskirk district it appears that a huge mass of basic magma was intruded in Devonian time into a thick series of overlying sedimentary rocks. The magma rose to different heights, and while still deep below the surface, and at a very high temperature, magmatic differentiation caused a partial separation into sub-magmas, one more basic than the other, and tending to form towards the margin of the intrusive mass. As the magma cooled and finally solidified the resulting rocks differed from each other in their extreme variations, from a basic (gabbro) to an ultra-basic (peridotite), but gradually merged into each other.

The portion of the rock which would represent an intermediate type between those described is that which did not originally rise to the same elevation as some other portions of the magma, and which, in consequence, has not yet been exposed by the removal of the overlying sedimentary rocks, *i.e.*, it would be portion of the rock-mass which forms the base on which the slates between Trial Harbour and the Comstock rest.

The occurrence of serpentine ([47]) to the north of the gabbro-amphibolite described indicates that the marginal development of ultra-basic rocks may be more complete than has been suspected.

Age of the Basic Rocks.—There is little direct evidence in the district to fix the age of the basic intrusives. The rocks are intrusive into Pre-Silurian sedimentary rocks, and are consequently younger than these sediments.

In another part of this report ([48]) the relation of basic to acid igneous rocks is discussed, and the opinion expressed that the two are of approximately the same age, being both derived from the one magma. The evidence available to fix the age of the granite is rather more abundant than is the case with the basic rocks, and in view of this evidence ([49]) the age of the granite is assumed to be Devonian.

([45]) *Vide* Geol. Surv. Tas. Bulletin 1., pp. 18–24.
([46]) *Vide* Geol. Surv. Tas. Bulletin 17, pp. 5–8.
([47]) *Vide* Geol. Surv. Tas. Bulletin 8, p. 21.
([48]) *Vide infra*, pp. 97-100.
([49]) *Vide infra*, p. 95.

Thus the basic rocks also are believed to be of Devonian age, as both groups belong to the one period of igneous activity.

If the rocks are to be correlated with the basic rocks occurring in other districts in close association with granite—and there is good reason to believe that such a correlation is justified—the Devonian age attributed to them coincides with the opinions expressed for the other rocks by different writers in the Geological Survey publications.

Mode of Origin of the Basic Rocks.—There can be little doubt but that the different exposures of basic igneous rock in the district are to be correlated with each other, in spite of the differences in their mineralogical composition in different localities. The gabbro-amphibolite at the Comstock, that near McIvor's east of Mt. Agnew, and the small outcrop of a similar rock further to the south-west in the bed of the Burnt Bridge Creek, have many features in common, and probably all are surface outcrops of a single igneous mass. The Trial Harbour serpentine probably differs little in composition from the gabbro-amphibolite, and its occurrence suggests that it, too, belongs to the same period of intrusion. Reasons are given elsewhere for the opinion expressed that the intrusions occurred in Devonian time.

Unfortunately no analyses of these rocks are available. From the descriptions given of the mineralogical constitution and structure of the rocks as determined by microscopical examinations of thin sections, it is clear that the rocks in their present state are not primary igneous rocks; they have undergone a good deal of alteration, and in fact it would appear that they are really reconstituted rocks.

They occur in a district where the prevailing country rocks are much metamorphosed, and have undergone intense crushing, accompanied by folding. It seems clear, however, that these rocks had already undergone intense alteration before the intrusion of the basic rocks. No marked schistose structure is anywhere to be seen in the basic rocks, and at several points the igneous rock occurs in dyke-like intrusions in the old sedimentaries, these dykes or tongues conforming with the strike of the slates, having apparently been forced into the bedding-planes of the series. A certain schistose structure would certainly have been developed in the rocks had they been subjected to the same intense regional metamorphism which has so powerfully affected the surrounding sedimentary rocks.

The relationship of the igneous rocks is discussed elsewhere, and the opinion expressed that, although the acid

and basic rocks are very nearly of the same age, and derived from the same magma, the acid rocks are slightly later than the basic ones.

It has been shown that there is a variation at different points in the basic rock, but that these variations are only of minor importance, the rock retaining its general characteristics over a considerable area. The serpentine area is distinct from that of the gabbro-amphibolite, and the fact that it has altered to serpentine is probably due to the fact that this particular area consisted of more basic rocks richer in olivine than the northern areas. The hydration of olivine would result in the formation of serpentine.

In the North Dundas district is a considerable development of basic rocks which have been described by Mr. L. K. Ward ([50]) as gabbros and norites (with gabbro-amphibolites and saussurite-norites as modifications), and pyroxenites and peridotites (with serpentine as a modification). In accounting for the conversion of the gabbro to gabbro-amphibolite in this district, Mr. Ward says ([51]): "Certain modifications of the gabbroid varieties have been effected by the conversion of the pyroxene into amphibole, but this alteration has nothing to do with the processes of differentiation. It is commonly effected by dynamic metamorphism, but in the present case there has been very little, if any, actual crustal deformation. In seeking for the cause of the transformation of the pyroxene to hornblende, the writer has come to the conclusion that the stresses have their origin within the rock-mass itself. It seems, therefore, that the explanation may possibly be found in the processes of alteration which have gradually converted considerable masses of basic igneous rocks into serpentine. This serpentinisation would be attended with a considerable increase in bulk, and the rocks associated with the serpentine would share in the small differential movements which occur within the basic mass. This explanation would account for the presence of the gabbro-amphibolite with the serpentine on the borders of the granite areas, whatever be the relation of the granite to the basic types."

It must be borne in mind that no granite is present in this district, although the acid rocks are represented by dykes of granite-porphyry and pegmatite, the former intersecting the basic rocks.

In the light of present knowledge of the distribution of the serpentine, it does not appear very likely that the increase in bulk due to serpentinisation, could have

([50]) Geol. Surv. Tas. Bulletin 6, pp. 18–24. ([51]) *Op. cit.*, p. 31.

exerted sufficient pressure on the areas now converted to amphibolite, to have caused the modification of the original gabbro, which is so universally observed in the area examined. The complete conversion of the pyroxene into amphibole, the development of secondary albite, and the saussuritisation of the original felspar noticed in some cases, certainly indicate that considerable pressure has been exerted on the igneous rock since consolidation. On the other hand, a careful microscopical examination of various thin sections of granite failed to reveal in any instance evidence that the acid rock had been subjected to pressure since its consolidation. When the bulk of the Heemskirk granite *massif* is considered, it is clear that the intrusion of such a mass of rock could not have been without its effect on the surrounding rocks. The actual contact-metamorphic effects on the sedimentary rocks adjacent to the contact are dealt with elsewhere, and are shown to be due partly to heat and pressure, partly to the action of solutions and vapours introduced from the igneous mass. Further away from the contact, however, although the same intense effects would not be felt, the pressure of such a huge mass intruded into a mass of sedimentary rocks, must have some effect on those rocks, the effect decreasing with the distance from the contact. Although at no point was the gabbro-amphibolite seen to be in contact with the granite, it is never very far removed, and the rocks between the two igneous masses are always intensely metamorphosed. It seems possible, then, that in this district the pressure exerted by the intrusive granite mass may have been sufficient to cause the amphibolitisation of the gabbro, without being sufficiently intense to convert the rock into an amphibolite-schist.

Changes such as those described are recognised as having resulted from metamorphism, such as that which would have been caused by the intrusion of such a huge mass of igneous rock. Harker ([52]) quotes an example from Scourie (Scotland) illustrating the effect of the dynamic metamorphism of diabase. "The augite is transformed into green hornblende, and the felspar has recrystallised in water-clear grains, while the titaniferous iron ore has also been altered, giving rise frequently to granular sphene. These mineralogical changes may be produced without any schistose structure."

To come nearer home, the occurrence at North Dundas has already been referred to.

([52]) "Petrology for Students": A. Harker, 3rd Edition. 1902, p. 322.

In the North Heemskirk tinfield, the writer recently recorded ([53]) the occurrence of gabbro, in which the monoclinic pyroxene is partly uralitised. This occurrence is a little over 1 mile from the northern boundary of the Heemskirk granite *massif*.

In the Stanley River District ([54]) Devonian basic rocks—gabbro, norite, pyroxenite, and serpentine—occur, intrusive into sedimentary rocks of Pre-Silurian age, adjacent to the margin of the Meredith Range granite *massif*, which is of Devonian age, and slightly later than the basic rocks. Saussuritisation of the felspars and partial uralitisation of the pyroxenes have been recorded.([55])

Further north, near the Heazlewood,([56]) are gabbros, pyroxenites, and peridotites, with serpentine. These are of similar age, and are also associated with acid igneous rocks, being just to the north of the Meredith Range *massif*. In these rocks saussuritisation of the felspars has been recorded, but there is no record of amphibolitisation of the pyroxene, although actinolite rock is abundant in certain localities (a contact-rock, apparently, and not an intrusive igneous rock).

South of Macquarie Harbour, at Asbestos Point, and near the Spero River, are occurrences of serpentine, gabbro, saussurite-gabbro, and bronzite rock, ([57]) while in the neighbourhood are intrusions of acid rocks, which indicate the presence of a granitic reservoir.

At Anderson's Creek, near Beaconsfield, serpentine occurs intruded by granite.([58]). The serpentine here has been derived from peridotite.([59])

Thus, although there have been several recorded occurrences of basic and ultra-basic rocks, under conditions generally similar to those existing in the area under review, little information is available to throw light on the particular subject under investigation.

It must be borne in mind that there was a considerable thickness of overlying sediments, long since denuded, at

([53]) *Vide* Geol. Surv. Tas. Report 6, pp. 5-7.
([54]) *Vide* Geol. Surv. Tas. Bulletin 15, pp. 18-24.
([55]) *Op. cit.*, pp. 20-23.
([56]) *Vide* Sec. for Mines, Tas., Ann. Report, 1899-1900, pp. cxlvi, cxlvii. Also Geol. Surv. Tas. Bulletin 17, pp. 5-8.
([57]) *Vide* Geol. Surv. Tas. Bulletin 18, p. 12.
([58]) W. H. Twelvetrees: Report on Mineral Resources of Beaconsfield and Salisbury, 1903, pp. 3-9. Also Ann. Report Sec. for Mines, Tas., 1899-1900, pp. xxxi-xl.
([59]) *Idem*, p. xxxv.

the time of these igneous intrusions. As denudation has proceeded, more of the underlying plutonic masses have been exposed, but it is certain that in some districts plutonic masses exist below the present surface which have not yet been exposed by denudation. The intrusion of a huge mass of rock would necessarily exert a considerable pressure, vertically as well as laterally, the amount of pressure depending on the resistance offered, *i.e.*, on the thickness of the overlying rocks. It is possible that in this way masses of basic rocks in some of the areas distant from *surface outcrops* of granite masses, may have been affected by the pressure exerted by *massifs* still below the surface, but whose presence is in all cases indicated by the presence of acid dykes where no surface outcrops are available.

This might explain some of the apparent anomalies, when uralitisation has taken place at a distance from an exposed *massif*. It is worthy of note that the amphibolitisation of the original gabbro has been more complete in the area under review, near Mt. Agnew, than in any other area of which full details are available, and that the granite is nearer in this instance, although details are lacking in one or two localities where the granite appears nearer still.

It must be borne in mind, however, that there may be a considerably larger extent of serpentine than is exposed at the surface near Trial Harbour, and as the two masses belong to the one igneous intrusion, and are believed to be continuous at no great depth below the present surface, it may be that the serpentinisation of one portion of the rock-mass (perhaps the more basic portion, which has segregated owing to magmatic differentiation to form an ultra-basic rock-mass) would exert sufficient pressure to cause the amphibolitisation of the less basic portion.

There is one point on which further information is required, *i.e.*, as to whether amphibolitisation of portions of the basic rocks near serpentine has always taken place. In almost all localities where basic rocks are developed, some of them are converted to serpentine. If serpentinisation caused amphibolitisation of the gabbro in one area it is reasonable to expect that it should have caused similar effects in other areas where it is developed in quantity. Owing to the lack of detailed information of all occurrences, the matter cannot be finally determined, but details of other occurrences will doubtless throw light on the question.

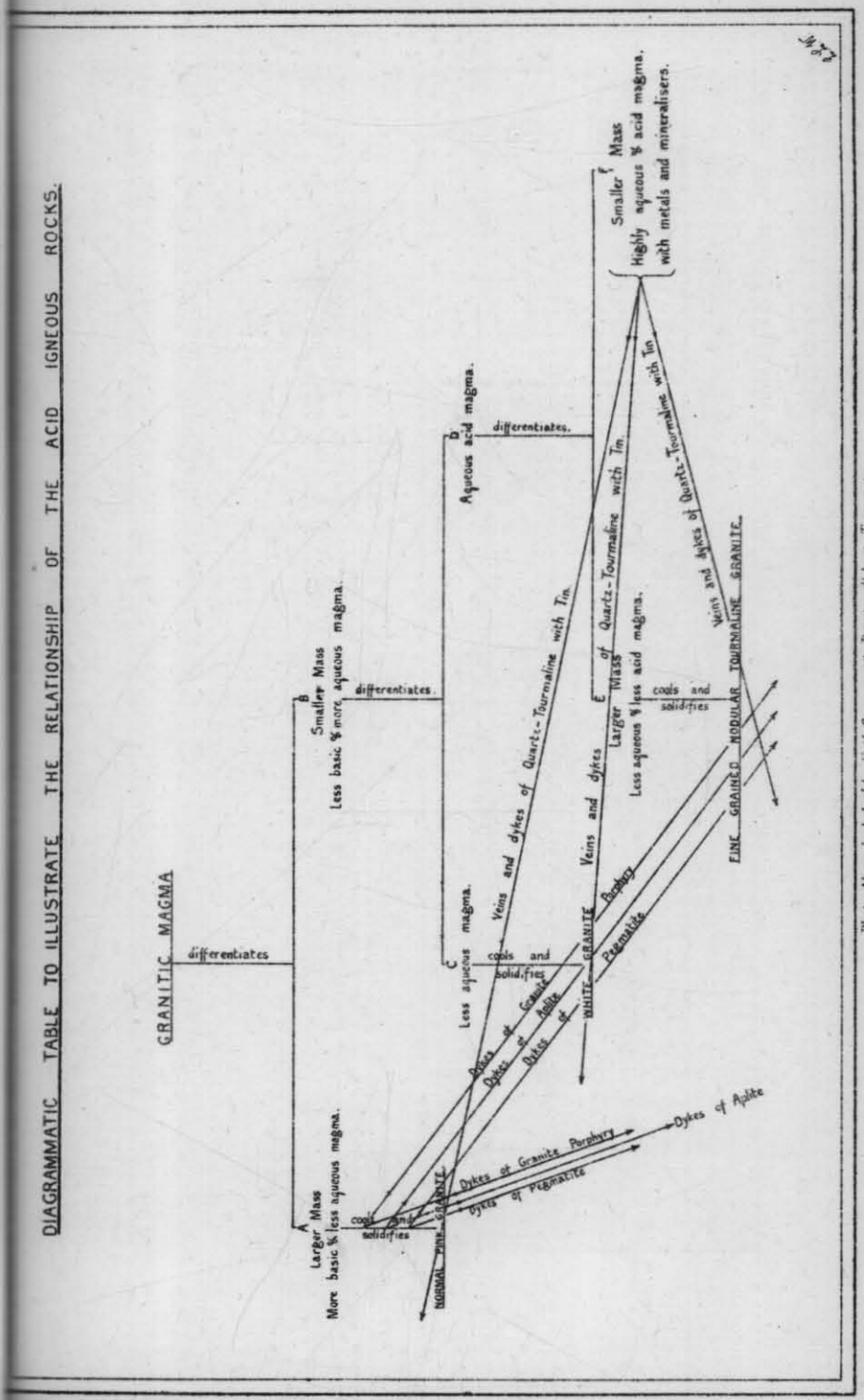


Plate Autographed by John Watt Government Printer Hobart Tasmania

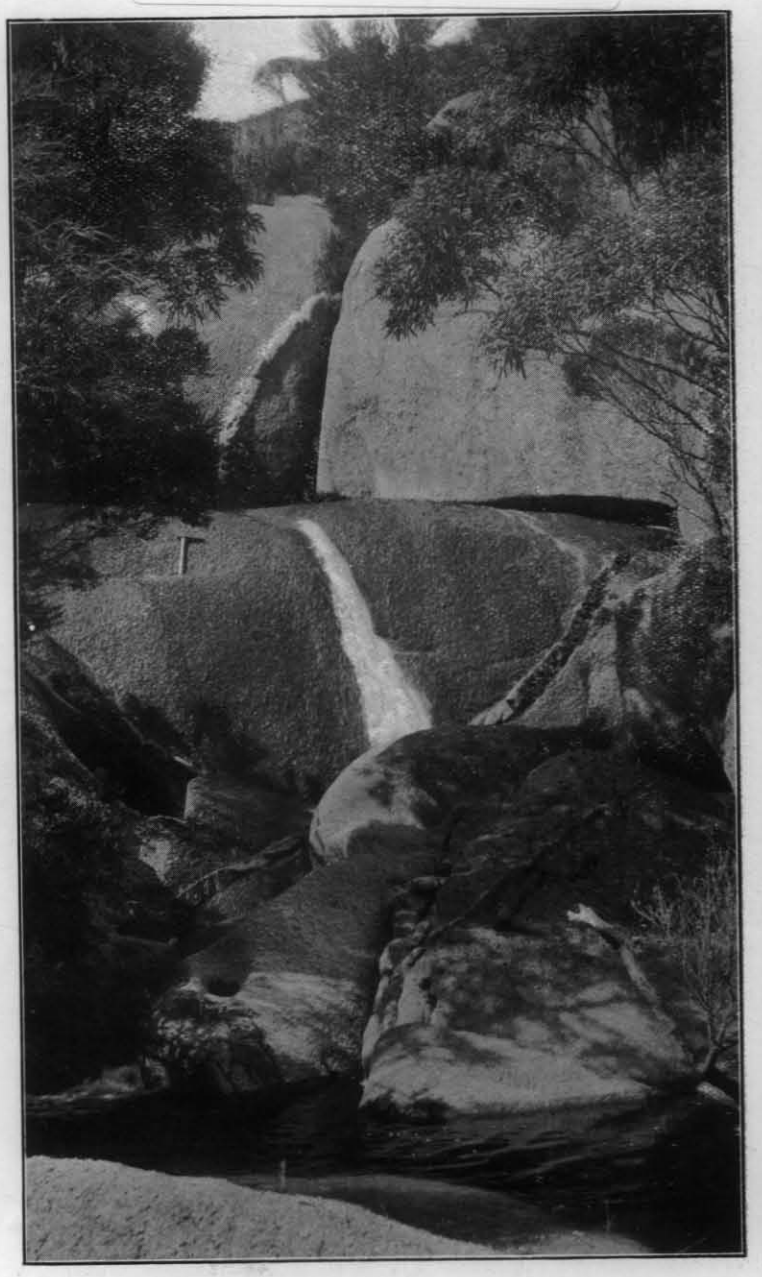


PHOTO. 9—COARSE-GRAINED PINK GRANITE TRAVERSED BY VEINS OF APLITE. MONTAGU CREEK, SOUTH HEEMSKIRK.

[L. Lawry Waterhouse, Photo.

(2)—*Acid Group.*

The acid group of igneous rocks in the district includes granite, granite-porphyry, aplite, and pegmatite, all closely related.

Granite is extensively developed, and occupies the largest portion of the area dealt with in this report. The northern portion of the area has been described in the writer's report on the North Heemskirk district, recently published.([60]) The boundary, as shown in Plate II. of that report, has been reproduced in the accompanying general map of the district (Plate II.) to make the latter more complete. It will be seen that the granite extends northwards to Granville Harbour, of which it forms the southern shore. It sweeps about south-east for 1½ mile, then east for 9 miles, beyond the Gentle Annie Rise, when the line of contact runs about south to the Trial Harbour Road. Its general course is then a little south of west to the coast, the actual line of contact being exposed on the cliffs about 1 mile north-west along the coast from Remine ([61]). Along the coast granite is exposed for over 10½ miles, where it forms precipitous cliffs ([62]) from 100 to 300 feet above sea-level. The width of the belt, measured from the coast-line, attains a maximum of about 6 miles. The same rock forms the bulk of the Heemskirk Range and the coastal peneplain for the length mentioned.

Pink Granite.—What may be called the normal granite of the district is pink in colour, owing to the abundance of pink orthoclase felspar.([63]) It forms the bulk of the granite developed in the district. Typically the rock is of medium and fairly even grain-size, although it shows a slight tendency to become porphyritic in places, with phenocrysts of pink orthoclase up to 20 millimetres in length. Normally, the orthoclase reaches about 10 millimetres in length; it is usually fresh in newly-broken specimens, and shows good cleavages. In rather smaller quantities is present a white plagioclase felspar, greenish when partly weathered, as is the case in most specimens collected, and becoming kaolinised on further decomposi-

([60]) Geol. Surv. Report No. 6: Reconnaissance of the North Heemskirk Tin Field, by L. Lawry Waterhouse, 1915.
([61]) *Vide* Photo. No. 16.
([62]) *Vide* Photo. No. 6.
([63]) A coloured plate of this granite, prepared from a specimen collected by the writer from Pyke's Creek, near Sweeney's Mine, on the southern slopes of Mt. Agnew, is reproduced in "Building and Ornamental Stones of Australia," by R. T. Baker, 1915, facing page 32.

tion. Throughout the groundmass of the rock is fairly abundant glassy quartz, in irregular masses of about 5 millimetres in diameter. In some localities quartz becomes quite subordinate in amount. Scattered through the rock are small crystals and crystal aggregates of black biotite mica; individual crystals are rarely more than 2 millimetres in diameter. A mineral often noticed in addition to those named is black tourmaline. It occurs in small crystal aggregates up to 4 millimetres across. It appears to be almost universally present, but never in large amount in the normal granite.

A microscopical examination of thin sections of this granite does not give a great deal of additional information. The minerals noticed in the slides examined were orthoclase felspar, plagioclase felspar, quartz, biotite, tourmaline, apatite, zircon, magnetite, and undetermined inclusions.

The rock is holocrystalline, relative grain-size variable, average grain-size medium. The orthoclase is fairly fresh; it is idiomorphic, and shows characteristic cleavages and Carlsbad twinning. The plagioclase is a good deal decomposed. From the extinction angles, measured on the distinguishable twin lamellations, the felspar is mostly albite, although in a few cases the angles measured approach albite-oligoclase; good crystal outlines are exceptional. The mineral is partly moulded on the orthoclase, partly on biotite. A few inclusions of quartz occur in orthoclase. The biotite occurs in scattered crystals and in aggregates of crystals, usually showing good crystal outlines, sometimes with frayed-out ends. In some cases idiomorphic crystals are included in the felspars. Obviously the mineral has crystallised out early. Inclusions of magnetite were noticed in some of the biotite. The quartz appears to have been one of the last minerals to crystallise out. It has quite irregular outlines, generally determined by the form of the adjoining minerals. It fills interstices between the other minerals. In particular cases, however, some of the quartz shows idiomorphic outlines. A striking feature is the presence in most of the quartz crystals of abundant minute hair-like crystals of tourmaline. Although of very small diameter, the length of some of these minute needles is appreciable, reaching ·03 inch in some instances. Although sometimes in single crystals, they are frequently crowded thickly together; in some cases they cross each other at various angles indiscriminately; in others they have a well-defined radial

structure. Most of the needles are straight, but some are decidedly curved. Frequently they appear to be crowded more thickly towards the edges of the quartz grains, but this is not invariably the case. A very careful examination failed to show any instance of the tourmaline needles penetrating two adjoining grains of quartz. In addition to the tourmaline rods, there are in the quartz abundant inclusions of a dark colour, but too minute to be resolved with the microscope objectives available. These inclusions are distributed sometimes quite irregularly, sometimes in groups, and sometimes in definite lines. It is noteworthy that occasionally these lines extend, apparently without any interruption, from one crystal of quartz to an adjoining one, which is not optically continuous. A close study of the available slides shows that although the tourmaline needles are so abundant in some of the quartz grains, they are entirely absent from others. Further, one portion of a grain may be crowded with tourmaline needles, while another portion of the same grain, optically continuous with it, may be clear, and contain no distinguishable tourmaline. The minute inclusions described appear usually to be far more abundant in the grains and portions of grains which carry the tourmaline, although never absent entirely from the tourmaline-free grains. Another feature worthy of note is the inclusion in some of the clear quartz grains of smaller crystals of quartz showing idiomorphic outlines, indistinguishable from the host excepting when viewed between crossed nicols. It would appear, then, that the quartz present in the slide is of two generations. Some has crystallised out in the earlier stages of the consolidation of the rock, and has included the needle-like tourmaline crystals which had already separated out. At a later stage more quartz has separated out, and, as often happens under similar conditions, has sometimes formed in optical continuity with some of the earlier-formed grains. In addition to its occurrence in the form of needle-like crystals noted above, tourmaline is sporadically distributed through the rock in shreds and irregular aggregates; sometimes small quantities occur between adjacent quartz grains as an interstitial filling. It is usually green in thin section, and distinctly pleochroic, but in a few instances is almost opaque; it is without well-defined crystal outline. A few crystals of magnetite are present, usually closely associated with, and sometimes included in, biotite. Apatite, too, occurs in idiomorphic prismatic crystals, included in

the later-formed minerals. It is frequently associated with biotite, some of the prisms penetrating the latter mineral. Zircon, in highly idiomorphic crystals of minute size, is present included in the quartz and felspars. In one slide a little fluorite was noticed, apparently as a primary mineral, moulded on adjacent biotite and orthoclase. In one instance minute threads of tourmaline were noticed filling cracks in a crystal of felspar. Biotite is scarce: it sometimes shows crystal outlines, but appears to be partly moulded on the orthoclase, and has apparently crystallised after that mineral. Several inclusions of idiomorphic prisms of apatite occur in the biotite. A little muscovite mica is present in ragged crystals, which may be of secondary origin. Some of the quartz crystals contain abundant inclusions, which are extremely minute, and could not be definitely determined.

The pink granite has been rather fully described, for it appears to be widely distributed, and can fairly claim to be the normal granite of the district. Local variations in the amounts of the constituent minerals present cause variations in the general appearance of the rock. Thus there is exposed in the side cuttings of the Trial Harbour Road, on descending from the turn-off to Remine, a handsome grey granite: quartz is almost entirely absent, and white felspar subordinate, the most abundant constituent being orthoclase of mole colour, showing very perfect cleavages. Tourmaline and biotite are present, but are not abundant. Molybdenite was found in this granite at one spot on the roadside, but not in sufficient quantities to render it of economic value.

White Granite.—A variety of granite which needs special notice is the " white granite," because of the abundance of quartz-tourmaline nodules in it and the number of tin ore deposits which occur within its boundaries. This granite is sometimes called the " tin granite " of Mt. Heemskirk. In general appearance the granite, as its name implies, is of a light colour, the excess of white felspar giving it its white appearance. Unlike the normal granite, no pink orthoclase felspar is present. Macroscopically, the white felspars appear to form the bulk of the rock. Many of the felspars are distinctly lath-shaped, 5 to 10 millimetres in length, and show perfect cleavages. Glassy quartz is present in variable amount. Black tourmaline is almost universally present, and a little black biotite is usually distinguishable. The rock is medium to fine grained, and distinctly less coarsely crystalline than the normal pink granite

of the district. Microscopically the rock differs somewhat from the normal granite previously described. The minerals present in the slides examined are orthoclase, quartz, plagioclase, tourmaline, biotite, muscovite, apatite. The rock is holocrystalline, the grain-size being variable. Orthoclase felspar is abundant in hypidiomorphic crystals throughout the slide. The plagioclase shows narrow twin lamellæ, and proves to be albite: it usually occurs in idiomorphic crystals which have evidently partly crystallised before the orthoclase, although the crystallisation of these two minerals has been to some extent contemporaneous. Much of the felspar is partially decomposed. Quartz is fairly abundant, largely moulded on the felspars which have crystallised before it. In one slide, micropegmatitic intergrowth of quartz and orthoclase is noticeable. Tourmaline is fairly common in irregular crystal aggregates, appearing blue, brown, or greenish by transmitted light.

It is not easy to trace the distribution of the " white granite " in detail. In places it appears to merge gradually into the " pink granite," although usually the outcrops are not continuous, and this merging cannot be very definitely traced. Search was made for the boundary between the two varieties, but in no instance was successful. The bulk of the Heemskirk Range appears to be composed of the pink granite, so far as an examination of this rough country was possible. It is well developed along the southern extremity of the range, and again in the northern portion, where there appears to be an even larger area. It is not confined to the elevated ground, however, for at many points on the coastal peneplain, and along the coastal cliffs, coarse-grained pink granite outcrops.

In the vicinity of the Federation Mine is a belt of nodular white granite of varying width, from $\frac{1}{4}$ to 2 miles. This has a general south-westerly trend, and is exposed at points on the plain and sea-shore as well as in the mountain range. Several proved tin lodes occur in this belt.

Along the Trial Harbour-Corinna Road, where a fairly good section is obtained owing to the removal of the button-grass cover which hides the character of so much of the granite, it is seen that pink and white granite alternate.

Travelling northwards along the road from the Zeehan turn-off, it is seen that typical coarse-grained pink granite forms the bedrock. Near the Montagu Creek this gives way of nodular white granite, which is exposed for about 2 miles along the road, until descending to Falconer's Creek, when a belt of coarse pink granite, 5 or 6 chains in

width, makes its appearance. From this point there is seen to be an alternation of the two varieties: the road passes over 10 chains of white granite, and then 15 chains of pink granite, the two varieties occurring apparently in bands for a considerable distance along the section exposed by the road, these bands varying considerably in width. Pink granite is common along the coast, while an examination of the outcrops along the track representing the old road from Corinna to Remine, shows that white granite with the usual quartz-tourmaline nodules, occurs as far as The Gap. In the time available it was not found possible to map the varieties of granite: sufficient has been said to indicate that the distribution is irregular. It is noticeable that most of the ore-deposits of the district occur in the white granite.

Fine-grained Tourmaline Granite.—Still another variety of the granitic rocks which may conveniently be referred to at this stage is a very fine-grained granite with a distinctly aplitic facies, usually very rich in tourmaline. This rock has been called by Mr. Waller a "tourmaline aplite."([64]) It is distinct from the aplite to be described later, and the writer would prefer to call the rock a fine-grained tourmaline granite, to distinguish it from the pink and white granites, and from the true aplite, although it has been shown that both pink and white granites also carry tourmaline.

The rock occurs as irregular masses and also as dykes in the white granite, and also as dykes in the normal pink granite.

Macroscopically the rock is seen to consist of a fine-grained aggregate of quartz and felspar, abundant tourmaline, and less abundant biotite. Microscopically it is seen that both orthoclase and plagioclase felspars are present: the plagioclase is albite and oligoclase. It is noticeable that both quartz and felspar are hypidiomorphic, and that the felspar in some cases is moulded on the quartz, showing that portion at least of the quartz has crystallised out from the magma earlier than the felspar. In none of the quartz crystals were needles of tourmaline noticed, although these are so abundant in the pink granite. Tourmaline is present in allotriomorphic grains moulded on quartz and felspar, and small quantities of both biotite and muscovite mica are noticeable. Thus it will be seen that the rock is really a fine-grained tourmaline granite,

([64]) Report on the Tin Ore Deposits of Mt. Heemskirk p. 3.

although the scarcity of ferro-magnesian constituents gives it an aplitic facies.

The striking feature of the rock is the abundance of nodules of quartz and tourmaline which it contains.

Mention has been made above to the occurrence of quartz-tourmaline nodules also in the white granite, but they appear to be most abundant in the fine-grained tourmaline granite. The presence of nodules gives the granite a striking appearance, which justifies the name "nodular granite" being given to it. The nodules vary considerably in size: sometimes they are represented by mineral aggregates in the rock, but a fraction of an inch in diameter: on the other hand, nodules were observed as much as 6 inches in diameter, although this was rather exceptional, 3 inches being a common size. The nodules are composed almost entirely of quartz and tourmaline. A little felspar is usually present towards the outer edge, but apparently belongs rather to the matrix than to the nodules. Traces of cassiterite are usually present, and in two specimens collected on the Federation property a little amethyst-coloured fluorite was present in the centres of the nodules: this appears to be the exception, as no other cases were noticed during the examination of the district, although many nodules were broken. In some specimens it was noticed that the quartz and tourmaline in the centre of the nodules were crystallised, the crystals projecting slightly into a central space. The main mass of the nodule consists apparently of about equal quantities of quartz and black tourmaline. A thin section of a nodule from a mass of aplite shows that quartz-tourmaline and felspar are the minerals present. In another section the same minerals are present, with zircon as well, while in a third case only quartz and tourmaline were observed. The texture of the rock in each case is holocrystalline, the grain-size being variable, but small on the average. Quartz is the most abundant constituent present, and is usually idiomorphic. It has evidently crystallised before the tourmaline which frequently surrounds crystals of quartz or fills interstices between them, and is consequently moulded on them. The tourmaline occurs usually in crystal aggregates, and varies in colour from brown through green to blue. It is abundant, but in each case appears to be subordinate in amount to the quartz. Where present the felspar is idiomorphic, and has crystallised earlier than either quartz or tourmaline. From the extinction angles measured on sections perpendicular to the albite twin lamellæ it is seen that the plagio-

clase present in each case is albite: the mineral is only sparingly distributed through the slide. It is interesting to note that minute, highly idiomorphic prisms of zircon are present included in the quartz.

In certain localities green tourmaline takes the place of the black, and in several such cases, particularly in the vicinity of the Cliff Mine, cassiterite was noticed as well.

Normally the tin content of the nodules is small, although traces of cassiterite are usually present, particularly in the central portions. The nodules are so abundant in places, lying about on the surface where they have weathered out of the granite, that the question whether they would pay for treatment naturally suggests itself. From tests made by the writer, however, it is quite unlikely that such will be the case: usually tin is present in traces only, and not in payable quantities, and it is quite exceptional to find rich specimens.

It has been remarked that the size of these nodules varies from a fraction of an inch to 6 inches in diameter. While they are sometimes scattered quite irregularly through the rock-mass, in certain localities they are very abundant, and sometimes several nodules are joined together to form one irregular mass of quartz-tourmaline. A striking feature is the manner in which the nodules resist weathering. The essential constituents, quartz and tourmaline, are both hard and very resistant to the attacks of weathering agencies, while the felspars and mica of the enclosing granite break down much more readily. In consequence of this difference in mineralogical composition, the nodules stand out in striking relief from the weathered surfaces of the granite in which they occur.([65]) Ultimately they become detached from the parent rock, and accumulate on the hill-sides and in the watercourses of the neighbourhood. The majority of them are spheroidal, but some are rather irregular.

Somewhat similar, but less perfect and less abundant nodules of quartz-tourmaline were noted by the writer in the Meredith Range granite of the Stanley River Tinfield,([66]) but probably in no other locality in the State are the nodules so abundant and so well developed as they are at South Heemskirk.

Their habitat is somewhat variable. They reach their maximum development in the fine-grained aplitic tourmaline granite of the district, but are also extremely well

([65]) *Vide* Photos. Nos. 1 and 10.
([66]) *Vide* Geol. Surv. Tas. Bulletin 15, p. 28.

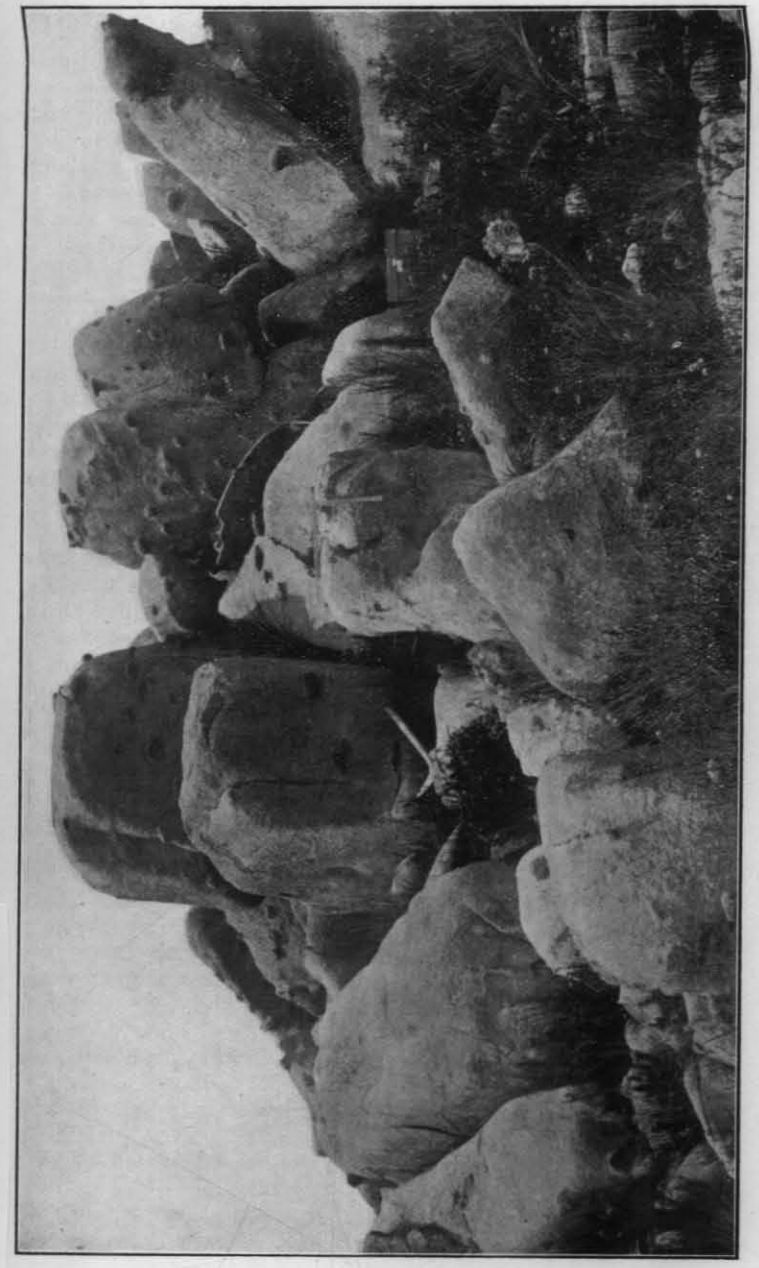


PHOTO. 10—NODULAR GRANITE. QUARTZ-TOURMALINE NODULES STANDING OUT IN RELIEF FROM WEATHERED SURFACE OF "WHITE" GRANITE, FEDERATION MINE. [L. Lawry Waterhouse, Photo.

developed in the " white granite " described above. Even in the coarser-grained normal pink granite, however, there are small irregular aggregates of quartz and tourmaline, which, in reality, are identical in composition and mode of origin with the more easily recognisable nodules.

Among the localities at which the nodules are particularly well developed may be mentioned The Cliff Mine, Federation Mine, and Gap Peak.

Before leaving the subject of quartz-tourmaline nodules, reference must be made to their occurrence under conditions which have not previously been described. Their home is in the fine-grained tourmaline granite and the white granite, and it is in the former variety that they undoubtedly reach their maximum development. It is important to notice, however, that they do occur in the pink granite, which has been described as the normal granite of the district. Usually they are not abundant, although they are not uncommon in some localities, particularly near the white granite, although it must be admitted that the most favourable opportunities for examining the rock usually occurred in the vicinity of the white granite. In the pink variety the nodules are never well developed. They are small (usually not more than 1 inch in diameter), and appear to be more irregular in shape and composition than those previously described. They merge into mere crystal aggregates of tourmaline. On weathered surfaces of the granite they are inclined to stand out in relief, but on account of their smaller size are not so noticeable as in the case of the white granite.

Granite Porphyry.—At various points throughout the granitic area, the rock is seen to be fine-grained or porphyritic. Usually the constituents of the normal granite are distinguishable, while in certain cases the groundmass of the rock is so fine-grained as to be resolved only with difficulty. The rocks occur as dykes in the main granite mass, usually not more than a few feet in width.

Near Sweeney's Mine is a good example, in which the rock has a general pink colour, owing to the presence of orthoclase felspar. The groundmass consists of an intimate mixture of quartz and felspar, with smaller amounts of biotite and a little tourmaline in places, individual crystals being usually less than 1 millimetre in diameter. Scattered through this groundmass are phenocrysts of flesh-pink orthoclase, up to 10 millimetres in length, singly twinned and showing good cleavages.

A somewhat different type is developed on the pack-track across the southern spurs of Mt. Agnew to the Federation Mine. The rock is a handsome one, consisting of a very fine-grained bluish-grey quartzo-felspathic groundmass, with biotite and scattered tourmaline. Scattered abundantly through this matrix are phenocrysts of pink orthoclase felspar in idiomorphic crystals, averaging about 4 × 14 millimetres, some individuals measuring 8 × 20 millimetres. These crystals are twinned, and show perfect cleavages. In some instances decomposition of the felspars has commenced, and it is noticeable that this change commences from the periphery of the crystal and proceeds inwards.

The particular examples of granite porphyry described are fairly typical, but there are intermediate varieties.

A thin section cut from a specimen collected near the Cumberland dam does not yield very much additional information. One feature, however, is worthy of special mention, viz., the occurrence of minute, needle-like crystals of tourmaline in bunches and radiating sheaves and aggregates in some of the quartz crystals. These needles are not confined to one grain of quartz, but pass without interruption from one grain to another, showing clearly that they have been introduced subsequently to the consolidation of the quartz. Idiomorphic crystals of zircon are also present as inclusions in the quartz, but these are primary.

Aplite.—Quite a feature of the Heemskirk granite *massif* is the presence of aplite at various points. The rock varies somewhat, but is typically a fine-grained aggregate of quartz and felspar, of a flesh-pink colour, sometimes carrying a little biotite, and tourmaline may also be present in appreciable quantities. The aplite occurs both in the pink and white granites previously described, in the latter in the form of dykes, and in the normal pink granite as irregular masses and nodules, as well as in dyke form.

In distribution it does not appear to be limited to any one part of the district, but occurs at intervals throughout the granite area.

A microscopical examination of thin sections shows that hypidiomorphic quartz is abundant, and that some of it has crystallised before the orthoclase, being partly surrounded by, and at times included in, that mineral. While usually clear, it is noticeable that in some of the quartz grains are minute, needle-like crystals of tourmaline, similar to those noted in the quartz of the normal pink

granite. The plagioclase felspar is not very abundant, and is usually a good deal decomposed. Some of it is albite, and other crystals appear to be more basic, and to more nearly approach andesine, although extinction angles are rather indefinite owing to the decomposition products. The plagioclase shows by its crystal edges that it has crystallised before the orthoclase. The latter is fairly abundant throughout the slide, and gives the rock its general pink appearance in hand specimens. Fragments of biotite and tourmaline are present, but are not common. Occasional idiomorphic crystals of apatite were noticed, usually included in biotite.

In thin section the rock resembles the white granite, although there are minor differences noted above.

Mention has already been made of the fact that the aplite occurs in the form of dykes in both the pink and white granite, as well as in irregular masses in the pink variety. Both varieties of granite are traversed by numerous fissures only a fraction of an inch in width, and usually filled with black tourmaline. It is worthy of note that in several instances dykes of aplite were seen to be intersected, and sometimes slightly displaced by tourmaline-filled fissures, which consequently must be later than the aplite.

Pegmatite.—Another variety of the granitic rocks not hitherto described is pegmatite. Although not abundant or important, it is interesting to note that this rock does occur in the district. Dykes of pegmatite were noticed intersecting both the pink and white granites. These were usually but a few inches in width, varying somewhat from point to point. The pegmatite consists essentially of coarse crystals of quartz and felspar (usually orthoclase) and sometimes a little black tourmaline. Several examples were noticed in which the pegmatite occurred as a central seam in a dyke of fine-grained aplite. As a typical example may be taken an occurrence in the north-western portion of Section 3917-M (the Federation Mine), on the northerly slope towards Packer's Creek. There the outcrop is very noticeable on the weathered granite surface, the quartz crystals standing out boldly more than an inch, owing to their resistance to the attacks of weathering agencies, to which the surrounding aplite has succumbed. The pegmatite occurs in a dyke of aplite about 12 inches in width, which itself intersects the white granite, the latter rock carrying abundant quartz tourmaline nodules in the vicinity. The seam of pegmatite is from 3 to 6

inches in width; it is composed of quartz and orthoclase, with accessory black tourmaline. The quartz prisms are sometimes 3 inches in length, terminated at one end by pyramidal faces. The orthoclase is intimately associated with the quartz, having to some extent crystallised before it. It usually occurs in prisms of, approximately, square section up to $\frac{1}{5}$-inch across and $1\frac{1}{2}$ inch in length. They are pink in colour, and when fractured longitudinally frequently show simple twinning. The orthoclase is very frequently included in the quartz, and as it weathers much more rapidly than that mineral, long cavities of approximately square section, sometimes crossing each other at various angles, are common in the quartz. Incidentally, it may be remarked that much of the quartz lying about the surface is derived from these pegmatite dykes in the granite, and many of the fragments show cavities (the so-called " negative crystals ") similar to those described: cavities of different cross-section are caused by the removal of tourmaline.

In the pegmatite dyke referred to, irregular crystal aggregates of black tourmaline are present, sometimes interstitial and moulded on the quartz prisms. The tourmaline aggregates noticed were never more than $\frac{1}{2}$-inch in diameter. In one place this pegmatite dyke and the enclosing aplite are intersected by a narrow tourmaline-filled fissure, which passes without interruption into the granite beyond. Miarolitic cavities into which projected crystals of quartz were noticed in several places along the course of this dyke.

All the pegmatite dykes noticed were of comparatively small size, and they are not likely to become of any importance commercially. None of them is known to be stanniferous. The component minerals of the dykes are not sufficiently well developed to be of any value, as sometimes happens where pegmatites occur.

Quartz-Tourmaline Veins and Dykes.—Throughout the area occupied in the district by the acid rocks described above, there are numerous occurrences of tabular deposits of quartz and tourmaline in varying proportions, sometimes with accessory minerals as well. When the accessory mineral is cassiterite, the deposits may become commercially important.

An examination of the various occurrences shows that two classes of deposits are to be distinguished in the district, veins and dykes. The veins are characterised by a central seam of tourmaline with varying amounts of quartz,

and frequently with cassiterite, bordered on either side by a tabular mass of quartz and tourmaline, sometimes with abundant white mica, and with or without cassiterite as well: pyrite may also be present. The line of contact of this mass with the granite which forms the country rock is usually well defined, although sometimes there is a gradual merging into the granite. The dykes, on the other hand, while composed essentially of quartz and tourmaline, have no central seam, and have sharply-defined walls. Both veins and dykes occur in the surrounding sedimentary rocks as well as in the granite.

Mr. Waller has called attention to this distinction,[67] pointing out that Mr. F. J. Ernst was the first to discover these dykes. He also remarks that some of the tabular deposits appear to occupy an intermediate position between dykes and veins. The writer's observations confirm those made by Mr. Waller.

The formations referred to above merit a more detailed description, as the occurrence of the different types is interesting. Economically the veins are by far the most important, for they frequently carry cassiterite in such quantities as to become payable ores of tin. This aspect, however, and the classification of the vein-types according to the mineral contents, are dealt with in the chapter on Economic Geology. The central seam has been called by Mr. Waller[68] the " vein-stone," and the enclosing quartz-tourmaline material, extending from the central seam to the walls, the " vein-rock ": the terms are useful for descriptive purposes. The veins occur most frequently in the white granite and in the fine-grained tourmaline granite which have been described: a few cases only were noticed in the normal pink granite. A striking fact was noticed in several instances where veins occur in nodular granite: quartz-tourmaline nodules occur unaltered in the vein-rock, itself a granular mass of quartz and tourmaline, but showing no felspar. In no instance were nodules noticed in the vein-rock when they were absent from the surrounding igneous rock. A microscopical examination of thin sections of vein-rock shows that there are two generations of quartz present, and close investigation and comparison with slides of the surrounding granite disclose some interesting features. In the case of vein-rock from a vein traversing the normal pink granite it is seen that many of the larger allotriomorphic quartz grains include abundant minute needle-like prisms

(67) Report on the Tin Ore Deposits of Mt. Heemskirk, pp. 6 and 7.
(68) *Op. cit.*, p. 6.

of tourmaline, while the smaller quartz grains, which are usually hypidiomorphic, are clear and contain no tourmaline needles. The quartz of the normal granite is quite similar, being allotriomorphic, and including abundant tourmaline needles as a rule. It seems clear that the hypidiomorphic quartz of the vein-rock is secondary, the grains of primary quartz remaining unaltered. Again, taking the case of a vein in white granite, although the distinction is not so sharp, under the microscope the quartz of the vein-rock occurs in grains of different sizes, the smaller usually hypidiomorphic, sometimes idiomorphic, both larger and smaller grains being free from included tourmaline needles: it corresponds in this latter respect with the quartz of the surrounding white granite, and a comparison shows that the larger grains of the vein-rock correspond in size with the quartz of the unaltered granite.

In both varieties of vein-rock described it is noticeable that in certain portions of the slides examined, groups of the smaller hypidiomorphic quartz grains extinguish simultaneously between crossed nicols, suggesting that each group may represent portion of a replaced felspar crystal. At least it seems clear that both primary and secondary quartz are present in both varieties of vein-rock, and that the primary quartz is really the unaltered quartz of the granite, of which the felspar has been replaced. No biotite is present, but tourmaline is usually abundant, occurring both in ragged crystals and in aggregates of small prisms showing idiomorphic and hypidiomorphic outlines. The later variety is usually closely associated with the secondary quartz, and sometimes small grains of quartz are included in tourmaline. It seems clear that some at least of the tourmaline is secondary, doubtless replacing the biotite as well as the felspar of the original granite: some of the ragged fragments may represent the original tourmaline of the granite which has remained unaltered during the lode-forming processes.

The vein-rock described above belongs to the quartz-tourmaline-cassiterite vein-type, and to the sub-class which Mr. Waller has termed " quartz-tourmaline veins."([69]) In the sub-class " greisen veins," however, the structure of the vein-rock is rather different, as abundant white mica takes the place of tourmaline. The vein-types are dealt with in a later part of this report,([70]) but from evidence obtained the writer believes that a hard and fast line cannot be drawn between the sub-classes described by Mr. Waller.

([69]) *Op. cit.*, p. 8. ([70]) *Vide infra*, pp. 153–177.

In the extreme type of the greisen vein, muscovite takes the place of tourmaline, but it may be remarked that in no instance was tourmaline found to be entirely absent. In the thin sections examined, in which mica was seen to be present in hand specimens, the primary quartz surviving from the original granite has in some cases suffered alteration and partial replacement by muscovite mica, but has not altogether lost its individuality: it is still usually recognisable as quite distinct from the aggregates of small clear grains which occur in association with muscovite, and which are clearly secondary. The felspars of the original granite seem to have been replaced essentially by mica, which, however, is usually accompanied by small quantities of quartz of the form described. The muscovite is often present as shreds, and some of the aggregates show a distinct radial structure. Small quantities of tourmaline in hypidiomorphic crystals are usually present.

Pyrite sometimes becomes abundant in the vein-rock, accompanied by quartz, forming Waller's " pyritic veins ": these are preferably to be regarded as belonging to a type distinct from the quartz-tourmaline-cassiterite vein-type, viz., the " pyritic-cassiterite deposits " of Mr. L. K. Ward.([71]) The type does not call for special mention at this stage.

One slide only of Mr. Waller's fourth class, " pinitoid veins," was examined. This, again, is certainly only a variation of the quartz-tourmaline-cassiterite type. The vein-rock appears to carry less quartz than that of the types previously described. The structure suggests that while most of the primary quartz of the granite remains, altered and partly replaced here and there, that little if any secondary quartz has been introduced during the lode-forming activity. The main change which has taken place has been in the formation of micaceous aggregates, termed pinitoid, doubtless at the expense of the felspar.

In all these varieties or sub-classes, there is a well-defined central seam, forming what Waller([72]) has termed the " vein-stone." This central seam consists essentially of tourmaline, usually accompanied by quartz, with or without cassiterite. The vein-stone frequently carries very rich tin. The tourmaline occurs in long prismatic crystals, frequently grouped in radiating aggregates, individual crystals sometimes reaching 6 inches in length. In one instance where a vein extended from the granite into the adjacent sedi-

([71]) *Vide* Geol. Surv. Tas. Bulletin 6. p. 86. ([72]) *Op. cit.*, p. 6.

mentary rocks, the tourmaline was observed to decrease in amount as the distance from the granite increased, and eventually the vein became a quartz vein: although this was clearly shown in one instance, it perhaps does not occur in every case, but it seems likely that the quartz veins of the sedimentary rocks are but special cases of the quartz-tourmaline-cassiterite veins of the granite.

The foregoing description has been confined to veins: mention has already been made of the fact that certain of the quartz-tourmaline formations appear to be dykes, and that they have been previously described by Mr. G. A. Waller as such.(73) There seem to be three outstanding features of these dykes to distinguish them from the true veins already described: (*a*) There is no central seam, (*b*) the texture is even and the composition simple and uniform (quartz and tourmaline), (*c*) the walls are sharply defined. Examples of dykes were noticed both in the granite and also in the adjacent sedimentary rocks, sometimes passing from one to the other without apparent change. No cases came under the writer's notice in which cassiterite was proved to be present in a dyke of this description. Microscopical examination of thin sections shows that the rock is composed of quartz and tourmaline. The latter mineral varies a good deal in habit, usually occurring in idiomorphic prisms, with associated aggregates and grains, some of the smaller prisms showing at times a radiating habit. The quartz is quite allotriomorphic, and sometimes partly encloses prismatic crystals of tourmaline. Obviously the tourmaline has crystallised out earlier than the quartz, and there are probably two generations of tourmaline crystals, some of the larger idiomorphic prisms having crystallised out first, and formed nuclei about which the second generation have gathered in radial aggregates, to be followed by, and partly included in, the quartz. The grains of quartz are clear and free from noticeable inclusions. Although there is naturally a variation in different dykes, it is only of minor importance, the general features being the same in all slides examined. Mention has been made of the sharply defined walls: there is usually, but not invariably, an alteration in the wall rock, but apparently never to any great extent: this alteration usually takes the form of silicification, or silicification and tourmalinisation.

If all the tabular deposits clearly exhibited the features described above, it would not be a very difficult matter to classify them as veins or dykes, and such a classification

(73) *Op. cit.*, p. 7.

would perhaps be warranted. In view of all the evidence available, however, this classification cannot be insisted on, and it is found in practice that there are some deposits which do not strictly conform to either type. In referring to the difficulty of distinguishing between veins and dykes, Mr. L. K. Ward says(74):

"It has recently been urged by many writers on ore-deposits that there is no essential difference between 'dykes' and 'veins' of certain types. In the case of these quartz-tourmaline intrusions the impossibility of making the distinction is admirably shown. The criteria by which we judge a tabular mineral aggregate to be a 'dyke' rather than a 'vein' are not definitely established, nor can they be established in such a way as to limit both classes by hard and fast lines.

"In the latter stages of consolidation the residual portion of the magma from which the acidic rocks are derived becomes progressively more siliceous and more aqueous. And when finally the still liquid material is forced out through the cooler rocks, there results a rock which often possesses the characteristics of material which has crystallised out from *solution*. Thus the phenomena of crustification are visible in these rocks."

In the South Heemskirk district these remarks certainly apply, and the conclusion arrived at by Messrs. Waller and Ward, that there is no essential difference between quartz-tourmaline veins and quartz-tourmaline dykes, has been verified by the observations made by the writer in this district. There are in various localities intermediate types of deposits between the extreme types which have been described. The granular texture sometimes gives place to a more irregular arrangement of the quartz and tourmaline, the latter tending to occur more in radiating aggregates: in several cases the central portions of "dykes" were seen to be nearly free from tourmaline, while in two cases the tourmaline occurred centrally almost to the exclusion of the quartz, in each instance the bulk of the rock being composed of granular quartz-tourmaline, similar to that occurring in the extreme "dykes" described.

Mention has been made of the fact that so far as the writer was aware, no cassiterite had been shown to occur in the so-called "dykes" of the district. Naturally this does not prove its absence, and if the two classes of deposits grade one into the other, so that the "dykes" are but a variation of the quartz-tourmaline-cassiterite vein-type,

(74) Geol. Surv. Tas. Bulletin 6, p. 91.

then there is no sound reason why cassiterite should not occur also in the deposits of dyke form. It probably does occur in small quantities, which may not have been recognised in the past: it must be borne in mind that certain of the veins which show well-defined vein-stone and vein-rock do not carry appreciable cassiterite.

Basic Dyke with Axinite, &c.—A very interesting occurrence was noted at one point on the coastal cliffs near the southern margin of the granite mass. This was a basic dyke, consisting essentially of augite, with other minerals in smaller quantities, traversing the granite. The dyke occurs between the Cliff Mine and the Pulpit Rock, apparently on Section 3182-M, and was accidentally discovered when scaling the steep cliff face, here rising to a little over 300 feet above sea-level. The granite in the locality is the coarse-grained pink variety, and is quite similar to that occurring in various parts of the district, carrying a little disseminated tourmaline, and being traversed at times by narrow veinlets of the same mineral. The dyke is approximately parallel to the cliff face on which it is exposed, with a strike about north-west; its dip is about vertical. The width varies from 3 inches to 5 feet. It can be traced for about 50 feet, but is quite inaccessible for most of this distance, owing to the precipitous nature of the cliff face.

The exposed margin of the granite is distant about 15 chains to the south.

A striking feature of the dyke as exposed is its variability in composition. In some parts quartz occupies a width of 2 feet, while in others this mineral appears to be absent, and green pyroxene is the predominant mineral.

The abundance of augite in the deposit is an outstanding feature. It sometimes forms dark-green masses which cannot be resolved without the aid of the microscope, but which in thin section are seen to be composed of granular pyroxene, individual grains being of very minute size. Occasional larger plates of the same mineral may occur, and in one section several groups of comparatively large crystals were noticed in this fine-grained groundmass; in some cases no other mineral is present. Monoclinic pyroxene is present not only in granular form; in different parts of the formation it occurs in larger crystals and crystal aggregates, and at the particular point visited the individual crystals are exceptionally large. Here the granite forming the immediate wall-rock is comparatively

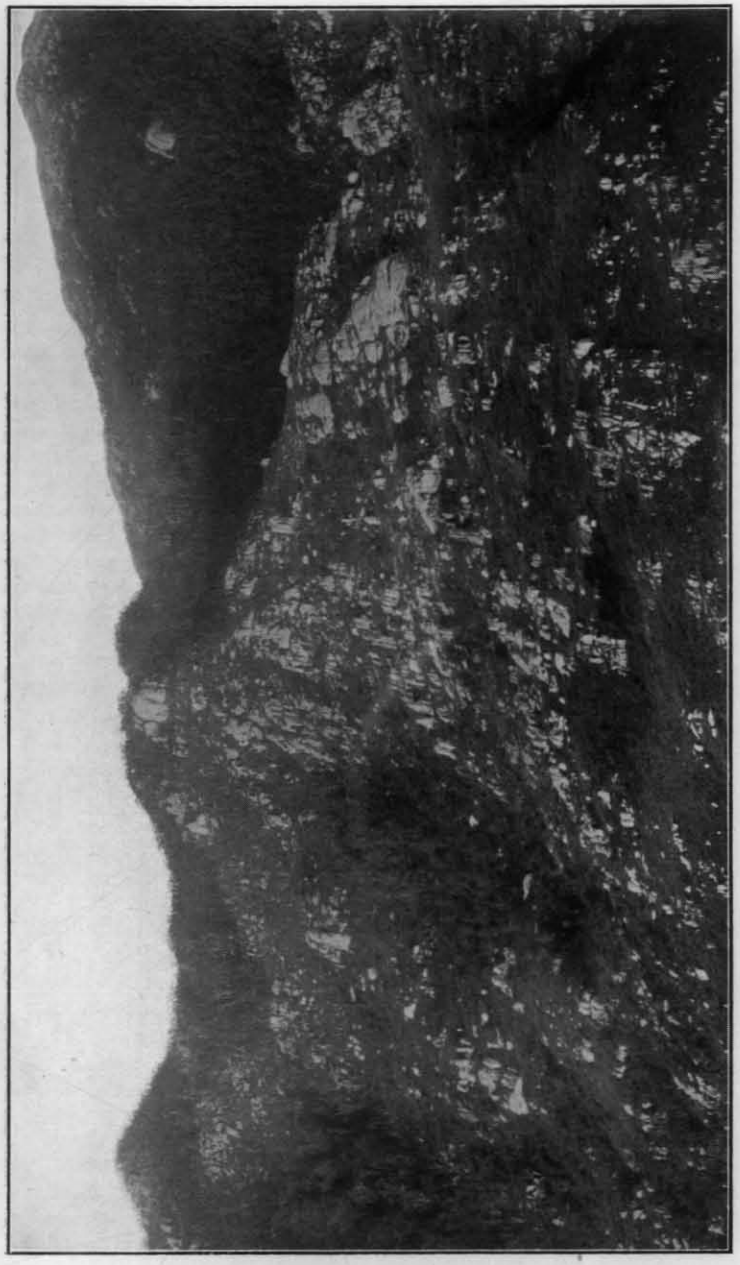


PHOTO. 11.—TYPICAL GRANITE COUNTRY OF THE HEEMSKIRK RANGE, SHOWING PARALLEL FISSURING OF THE GRANITE: LOOKING NORTH FROM FEDERATION MINE. [L. Lawry Waterhouse, Photo.

fine-grained and aplitic in character, and white in colour. Projecting into this white groundmass on the edge of the formation are abundant large dark-green crystals of monoclinic pyroxene, reaching 3½ inches in length and 1¼ inch in breadth. The crystals are thus prismatic, and comparatively long in proportion to their width; of six crystals measured, this proportion was found to vary from 3:1 to 4:1. Cross-sections are nearly square with truncated corners. The forms recognisable are prisms, pinacoids, and negative and positive pyramids.

Twinning is not easily recognisable, but appears to be present in a few instances. Typical cleavages are perfectly shown. Where single crystals are developed they are idiomorphic, but not infrequently they occur in groups, in which mutual interference has prevented the perfect development of some forms. These long finger-like crystals present a very striking appearance. They usually rest on a foundation of smaller crystal aggregates or grains of the same mineral. It is worthy of note that several of these crystals are intersected by veinlets filled with aplite corresponding with that which forms the groundmass in which the prisms are embedded, clearly showing that the aplite consolidated subsequently to the formation of the crystals.

The examination of a thin section of this aplite does not yield very much information; the felspars show hypidiomorphic outlines, the interstitial spaces being filled with quartz. The felspars are usually too decomposed for determination, although in a few cases indistinct extinction angles are discernible, which indicate that the felspar is oligoclase. Irregular shreds of pyroxene are present.

A good deal of the rock forming the mass of the dyke is granitic in texture, but is impregnated to a greater or less extent by masses of green pyroxene. The microscopical examination of a thin section of this material shows that grains and granular aggregates of pale-green monoclinic pyroxene are scattered through a felspathic groundmass, now decomposed. Some of the pyroxene is slightly uralitised. A little quartz is present. Masses of calcite are present, some of which have sharply defined outlines, and are wedge-shaped, others being quite irregular in the decomposed groundmass. A few tufts of chlorite were noted, also scattered scaly aggregates of talc. A noteworthy feature is the presence of small wedge-shaped crystals and granular aggregates of titanite. Closely associated with this mineral are colourless crystals and

crystal aggregates of idocrase. A few crystals of axinite were noted in one slide, and this mineral is distinguishable in some of the hand specimens collected. Axinite occurs in acute-edged crystals of about $\frac{1}{4}$-inch in length, of a clove-brown colour and vitreous lustre. The crystals show sharp outlines, and are almost invariably embedded in calcite. Closely associated with these minerals are masses of fluorite, and usually some quartz. The groundmass of the rock is monoclinic pyroxene, which occurs in granular aggregates and groups of prismatic crystals, with a tendency to radiating structure. No tourmaline was noticed in the formation.

Although the monoclinic pyroxene present in this interesting formation has been called augite, an analysis is needed before this determination can be regarded as decisive. The colour is dark-green in hand-specimens and light-green in thin sections. However, the crystal forms developed, and the habit of the crystals are noteworthy. They are not those most commonly developed in augite, but appear rather to resemble diopside.

The walls of the formation are not well defined. There is a gradual merging into normal granite.

Mode of Origin.—The mode of origin of the formation is not clear. It has been called a dyke above, but appears rather to be a vein than a true dyke. Obviously it was formed by solutions traversing a fissure in the solid crust of the granite mass. The writer is of opinion that these solutions were derived from the cooling granite mass, and not from any external source.

The abundance of lime-bearing minerals is striking, and a very noteworthy feature is the evidence of the presence of boron and fluorine, recognised "mineralisers." It is pertinent to enquire why this particular vein, if formed by the action of solutions containing mineralisers, expelled from the granite during its final stages of consolidation, differs so essentially from the various quartz-tourmaline veins, so abundant throughout the granite area, these veins having been assigned a similar mode of origin. The answer to this question is not easily found.

There appear to be no metallic minerals present, hence it is unlikely that the fissure connected with any of the reservoirs within which the metallic constituents had become concentrated. Although none were noted in this locality, the occurrence of basic segregations in the mass of granite rocks is well known, and is recognised to be due to the concentration by magmatic differentiation of

some of the more basic materials of the still molten rock mass. If such a reservoir had formed within the mass of the cooling granite, and the crust had fissured owing to the contraction caused by cooling, such a fissure might conceivably have tapped this reservoir and allowed the escape of the basic material to form such a vein as that under consideration.

The richness in lime-bearing minerals suggests that there may possibly be some relation between this formation and the various occurrences of lime-silicates described fully elsewhere.([75]) These occurrences, however, are never far distant from the basic rocks, and, as suggested elsewhere, the lime and magnesia contents may be derived therefrom by solutions from the granite traversing fissures which had during some portion of their course these basic rocks as walls. In the present instance the occurrence is within the granite itself. It is, however, adjacent to the contact of the granite with the sedimentary rocks, which themselves are in contact with the serpentine at a short distance further south. The relation of granite, slates, and serpentine, as interpreted by the writer, is illustrated in the geological sections published herewith, and, as indicated there, the slate is believed to be resting on a foundation of basic rock, which itself is in contact with the granite at no great depth. Nothing is known of the underground contour of the contact plane between these rocks, but it is certain that this is not regular, and it seems not impossible that there might be a projecting mass of basic rock vertically beneath the actual surface contact, partly surrounded by the later granite. If such were the case, it is conceivable that in this instance solutions derived from the deeper mass of granite might traverse such basic rock in their upward passage; if such were the case, possibly more iron and magnesia would be expected. In the absence of analyses, however, little is to be gained by pursuing the enquiry further. Analyses of the granite itself are not available, nor in the slides examined were the felspars fresh enough for determination, so that portion of the lime may have been derived from this source, although there is nothing in other occurrences of veins in the granite to suggest this.

Mode of Origin and Relationships of the Various Granitic Rocks.—In the preceding pages an attempt has been made to describe the leading features of the varieties

([75]) *Vide infra*, pp. 124–143.

of granitic rocks met with in the district, but no theory given as to the mode of origin of the different rocks. It is important in a discussion of this kind to have analyses of the various rocks dealt with, but unfortunately no analyses, even of the normal granite, have been made up to the present time.

From the occurrence of the various types described, their closer association with, and sometimes merging into, other types, as well as their similarity of mineralogical composition, the various rock-types appear to be genetically connected, one with the other. There can be little doubt but that this really is the case. The writer believes that all the different rock-types originally formed part of the same mass of molten igneous rock material, the granitic magma, which was forced up from below along a plane of weakness into a thick series of overlying sedimentary rocks. While still deep below the surface, and under considerable pressure owing to the thick cover of sedimentary rocks, the mass gradually commenced to cool. In the meantime the process known as magmatic differentiation was active, and the originally homogeneous material separated gradually into masses or sub-magmas varying slightly in composition. In one sub-magma the more acid materials tended to segregate with the bulk of the metallic constituents, and this mass contained more of the water of the magma than the other, which for this reason would tend to become less fluid. The more pasty mass would tend to solidify first, as the temperature gradually lessened, owing to the crystallising out of the mineral constituents which could no longer remain in solution in a magma which was becoming supersaturated for that particular temperature. The slow and gradual cooling of this sub-magma resulted in the formation of the normal pink granite of the district: this portion of the granitic magma would naturally be by far the larger. Within the cooling mass would be smaller reservoirs of molten material which would be forced through cracks in the cooling crust to form dykes of granite porphyry. The masses and nodules of aplite included in this variety of granite clearly indicate that the normal pink granite submagma must also have been the parent of this more acid rock, which was doubtless derived from it by a process of magmatic differentiation similar to that which had already taken place on a grander scale. While portions of the more aqueous and acid material were imprisoned in the cooling mass, before being able to segregate, in certain places larger reservoirs were formed, from which at a later

stage the molten material was forced, as soon as cracks formed in the cooling crust, and thus the aplite dykes were formed, intruding not only the normal pink granite, but also the white granite which had by this time consolidated.

Meanwhile, during the consolidation of the larger and more pasty mass to form the normal pink granite, the more aqueous (and consequently more fluid) portion was still molten. As it gradually cooled, certain of the constituents tended to segregate, and the phenomena of magmatic differentiation again played an important part in the formation of another sub-magma, still more acid and more aqueous, and containing the bulk of the metallic constituents of the original magma, owing to their tendency to form volatile compounds with such elements as boron, fluorine, chlorine, and sulphur. Probably this differentiation had been going on in place, after the magma had been forced by a variation of the pressure into a higher position in the cooling and solidifying normal pink granite submagma: that this was not yet solid throughout is shown by the presence of dykes of granite porphyry and of aplite, which appear to have emanated from within this mass. The pegmatite dykes appear to have been derived from this source also: they probably represent the final stages of consolidation, when the still fluid material was extruded into cracks formed in the solid and cooling crust. Obviously the pink granite must still have been at a very high temperature when the more acid mass was forced up into it, and this would mean that the cooling of the latter would be gradual, and that the conditions would be favourable for differentiation such as that indicated above. The larger mass gradually solidified to form the white granite: in solidifying it enclosed throughout its mass abundant small masses of material which had tended to segregate locally, but which had not been able to unite with the central and still fluid material, owing to the cooling mass becoming too pasty. These formed the quartz-tourmaline nodules which are abundant throughout the white granite: the fact that groups of nodules are found in places, actually touching each other shows that there was a tendency for them to come together, the actual material forming each nodule having been extracted from the magmatic material in its neighbourhood.

When the white granite solidified, there was still enclosed within its mass a quantity of fluid material, relatively more acid than that which formed the white granite, and which was itself undergoing further differentiation into two sub-

magmas, one of which contained much water in addition to volatile elements and the heavy metals, and was consequently able to remain fluid at the lower temperature prevailing. The magma was intruded into the still heated but solidifying white granite, and in cooling and solidifying itself included abundant quartz-tourmaline nodules in a manner quite similar to that described above for the white granite. The relatively greater abundance of nodules in this rock, which now forms the fine-grained aplitic tourmaline granite previously described, is to be explained by the fact that the boron contents tended to accumulate owing to the tendency of that element to form compounds which remained fluid at lower temperatures, and each succeeding sub-magma must have become relatively richer in that element.

The portion of the magma still remaining fluid was characterised by excess of water and of silica, and contained the tin and other metals of the original granitic magma, together with the so-called " mineralisers," boron and fluorine. As the huge masses of heated rocks cooled they contracted, and the crustal rocks fractured in various places to adjust themselves to the new conditions which the contractional strains set up. Into the fissures so formed (which sometimes extended beyond the limits of the igneous rocks to the adjacent sedimentaries) material was injected from the internal reservoir, which formed the quartz-tourmaline veins and dykes of the district.

The accompanying diagram is intended to illustrate graphically the relationship of the different types to each other as explained in this section. It must be understood that the table is merely diagrammatic, and is not quantitative, although in the writer's opinion it serves to illustrate the main processes which have been operative in producing the existing acid rock-types. A few explanations are needed of the table. The two sets of dykes emanating from the cooling sub-magma A are shown to indicate that these dykes penetrate both the outer solid crust of the pink granite itself, as well as the already solidified white and nodular granites. Probably similar dykes emanated from some of the other sub-magmas, penetrating the various rock-types, but they have not been shown, as the diagram would become too complicated and fail to serve its purpose. The quartz-tourmaline veins intersect all types of granite, as indicated: they probably intersect the other dyke rocks, although instances were not observed excepting in the case of the aplite.

It must be understood that although separate and distinct operations are indicated in the diagram, they are not so in nature. There is in many cases an overlapping, and the solidification of each rock-type is not necessarily separate and distinct, as indicated in the diagram.

Weathering.—A feature of the granite which deserves mention is its behaviour under the attacks of weathering agencies. Closely examined, the surface of weathered granite is seen to be very rough, the quartz grains standing out in relief. This is due to the fact that the felspars and mica of the granite are attacked first, and succumb fairly readily, the felspars being converted to kaolin, which is usually rapidly removed by surface waters. The plagioclase is usually decomposed before the orthoclase. The quartz is not only hard, but strongly resistant to the attacks of solvents, which rapidly decompose other minerals of less favourable chemical composition. Consequently, the quartz stands out in relief from the weathered granite surface, and as the groundmass of the rock weathers away, finds its way into the watercourses, where it forms quartz gravel. This effect is particularly noticeable in the pink granite; although the same change is taking place in the other varieties, the effect is not so noticeable, as the rocks are finer-grained.

Taking a broader view of the effects of weathering, it is seen that typically the rock weathers into more or less rounded boulders. This is shown in several of the photographs accompanying this bulletin.([76]) When these boulders are in exposed positions, there is always a tendency for the rock to weather in such a way that the boulders become " perched " (*i.e.*, undercut), and in course of time these boulders roll down the hill-sides. An excellent example of a perched boulder of pink granite is provided by The Pulpit Rock (see Photo. 12). This stands on a bluff about 450 feet above sea-level, $\frac{3}{4}$-mile north-west of Trial Harbour, and is little more than $\frac{1}{4}$-mile from the sea-coast. The rock is very conspicuous for miles around, and is easily distinguishable for some miles out to sea. The boulder is about 30 feet high, and from 20 to 25 feet in diameter. There is a horizontal fissure in the granite at the base of the boulder, and weathering has widened this, and has tended constantly to wear down any sharp edges and corners, with the result that the boulder is undercut, and in course of time must become unstable.

([76]) *Vide* Photos. 1, 6, 10, 11, 12.

This is but a typical example of the effect of weathering on the granite, various examples of which were seen in different parts of the field, though usually on a smaller scale. The photo. also affords another very typical illustration of the effect of weathering on the granite in the district, viz., the tendency of the granite to flake off in thin plates. These plates vary in thickness; they are usually between ¼-inch and 1 inch in thickness, but are occasionally thicker. The flakes decompose readily when freed from the parent block. The cause of this flaking is apparently to be found in the expansion and contraction of the outer crust of the rock, owing to rapidly alternating temperature changes. During a hot day the rock becomes heated to a limited depth and expands. The rock-mass below this expanding layer is comparatively cold, owing to the poor conductivity, and the result is that the expanding layer splits off. A cold night frequently follows a hot day in this district, and the heated layer contracts, the result being that it breaks off. It is worthy of note that no instances of this class of weathering were noticed in localities where the rock was well sheltered. As evidence in support of the explanation here given, it may be stated that on several occasions when returning to camp on cool nights after hot summer days, the writer noticed sharp cracking sounds coming from exposed outcrops, and on one occasion a flake of granite broke off and fell within reach.

Another factor which doubtless plays an important part in the weathering of the coarsely-crystalline pink granite of the district is the unequal expansion and contraction of the component minerals of the rock. As the different minerals have different coefficients of expansion, it follows that they must expand unequally under the influence of heat. If it does not lead at once to the disintegration of the rock, it must lead to the fracturing of the minerals, which are consequently rendered more susceptible to the attacks of weathering agencies.

Another distinctive feature of the weathering of the granite is worthy of notice: this is the weathering along approximately parallel lines, which gives the rock the general appearance, when viewed from a distance, of a bedded rock. This feature is very striking in certain localities, and is illustrated in the accompanying photo. (Photo. 8). The picture is taken on the coast at the Cliff Mine, and shows how the granite weathers and breaks off in slabs, and also shows what an influence this method of

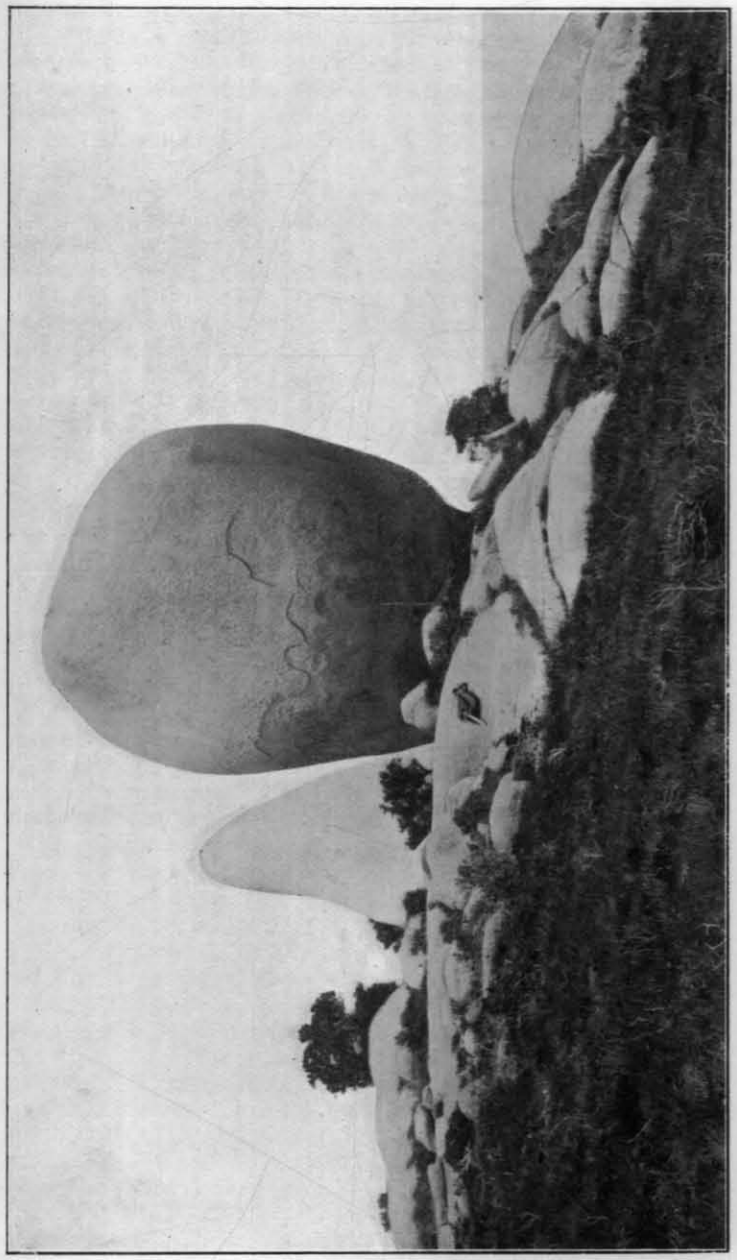


PHOTO. 12—PULPIT ROCK, ONE MILE N.W. OF TRIAL HARBOUR, A RESIDUAL WEATHERED BOULDER OF DEVONIAN GRANITE.
[L. Lawry Waterhouse, Photo.

weathering eventually has on determining the encroachment of the ocean, and the configuration of the coast-line. The fissures are in places very closely spaced, and are parallel, striking a little north of west. It is rather surprising to find that although the fissures appear so well defined, and certainly have a very marked effect in increasing the rate of disintegration of the rockmass, this effect is only noticeable near the water's edge, on the rock which has long been exposed. Within quite a short distance of the shore—certainly not more than 5 chains—excavations have been made in the granite at several points in connection with the old Cliff Mine. Although these excavations expose a fair width across the line of strike of these fissures, no sign of fissuring can be detected in the fresh granite. In the writer's opinion, the effect described is attributable to a series of joint planes in the granite, which have probably been caused through strains set up in the cooling of the rockmass. Although not noticeable in the fresh rock, the joint planes have been discovered by the repeated attacks of weathering agencies, and when the water has gained access, it has rapidly pressed home its initial advantage by attacking the parent rock forming the walls of these incipient fissures, and so enlarging the openings. As larger openings are made, the work of disintegration proceeds more rapidly. This work is doubtless assisted somewhat by the expansion and contraction of the slabs owing to changes of temperature. The proximity of the ocean doubtless increases the chemical activity of the attacking solutions. Actually, on the coast, in a place such as that illustrated in Photo. 8, the mechanical force of the waves would be a potent factor in assisting disintegration, but this cannot be classed as a weathering effect. In the locality referred to, occasional irregular horizontal joints occur in the granite, and where such are present, large flakes of granite break off.

A similar "bedded" effect to that described above is noticeable in the pink granite outcropping in the Heemskirk Range to the north-west of Packer's Creek. This is shown in Photo. 11, which is taken from the old horse tram on the Federation Mine, facing about north. It is noteworthy that the fissures in this vicinity strike approximately north and south. The writer believes that here, too, this marked "bedded" effect, so noticeable in the weathered granite, is due to the presence of a series of joint-planes, probably caused by strains set up in the granite mass in cooling.

The aplite usually weathers more rapidly than the enclosing granite, and it was found rather difficult on the field to obtain fresh specimens of this rock.

On the other hand, quartz-tourmaline veins and dykes almost invariably stand out in relief from the granite surface, sometimes to the extent of 9 or 10 feet. They can sometimes be traced for long distances outcropping boldly on the hillsides, while the surrounding granite is covered by button-grass. The fact that these quartz-tourmaline formations stand out so boldly is not to be wondered at, when it is remembered that the component minerals are themselves very hard and strongly resistant to the attacks of chemical agencies, and that they remain undecomposed by weathering, long after the felspar and mica of the granite have disappeared. From time to time fragments break off the exposed outcrops, and commence their journey downhill to the creek beds, and eventually to the sea. In the course of this journey the fragments gradually become more and more rounded under the grinding and battering action of other fragments. Their hardness and chemical stability enables the boulders to survive, long after fragments of such rocks as granite have suffered disintegration. This explains the occurrence of abundant quartz-tourmaline boulders in most of the creeks, often to the exclusion of other rocks, with the exception of quartz.

On most of the granite hill-slopes there is scattered abundant white quartz, usually in angular fragments. Many of these fragments show "negative crystals," *i.e.*, impressions left by the removal of some less stable mineral than the quartz itself. In some cases tourmaline is obviously the mineral which has been removed, but in others the cavities are approximately square in section, and in the form of long prisms. At times the quartz fragments are perforated by these square holes. This quartz is derived from the pegmatite dykes, and the cavities referred to are due to the removal of crystals of orthoclase felspar, which, in most of the pegmatite dykes observed in the district, occurs included in the quartz, and penetrating it in various directions.

A very striking result of the weathering of the various types of granitic rocks is the standing out in relief from weathered surfaces of the contained quartz-tourmaline nodules. As in the case of the veins and dykes of the same mineral constitution, the nodules resist the attacks of weathering agencies, which rapidly attack and remove

the surrounding granite rock, owing to the decomposition of the felspars and mica. The nodules frequently stand out several inches in relief, and the appearance is striking. The effect is illustrated in Photos. 1 and 10.

Akin to this effect, and to that of the quartz-tourmaline veins and dykes, is the effect produced by weathering on the narrow tourmaline-filled fissures, which are fairly common throughout the field. These also resist weathering, and are sometimes seen standing out as thin plates from the granite surface for a distance of more than a foot. One of these is shown in Photo. 10 in the right-centre of the picture, above the scale of inches.

Fissuring of Granite.—It is worthy of note that the different varieties of granite are cut through by fissures which are often continuous over considerable distances. In this section veins such as those discussed in the preceding section are excluded, although a narrow tourmaline-filled fissure is similar in mode of origin to a vein, and in reality is a narrow vein. A study of these fissures, however, is interesting, as it throws light on the movements which have taken place in the crustal portion of the granite after consolidation. In many instances the fissures are filled with black tourmaline, and appear as black threads running through the granite. In different parts of the district it was observed that these tourmaline fissures (as they may be called for the sake of convenience) cut through pink granite, white granite, fine-grained tourmaline granite, aplite, granite porphyry, and pegmatite. In several instances they were seen to cut through quartz-tourmaline veins, and also through nodules of quartz-tourmaline in the white granite and in the fine-grained tourmaline granite. Obviously, then, these fissures were formed and filled with tourmaline after the consolidation of all the granitic rocks. In addition to the fissures filled with tourmaline, five examples were noticed of fissures filled with white mica (which may for convenience be termed greisen fissures), and numerous fissures in the granite containing, and rendered distinct by, a small amount of kaolinised material, derived apparently from the felspars of the granite.

An analysis of the results of many observations on the behaviour of these fissures, and their relations to each other, is interesting. It indicates that there are two sets of fissures, and in certain localities one set is distinctly later than the other, since at the points of intersection the latter are displaced. The analysis of 50 observations on fissures belonging to all three classes referred to above,

shows that 19 strike approximately north and south, nine strike north-east and south-west, and 22 strike approximately east and west. There would appear to be two main sets: those approximately north and south vary in three cases as much as 20 degrees east of the meridian, and in two cases 30 degrees east, but with these exceptions are all within a few degrees of magnetic north and south. In the case of the approximately east and west set, one variation of 20 degrees south and one of 30 degrees north were noted, but the strike of the remaining 20 fissures was never more than a few degrees from east and west. As noted elsewhere, many of the quartz-tourmaline veins strike north and south or east and west.

Whenever intersections were available, care was taken to determine, if possible, the relative ages of the different fissures. The results of these observations appear to be worthy of record. With regard to the tourmaline fissures, 10 instances were noted of their intersecting and being displaced by kaolin fissures, while in no case was the reverse observed: it seems quite clear that the fissuring of the granite now represented by the kaolin fissures took place *after* the consolidation of the tourmaline in an earlier set of fissures, as we should expect to find, for the kaolin fissures probably record disturbances of the crust of the igneous rock after all igneous activity had ceased: had they been formed before, and extended to within reach of the still fluid portion of the cooling magma, they must have formed channels of escape for some of the heated gases and solutions.

An instance of a greisen fissure cut through and slightly faulted by a kaolin fissure was also noticed.

Of six intersections of tourmaline fissures noticed, four occurred without appreciable displacement: there was usually a bulging caused by the formation of a larger mass of tourmaline, at the intersections. In one instance a north and south tourmaline fissure was slightly faulted by a similar one striking east and west, while at another locality a single instance of the reverse was noted, the east and west veinlet being faulted by a north and south one.

With regard to kaolin fissures, four intersections were noticed in which the north and south were slightly faulted by the east and west veinlets, while no instance of the reverse was observed: in three cases, however, kaolin-filled fissures striking north-east and south-west were displaced by similar ones striking north and south. Insufficient evidence has been collected to enable definite conclusions

to be drawn, and it would not be wise to generalise, but the features noted in this connection prove that in some instances at least, the earliest formed fractures of the series which occurred after the final consolidation of the crust, were those striking north-east and south-west. Somewhat later, a series of north and south fractures was developed, while the latest formed were those striking east and west.

The Structure of the Granite Massif.—In a previous section the writer has discussed the mode of origin of the varieties of granitic rocks, and has expressed the opinion that all are closely related genetically, and that all have resulted from the differentiation of a huge mass of igneous rock material *in situ*, *after* it had been forced up into a thick series of sedimentary rocks. In other words, although different rocks are noticed, they are but variations of one main granite intrusion, and all the variations constitute the one granite *massif*. It remains to consider the structure of this *massif*, and its relationship to other similar rock-types.

This question was studied by Mr. L. K. Ward a few years ago, and the results of his observations and the conclusions drawn therefrom are incorporated in a valuable paper read before the Australasian Association for the Advancement of Science at its Sydney meeting in 1911, entitled "The Heemskirk Massif—Its Structure and Relationships." After careful consideration, and by kind permission of the author, it has been decided to reprint this paper herewith, as it deals fully and directly with the subject under consideration, and leaves little to be said. This paper will be found at the end of this bulletin.(77)

Mr. Ward concludes from a study and discussion of the question, that the *massif* is an irregular transgressive intrusive body of limited mass, *i.e.*, with a definite bottom, and "not an ever-expanding mass of granite which is connected with the deeper portions of the earth." He proposes to give to the mass the name chonolite, which was invented by Professor Daly to meet such a case.

After his investigation of field occurrences, in a more detailed manner than Mr. Ward was able to undertake, the writer agrees with the views expressed so ably by the above author, which appear to explain satisfactorily the known features of the granitic outcrop and the associated dyke rocks and metal-bearing veins.

Age of the Granite.—It remains to investigate the age of the granitic rocks which have been described. From what

(77) *Vide* Appendix III., pp. 441–450.

has already been said it is clear that the different varieties of granitic rocks all belong to one period of igneous activity. The rocks have been referred to as Devonian, but no reason given for this statement.

Lithologically, the rock does not differ in any essentials from other outcrops of tin-bearing granites throughout the State. The pink orthoclase and tourmaline of the normal pink variety, and the abundant tourmaline of the white variety, are certainly not characteristic features elsewhere, but it is noteworthy that no slides of the various granites from the district revealed any signs of crushing, a very characteristic feature of the older granite of the State, which is believed to be of Cambro-Ordovician age.

The occurrence of basic rocks towards the margin, and the nature of the ores associated with the granite are features which suggest a correlation with similar outcrops in other localities. The development of similar *massifs* along certain well-defined lines also suggests a correlation for the outcrops. In the district itself the plutonic rock is intrusive into sediments which are of Pre-Silurian age.

The prevalence of dykes of acid rocks within and near the granite borders has been remarked upon; these dykes are undoubtedly genetically connected with the main granite mass, and represent portions of the magma which have been intruded into the upper portion of the igneous rock and into the surrounding sedimentaries during the consolidation of the main mass.

To the west, however, in the Zeehan field, are numerous dykes of granite porphyry.([78]) These are undoubtedly apophyses of the Heemskirk granite *massif*, which is believed to underlie this field. These dykes intersect the fossiliferous Upper Silurian strata,([79]) and some of them are affected by Post-Silurian faulting. This evidence is valuable in attempting to fix the time of the igneous intrusions, in the geological column.

In various parts of the State where the basal conglomerates of the Permo-Carboniferous system are developed, this rock is found to contain abundant boulders of granite which is to be correlated with that under review, but in no locality is granite known to be intrusive into the Permo-Carboniferous or later rocks: hence the granite is apparently earlier than Permo-Carboniferous.

It is in view of this evidence that the granite *massif* is assumed to be of Devonian age.

([78]) *Vide* Geol. Surv. Tas. Bulletin 8, p. 26. ([79]) *Op. cit.*, p. 27.

B.—SUMMARY OF THE SEQUENCE AND RELATIONSHIPS OF THE IGNEOUS ROCKS.

In different parts of this report assumptions have been made with regard to the relationship of the acid and basic igneous rocks of the district, but it is necessary to summarise and define more clearly what these relationships really are.

In the description of the acid rocks, it has been shown that differentiation processes have been active in the acid magma, and have resulted in the formation of closely-related, yet different, rock-types.

Similarly, in the basic magma differentiation processes have produced related but distinct rock-types.

Just as the white granite and pink granite are related, both having been derived from one magma, and as gabbro and peridotite are related, having been derived from another magma, so, in the writer's opinion, are both acid and basic groups of rocks related, in having been originally derived from the one parent magma. There is, however, a difference in the processes, in that the various types of acid and basic rocks have been derived from acid and basic magmas respectively by differentiation *in situ*: the acid and basic magmas themselves have not been produced by differentiation *in situ*. The parent magma was introduced from some deeper reservoir, into a position where it remained for some considerable time, during which period differentiation caused a separation into two sub-magmas, differing considerably in composition, one being basic and the other acid. A partial relief of pressure in the overlying rocks caused the basic mass to be forced up into a new position, still deep below the crust, where it underwent further differentiation, gradually cooling and solidifying to form the gabbro and peridotite, which were subsequently exposed by the removal of the overlying rocks. At a slightly *later* period, and immediately after the consolidation of the basic rocks, the differentiated acidic magma, of immensely greater bulk than the basic one, was in turn forced up into the overlying rocks, into a position determined by some crustal weakness. The acidic magma was still at a great depth below the surface, and after coming to rest, further differentiation resulted in the formation of the various rock-types described under the heading of acid igneous rocks.

Briefly, this is believed to be the explanation of the mode of origin of the different rock-types which the evidence at our disposal indicates.

Having stated the theory which is believed to satisfactorily account for the rock-types present in the field, it remains to indicate the reasons for accepting this theory.

It is not necessary to again discuss the various acidic and basic rocks, and their inter-relationship, but rather to consider the relation of the acid to the basic group of rocks as a whole.

The constant association of the acid and basic rocks is a striking feature of their field occurrence. It is noteworthy, too, that the basic rocks occur near the margin of the granite, but never within its borders. In one locality ([80]) veins of quartz and of tourmaline intersect the basic rocks, showing clearly that the latter had consolidated before the final consolidation of the granite. North of Trial Harbour, although the granite is not seen to definitely invade the serpentine, the impression gained certainly indicates a later age for the granite. The veins of quartz (distinct from the chalcedonic silica described elsewhere) which traverse the serpentine here may perhaps be attributed to the granitic intrusion. The occurrence of tabular masses of lime-silicate hornstones in the serpentine has been discussed elsewhere; although, perhaps, it can scarcely be admitted as evidence, not having been proved to be due to the granite, the fact is suggestive. The amphibolitisation of the gabbro, again, is suggestive, since no regional metamorphism has taken place since the invasion of the Devonian igneous rocks. The suggestion has been made by another writer ([81]) that this amphibolitisation in another district may have been due to the pressure exerted during the serpentinisation of portion of the basic mass. This question has already been discussed,([82]) and the opinion expressed that the amphibolitisation is due to the pressure exerted by the granitic intrusion. Could this be proved, no better evidence could be asked for to determine the relative ages of the two groups of rocks, but the question can scarcely be regarded as finally settled.

If the occurrences in this district are to be correlated with others in different parts of the State, important confirmatory evidence that the two groups of rocks are genetically related, and that the granite is slightly younger than the gabbro and serpentine, becomes available.

A close examination of the various occurrences makes it practically certain that such a correlation is justified.

([80]) *Vide supra*, p. 39.
([81]) Mr. L. K. Ward: Geol. Surv. Tas. Bulletin 6, p. 31.
([82]) *Vide supra*, p. 62, *et seq*.

Lithologically the rocks are similar. The actual association of different rock-types is similar to a remarkable degree. The intrusion of the rocks has taken place in many localities along definite lines determined by some crustal weakness.([83]) In several instances confirmatory evidence of age is obtainable, showing that different outcrops are to be correlated. The ore-deposits in different districts are similar, or give evidence of being genetically connected.

Unfortunately, chemical analyses of different rocks are not available.

Without dealing in minute detail with the different occurrences, from the general characters presented above there can be little doubt of the justification of the correlation of different outcrops.

Some of the known associations of basic with acid igneous rocks have already been enumerated.([84])

In the North Dundas tinfield basic rocks are traversed by dykes of granite-porphyry,([85]) indicating that the portion of the exposed basic rock was at least solid before the final consolidation of the granitic magma.

At Anderson's Creek, the serpentine is intruded by granitic rocks.([86])

For a more detailed discussion of the question the reader is referred to recent bulletins of the Geological Survey.

It is necessary to state clearly that there is no gradual merging in any district examined of granite into gabbro; the boundaries of the two rocks are distinct. In one district (Stanley River) rocks of intermediate composition (diorites) occur ([87]); they do not occur in contact with either granite or gabbro, but intrusive into the Pre-Silurian sedimentaries, and do not represent types which have resulted from differentiation *in situ* of the igneous mass.

This feature of the association of the basic and acid igneous rocks in so many districts clearly indicates a slight difference in age of the two groups. In view of the evi-

([83]) As pointed out by Mr. Ward: *vide* "The Heemskirk Massif—Its Structure and Relationships," by L. K. Ward, B.A., B.E., Proc. A.A.A.S., Sect. C. Vol. xiii., p. 172, *et seq*.
([84]) *Vide supra*, p. 63.
([85]) *Vide* Geol. Surv. Tas. Bulletin 6, p. 30.
([86]) Report on the Mineral Resources of the Districts of Beaconsfield and Salisbury, by W. H. Twelvetrees, 1903, pp. 7-9.
([87]) Geol. Surv. Tas. Bulletin 15, pp. 24-26.

dence presented above it seems clear that the acid rocks are slightly younger than the basic ones, although both are genetically connected.

C.—SEDIMENTARY ROCKS AND THEIR MODIFICATIONS.

(1)—*Pre-Silurian Slates, Sandstones, Breccias, and Tuffs.*

Surrounding the granite, and forming the country-rock into which all the igneous rocks of the district have been intruded, is a thick series of slates, sandstones, breccias, and tuffs. They form part of a series of sediments which occupy a considerable portion of the West Coast country. The sediments in the Heemskirk district appear to be quite continuous with the older rocks developed in the neighbourhood of Zeehan.[88] The most abundant members of the series developed in this district are fissile blue slates and white sandstones, which are interbedded. Fine-grained tuffs occur in places intercalated with slates, and in one locality (to be described) were breccias noted, interbedded with both slates and sandstones.

All the beds have evidently been subjected to intense crushing, and, in consequence, they are rendered schistose, and there has been a considerable amount of contortion of the beds.

Although strikes and dips were noted at various points where outcrops were exposed, these were found to be of no value in determining the strike and dip of the series as a whole, for the observed bearings varied from north and south to east and west. This is not surprising when it is remembered that in the district examined one is never far distant from the huge granite *massif* of the Heemskirk Range, which has highly metamorphosed the surrounding sediments. In the vicinity of the granite-contact, the rocks are always intensely altered, the commonest effects being silicification and tourmalinisation. Contact-metamorphic effects are described elsewhere.[89] A striking characteristic of the country near the granite-contact in which these sediments occur, is the presence of abundant angular quartz on the surface, shed from veinlets cutting through the rocks in various directions. Banded quartz-tourmaline rock (an original sedimentary in which the bands are replaced alternately by quartz and tourmaline) is also common.

(88) *Vide* Geol. Surv. Tas Bulletin 8. pp. 35-37.
(89) *Vide infra*, pp. 111-124.

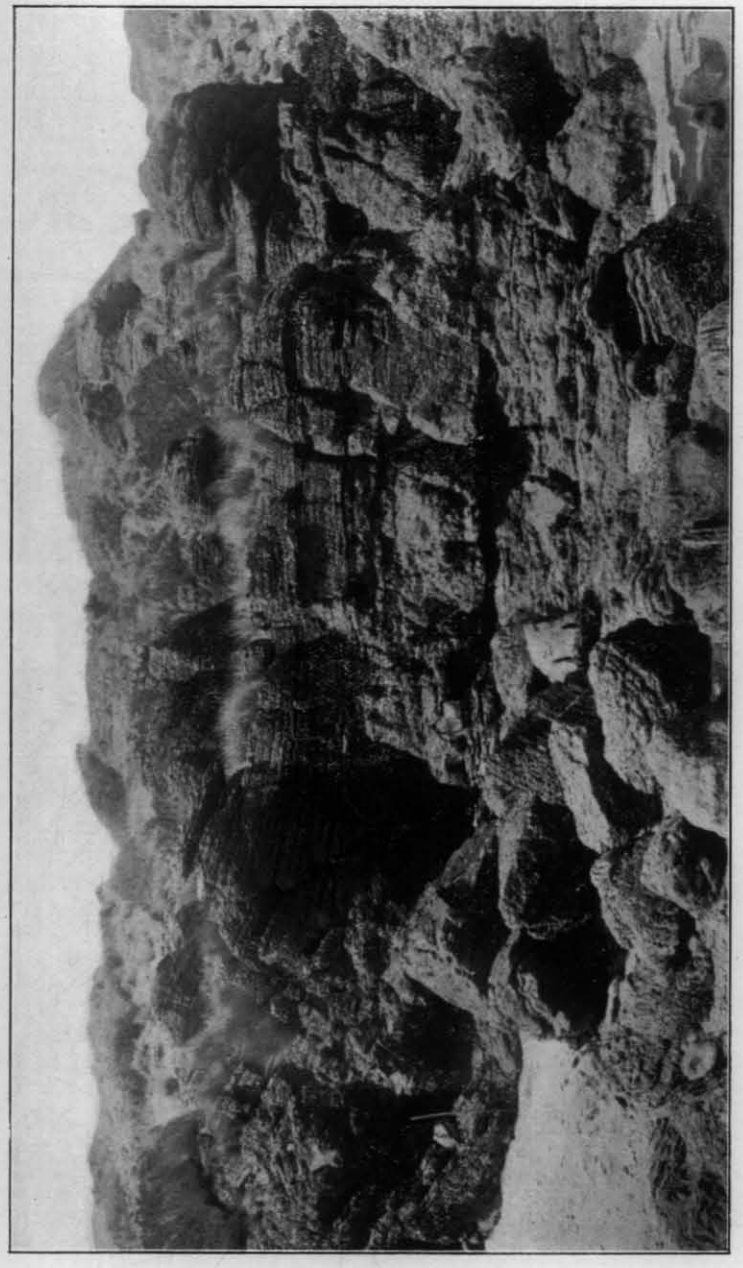


PHOTO. 13.—DIFFERENTIAL WEATHERING OF CALCAREOUS BANDS IN PRE-SILURIAN SEDIMENTS ON COAST ONE MILE SOUTH OF TRIAL HARBOUR. [L. Lawry Waterhouse, Photo.

In some localities sandstones predominate: here the soil is open and sandy, and usually supports little vegetation but button-grass. Where slates are represented most abundantly, however, there is usually a fair depth of clayey soil, brown in colour, which supports a luxuriant growth of scrub and timber. Between the granite-contact and the Little Henty River, although there are patches of open myrtle forest with tree-ferns, the slates support a heavy growth of dense scrub, which is frequently impenetrable. In fact, careful examination of this portion of the district was impossible, owing to the thick scrub.

To the eastward the series is overlain in the neighbourhood of Zeehan by fossiliferous Silurian strata. At no point in the area did any trace of organic life appear to be preserved, but this is only to be expected when the altered nature of the sediments is remembered.

Mention has been made of the thick scrub in the vicinity of the Little Henty River preventing a detailed examination of this locality. One traverse made of this country was down the course of the Burnt Bridge Creek to the Little Henty River. An examination of the rocks exposed in the bed of the creek disclosed some interesting information.

About 1 mile below the Trial Harbour Road is a hard bar of rock crossing the creek, which forms falls about 30 feet in height. This is seen to be a breccia, composed of angular and subangular fragments, varying in size from $\frac{1}{8}$-inch to 4 inches in diameter, enclosed in a reddish to greenish-coloured groundmass. The fragments appear to be distributed quite irregularly through the rock, which shows no defined banding. The whole rock is exceedingly hard, and breaks across the fragments with a tendency towards conchoidal fracture in places. The prevailing colour on freshly-fractured faces is a dark-reddish tint, merging into greenish in places, according to the nature of the groundmass. The appearance of weathered surfaces is striking: the groundmass weathers away, leaving the included fragments standing out in relief from the rock face.

The fragments, which form the bulk of the rock, are usually very siliceous: the commonest variety is a dense chert, but some pieces have a chalcedonic facies, and a few resemble a close-grained igneous rock. The cement is normally reddish in colour and very siliceous: in places, however, there are masses of green actinolite up to 1 inch in diameter. These consist of aggregates of crystals up to 2

millimetres in length, pale-green and pleochroic in thin section, and frequently associated with pyrrhotite: in some cases irregular cracks running through fragments of chert are filled with actinolite, which forms continuous veinlets with similar aggregates in the cementing material. Obviously the actinolite is secondary, and has been formed in the rock subsequent to its consolidation. The presence of this mineral sometimes gives the rock a greenish tint.

The rock is similar in appearance and general characteristics to a breccia recently described from the Stanley River district by the writer,[90] and to one described from North Dundas by Mr. L. K. Ward.[91] Mr. Ward also compares the latter rock with a conglomerate from the Dial Range.

The width of the main belt of breccia exposed at this point is about 70 feet. The strike of the sedimentary rocks here is N. 65° E., and the dip south. An aneroid reading showed the height at the top of the falls to be about 400 feet above sea-level.

The breccia varies a good deal in texture from coarse to very fine. These beds are intercalated with finer-grained sedimentaries: these rocks are all very much hardened and silicified. Some are very fine-grained and are indurated slates: in others coarser grains are distinguishable in a fine groundmass, and while some bands are doubtless true sandstones, others appear from the nature of the fragments to be tuffs. They are exceedingly hard, and break with a conchoidal fracture. Some bands show lens-shaped inclusions of fine breccias.

Outcropping on the hill side about 2 chains east of the breccia exposed in the creek is a light-coloured lime-silicate rock: it was rather too decomposed for sectioning, but appeared to consist almost entirely of light-coloured diopside, with aggregates of pistache-green epidote, and a little scattered magnetite. On account of the thick undergrowth in this vicinity it was found impossible to trace the extent of the lime-silicate rock, or determine exactly its relation to the breccias: apparently it represents a calcareous band in the sedimentaries which has been reconstituted as a result of the metamorphism the rocks have undergone.

Before proceeding to deal with the mode of origin of the breccia, it seems advisable to refer to the succession of rocks exposed in the lower course of the Burnt Bridge Creek to its junction with the Little Henty River, as all belong to

(90) *Vide* Geol. Surv. Tas. Bulletin 15, p. 40.
(91) *Vide* Geol. Surv. Tas. Bulletin 6, pp. 34, 35.



PHOTO. 14—PRE-SILURIAN SLATES SHOWING ANTICLINAL AND SYNCLINAL FOLDING. CUTTING ON ZEEHAN-TRIAL HARBOUR ROAD. [L. Lawry Waterhouse, Photo.

the one great series, and this was the only section available in this part of the district.

For some chains below the breccia, the rocks are hardened sedimentaries where they could be examined, similar to those described above.

This is succeeded for several chains by another band more intensely altered, until in many places the rock has almost lost its sedimentary appearance: in places it approaches a breccia again, containing abundant cherty masses in a groundmass with abundant green actinolite. These cherty masses vary in colour from white to reddish, but it is so altered that a well-defined brecciated structure is nowhere distinguishable. In one or two places it almost appears as though there are irregular masses of some basic rock intrusive into the sedimentaries: detailed examination is impracticable, however. It is worthy of note that wherever these aggregates of actinolite occur, and they are very abundant, they are constantly associated with pyrrhotite, never very abundant, but always noticeable in disseminated masses. One specimen broken from this locality showed abundant minute bladed crystals of black hornblende facing the walls of a fissure in the rock.

Succeeding one narrow band, which appears to be a true breccia similar to that higher up the creek, is a horizon of very dense greenish and reddish slate, much folded, and showing faulting on a small scale in several places; these rocks appear to be intruded in several places by small irregular masses of a greenish igneous rock, with fairly abundant pyrrhotite in places. A short distance lower down the creek is a hard bar crossing the creek, iron-stained on the surface and pale-green on freshly broken surfaces. The texture is fine to medium, and it proves to be a gabbro-amphibolite: the rock is described elsewhere in this report.(92) The walls are ill-defined, and included in the rock are light-coloured cherty fragments. The mass occurs in tabular form, width 6 feet, strike N. 53° E., apparent dip south-east. The rock is very hard, and the bar crossing the creek bed forms falls about 12 feet in height.

About 3 chains lower down the creek, in the highly metamorphosed slates and sandstones, now converted to cherts and quartzites, are noticed several bands of a very hard greenish rock, which proves to be a lime-silicate hornstone, composed essentially of diopside, epidote, and idocrase, with a little calcite and quartz. This rock is described in detail below.(93) It occurs apparently interbedded with

(92) *Vide supra*, p 34. (93) *Vide infra*, p. 130.

the sedimentary rocks, but observations are limited to very few outcrops of the rock.

About quarter of a mile below this occurrence a branch creek joins the main creek from the north-east. At this point a little prospecting work was carried out, although without success: the work is described in another part of this report.(94)

From this point onwards to the Little Henty River, the rocks appear less altered. At the junction of the creeks a series of pink and white grits and quartzites make their appearance, forming a steep ridge, through which the creek has cut its gorge. The beds strike N. 75° W., and dip north at 30 degrees. This does not correspond with the observed strike and dip higher up the creek, and the question arises as to whether we have here represented a different series of beds, unconformable with those previously described. The writer prefers, however, to regard them as belonging to the same series: it must be borne in mind that we are dealing with an area in which the result of considerable metamorphic action is manifest, and also one in which continuous observations are impossible owing to the lack of outcrops. The rocks are usually hardened and silicified, and are noticed at intervals for at least 15 or 20 chains.

About the southern extremity of these beds is a band of greenish quartzite; clear quartz grains are abundant, but the groundmass cannot be distinguished. A thin section was cut, and shows that many of the quartz grains are surrounded by green chlorite, which also occurs in tufted aggregates; a few grains of epidote are present in these tufts.

At about a quarter of a mile above its junction with the parent stream, the creek bed is crossed by a band of very hard quartzite, which causes a small waterfall. This rock appears to have been crushed, and shows a poorly-defined schistose structure on weathered surfaces: it carries pyrite disseminated and in crystalline aggregates throughout its mass. From this point to the Little Henty River, a considerable thickness of rocks is exposed, well banded, and varying in strike at different points from N. 13° E. to N. 32° E., but with a constant dip to the east at 45 degrees. The rocks are bluish in colour, and are usually very fine in texture, but show bedding planes. They are soft, and resemble impure limestones in appearance: they contain harder siliceous bands in places, which strongly resist

(94) *Vide infra*, p. 423.

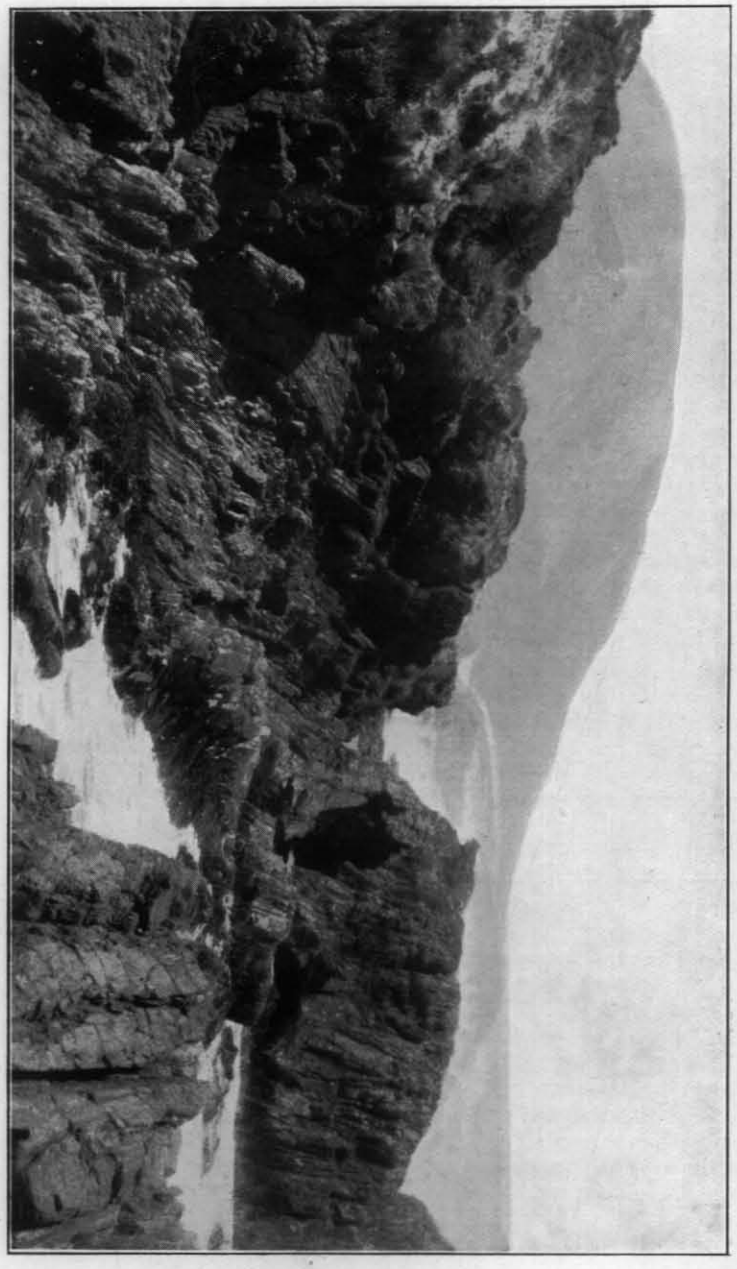


PHOTO. 15—OUTCROP OF PRE-SILURIAN SEDIMENTS ON COAST NORTH OF LITTLE HENTY RIVER, WITH HILL OF SILURIAN (?) SANDSTONE IN BACKGROUND.

[L. Lawry Waterhouse, Photo.

weathering, and stand out as hard bars crossing the creek-bed.

A sample from these softer beds was submitted to the Government Assayer for determination of the lime content: he reported —

Lime (CaO) ..... 10·85 per cent.

This figure is equivalent to 19·38 per cent. calcium carbonate, and clearly shows that the beds are impure limestones. This determination of calcareous beds in the old Pre-Silurian sedimentary series of rocks is important.

(2)—*Silurian (?) Sandstones and Grits.*

On the accompanying map of the district[95] a small area is shown near the coast between Trial Harbour and the Little Henty River as being of doubtful Silurian age. The writer hesitates a good deal about classing the rocks as Silurian, and admits that the evidence for doing so is very slight. The rocks form a well-defined hill about 30 chains in length, with a remarkably level crest, the axis of the hill striking about north and south. It is covered with button-grass on the summit and western slopes, but at the foot of the eastern slope heavy scrub comes in. This hill rises to about 300 feet above sea-level: it is isolated, and at no other place in the district were similar rocks found. The general shape of the hill as viewed from the north-west is shown in Photos. Nos. 7 and 15.

Unfortunately, although the crest and sides of the hill were covered with abundant debris, no definite outcrops, which could be regarded as certainly *in situ*, were seen. Fairly large boulders were seen in places, and these usually were lying partly embedded in the surface soil, with their bedding planes approximately horizontal. It may be that they really do represent the disposition of the beds and that they have become detached from the massive beds in the ordinary course of weathering without taking up fresh positions. If the beds be horizontal, they must be lying unconformably on the older sedimentaries which outcrop along the sea-shore.

The rocks are invariably very siliceous sedimentaries, white in colour, the predominating members being sandstones and grits, although sometimes coarser pebbles occur,

[95] Plate II.

giving the rock more the features of a conglomerate. Although hard and usually silicified, there appears to have been no crushing of the sediments. Individual particles vary in shape from angular to rounded. It is worthy of note that in many of the finer sandstones, as well as in the coarser grits, although the bulk of the rock is made up of grains of glassy quartz, there are softer fragments which show signs of kaolinisation.

The striking feature of the rocks is the occurrence of abundant cavities, many of which are strongly suggestive of fossil impressions, although no definite fossils were found. Some of the cavities are of quite irregular shape, and are doubtless caused by the weathering out of some of the softer constituents of the rock: others are approximately circular in plan, but of small thickness, while others again suggest the forms of brachiopods, although the impressions are not sharp. Some of the cavities are circular or slightly oval in shape, about one-quarter inch in diameter, and have a small circular central pillar, *i.e.*, the cavities are cylindrical. These cavities are very suggestive of crinoid stems. Although they do not appear to be common, one loose fragment of white sandstone was obtained which showed on weathered surfaces some irregular tubular casts up to about 1 inch in length, all lying parallel with the bedding plane of the specimen. In general form they resemble the so-called "pipe-stems" of the tubicolar sandstone which is associated with (and later than) the West Coast Range conglomerate in various localities on the West Coast. These casts, however, are rather more indefinite than typical "pipe-stems," and lie horizontally, and not perpendicularly, with reference to the bedding planes.

Thus it will be seen that there is no positive evidence for classing the beds as Silurian. It is not improbable, however, that they may be correlated with known Silurian beds at Zeehan, which are thus described by Messrs. W. H. Twelvetrees and L. K. Ward in their bulletin on the Zeehan field:—([96])

"Sandstone, pebbly grit, and greenish-grey slate. The next succeeding formation to the limestone is a coarse-grained sandstone, which merges into a grit on the one hand and into a greenish slate on the other. The coarser-grained varieties are loosely compacted, and ill-suited to preserve the details of organic remains, which are consequently lacking in structural details. There are present in the beds some obscure tubular casts which appear to be

([96]) *Vide* Geol. Surv. Tas. Bulletin 8, pp. 39–40.

related to, if not identical with, the similar casts more abundantly represented in the tubicolar sandstone. The principal point of difference between these tubular bodies in the two formations is concerned with their relations to the bedding planes. In the Silurian beds the tubes lie more or less horizontally, or are inclined at low angles to the planes of sedimentation, while in the tubicolar sandstone they cross the bedding planes approximately at right angles. In the Silurian beds they are associated with other organic remains, while in the older formation they alone are found."

Quartz veins are noticeable in some specimens, cutting across the bedding planes, containing a little scattered pyrite. One specimen was cut through by a veinlet of dark greenish-black tourmaline in fine radiating needles. These features indicate that the sediments have been influenced by the granitic intrusion, and that ore-bodies may be found in the vicinity.

(3)—*Recent Sediments.*

Recent Unconsolidated Sediments.—There are in several localities in the district accumulations of recent sediments which are unconsolidated: they are of no importance.

Along the coast there are naturally deposits at various points of shingle and sand, where conditions have been favourable for their accumulation. As a general rule, however, the coast-line is rugged and precipitous: sometimes there is a narrow strip between high-water mark and the base of the cliffs, which is covered with talus from the cliffs above; in other places the sea encroaches right to the base of the cliffs. At a few points where small bays have formed there are accumulations of sand or shingle. At Granville Harbour there is a strip of low-lying land fringing the shore, which is covered with recent deposits of shingle and sand. At Trial Harbour also, and for a short distance to the south, there are beach sands, which extend inland but a short distance. In this locality some of the recent accumulations both of sand and gravel are becoming consolidated as described below.

From a short distance north of the mouth of the Little Henty River, extending for between 15 and 20 miles southwards, is the magnificent sandy beach known as Ocean Beach. This is of considerable width, up to one-quarter mile in places, and is composed at its northern end partly of well-rounded gravel of about pea size, partly of white

sand, varying in coarseness. This forms dunes for a short distance inland from high-water mark. There are recent alluvial flats of limited extent at several points in the lower course of the Little Henty River, and a strip of low-lying ground to the south of the river, about half a mile in width: this was not visited, but appears to be alluvium.

Inland there are no extensive deposits. Along most of the creeks are patches of alluvium of limited extent, many of which have been found to carry payable tin; these are practically exhausted. At the Agnew Creek, near the point where it crosses the Trial Harbour Road, is a flat carrying abundant rounded pebbles and boulders of quartz-tourmaline forming beds up to 4 feet in thickness. This alluvium is usually tin-bearing, and has been worked in various places on the flat: it appears to be of Recent age. The well-rounded nature of many of the boulders forming these deposits, and their thickness, suggests that they may possibly be Tertiary, for the creeks do not carry very much water; but there is no direct evidence for classing the deposits as Tertiary.

Recent Sandstone, Conglomerate, and Breccia.—Examples occur in the district of the formation of sandstones, conglomerates, and breccias at the present time. Geological processes do not vary with time, and in this case we have examples of solid rocks being formed at the present day, although on a small scale, by processes similar to those which have been active since the beginning of time. By the processes to be described, loosely aggregated deposits of sand, gravel, and detritus are becoming consolidated to form sedimentary rocks.

All the occurrences to be described occur in the vicinity of Trial Harbour. On the edge of the beach below the site of the old township of Remine, and from 10 to 20 feet above high-water mark, are to be seen beds which appear to be composed of sand similar to that on the beach below, but which are found to be consolidated. The material is so hard in places that it forms a true sandstone. Where faces are exposed, the beds are seen to be distinctly banded, and cross-bedding is plainly visible in several places. The beds are never more than a few feet in thickness. Much of the sand is iron-stained; it rests directly on serpentine. The mode of origin is not far to seek: the sand is really dune-sand, blown up from the beach by the prevailing winds. Changes in the direction and velocity of the wind have caused the slight cross-bedding effect noticeable in some places. The cementing is evidently going on at the present

time. This is due largely to solutions derived from the serpentine. The latter rock is rich in iron, much of which is set free as the rock gradually decomposes, and taken into solution by the surface waters. In the hot and dry weather the iron-bearing solutions would be gradually absorbed into the body of the sand, and the evaporation of the water would leave the iron oxide as a cement. Probably the cementing material is also partly calcium carbonate: a certain amount of this substance would also be available in the solutions, derived from the weathering of the serpentine. Then, again, reference has been made to the presence of abundant veinlets of arragonite and of calcite in the serpentine: in the course of weathering, although some of this would be taken into solution, a good deal would be included in the sand as grains derived from the mechanical battering to pieces of the bedrock. This calcite and arragonite in the beds of sand would in course of time be dissolved, and would in part at least be reprecipitated to form a calcareous cement for the insoluble grains. A certain amount of silica would also be set free in the decomposition of the serpentine rock, and portion of this would be absorbed into the beds of sand by processes similar to those described for the iron oxide, and would form part of the cement.

About half a mile south-east of Remine, along the coast, a small creek trickles down on to the beach, after flowing through a somewhat marshy flat which is on serpentine country. At the mouth of this creek were noticed thin beds of brown iron-stained conglomerate. The pebbles are of all sizes up to about 3 inches across, and vary in shape from angular to rounded. The composition of the pebbles varies: most of the angular material is serpentine, very much weathered, while the rounded pebbles are mostly quartz and quartzite. The cement is almost entirely limonite. The material is quite compact and now forms a solid rock. There is no doubt as to the mode of origin of this rock: it really represents the detrital deposits brought down by the creek, cemented by iron oxide deposited from solutions which have derived their iron contents from the decomposition of the iron-bearing minerals of the serpentine. The deposit is of small thickness and extent, and of no importance, although of interest as showing the processes in operation.

A similar result is being effected about a mile further south along the coast, where the surface *debris* near the base of a hill is being cemented by iron oxide, derived from the weathering of lime-silicate and other contact rocks.

Sand blown in from the beach is being cemented in the same way.

Outcropping and lying about on the surface at the foot of a hill about ½-mile south-east of Remine, near a small creek flowing into the ocean, is a peculiar rock, different from any seen elsewhere in the district. It occurs very near the contact of serpentine and slate rock. The rock consists largely of opal and limonite. There are abundant irregular veins filled with opal varying in colour from white, through brown, to black. Interspersed with the opal are irregular masses of limonite, usually massive or earthy. This material, however, is subordinate in amount, opal forming the bulk of the rock. There are sometimes included masses, apparently of thoroughly opalised serpentine. The rock is very light, being of a very open texture. The masses of opal are usually quite open towards the centre, the central cavities being lined with projecting oolitic masses of opal, which has evidently been deposited from solution. Most of the opaline masses show a certain banded structure, owing to varying amounts of impurity included in the different layers deposited.

In one place the surface of the bed-rock is covered with a layer of opal varying in thickness from 1/16th to ¼-inch. This sheet of opal is divided into rectangles by a series of intersecting fissures, which have afterwards been filled with impure opal and iron oxide, the effect being to give the rock surface a strikingly tessellated appearance. The opal is distinctly mottled, owing to some patches being stained reddish-brown by included iron oxide. The rock itself is thoroughly silicified, and appears to have been a serpentine. The included fragments are also of silicified material, apparently serpentine.

The rock is practically a siliceous sinter, but on account of the included fragments may be classed as an opaline breccia. The silica is obviously secondary, and has been deposited from solution. It has probably been derived from the decomposition of the serpentine rock, being deposited from solutions as the solvent evaporated. It may have been brought to the surface by hot waters, but there can be little doubt as to the rock having been formed *in situ*, and the included fragments, and the situation of the deposit indicate that it is of quite recent age. The extent of the deposit is small, and it is of no economic importance.



PHOTO. 16—COASTAL CLIFFS SHOWING GRANITE-SLATE CONTACT, ABOUT ONE MILE NORTH-WEST OF TRIAL HARBOUR.

[L. Lawry Waterhouse, Photo.

D.—CONTACT METAMORPHIC EFFECTS OF THE IGNEOUS INTRUSIONS.

(1) *General.*

The South Heemskirk tinfield provides some unusually interesting contact-metamorphic effects which merit special description. Although one very important result of the intrusion of the igneous masses has been to form contact-metamorphic ore-bodies of economic importance, it is not proposed to deal specifically with these ore-bodies at this juncture, but rather to discuss the variations caused in the rock-types in the vicinity of the igneous contacts.

As described above, there have been two intrusions of igneous rock, both derived from the same source, and following closely upon one another, but of very different composition; the earlier intrusion was of basic material, and is represented by areas of gabbro-amphibolite and of serpentine; the later, of acid material, which formed the Heemskirk granite *massif*.

The igneous rocks have intruded Pre-Silurian sediments, and it is these rocks which exhibit the contact-metamorphic effects to be described. The rocks are described elsewhere as forming a thick series of essentially argillaceous and arenaceous sediments, with definite evidence ([97]) of certain calcareous beds intercalated with them.

Effects of the Basic Intrusions.—The effects of the basic intrusions on the sediments appear to have been small. It must be borne in mind, however, that basic and acid rocks are not only closely related genetically, but they are closely associated in the field, and any effect which the basic intrusion may have had may be quite masked by the far more intense alteration caused by the subsequent granitic intrusion. Few alterations which could be attributed to the basic rocks were observed in the district. The association in the field of lime-silicate rocks with the gabbro and serpentine is described below, but their formation is considered by the writer rather to be due to the effect of the granite. Along the Trial Harbour Road, about a mile south-west of Comstock, is a belt of andalusite slate, nearly 1 mile in width, with gabbro exposed on both sides, but this rock is described in detail below,([98]) as the alteration is probably due to the granite.

Mention should be made of the fact that at very few points was the actual contact of gabbro or serpentine with

([97]) *Vide supra*, p. 105. ([98]) *Vide infra*, p. 121.

sedimentary rocks observed, and any slight effect actually at the contact might easily be overlooked.

At one point on the cliffs north of Trial Harbour, the sedimentaries in contact with the serpentine are exposed, and the alteration observed in the rocks appears to be the result of the basic intrusion. The rocks appear to have been slates; they are hard and very close-grained, with no distinguishable constituents in the groundmass. The rocks are dark-brown in colour, and are evidently rich in iron. The rocks are traversed in all directions by veinlets filled with silica: these veinlets sometimes intersect. The silica is usually chalcedonic, but sometimes cavities occur, and their walls are usually encrusted with minute prisms of glassy quartz. This effect is believed to be due to the intrusion of the basic rocks, the silica being derived from the basic magma, and expelled during the final stages of cooling and consolidation of the igneous mass. At this period highly aqueous solutions carrying silica in solution would be set free, and would penetrate, not only the already consolidated igneous rocks, but also the adjacent sedimentaries. From the descriptions given below, it will be observed that the contact-metamorphic effects of the acid magma are distinct from those described above, and that they are intense even at considerable distances from the exposed granite contact.

Effects of the Acid Intrusions.—In contradistinction to those of the basic rocks, the contact effects of the acid intrusives are extensive, and well marked. Where it is exposed (and there is a particularly fine section on the coastal cliffs about 1 mile north-west of Trial Harbour, shown in Photo. No. 16) the actual line of contact between igneous and sedimentary rocks is sharply defined. At different places narrow dykes of aplite are noticeable in the sedimentaries near the contact, and in some cases these can be distinctly traced back into the mass of the granite itself. On top of the cliffs a few small irregular tongues of medium-grained aplitic granite extend a few yards into the surrounding rocks, gradually tapering out, different tongues sometimes coalescing, and so including blocks of slate. Fine examples are to be seen along the contact, and particularly at the base of the cliffs north of Trial Harbour, of blocks of country-rock included in the granite. Xenoliths of 30 to 40 feet in diameter are sometimes seen. Photo. No. 17 shows one such xenolith, near the contact, but completely enclosed in fairly coarse-grained granite.



PHOTO. 17.—XENOLITH OF SLATE INCLUDED IN GRANITE NEAR CONTACT, BASE OF COASTAL CLIFFS, ONE MILE NORTH-WEST OF TRIAL HARBOUR,

[*L. Lawry Waterhouse, Photo.*

The granite itself sometimes does not appreciably differ near the contact from its normal character: it is usually medium to coarse-grained right to the contact, clearly indicating that the country-rock itself must have been raised to a very high temperature; had there been any appreciable chilling, the igneous rock must have cooled more rapidly, and have shown the effects of this cooling in finer crystallisation. At some points the pink granite appeared rather more acid than the normal variety further from the contact. It was lighter in colour, and biotite and tourmaline were scarce. No analyses of normal or contact granites are available. A microscopical examination of a thin section of granite from within a few inches of the contact at the top of the cliffs overlooking Trial Harbour, where abundant garnet is developed in the adjoining slate, shows that the rock possesses some distinctive features not noticeable macroscopically. Quartz and felspar are present in about equal quantities. The quartz is in large allotriomorphic grains, partly moulded on the felspars. It is always crowded with abundant minute inclusions, which cannot be definitely determined. The felspars are all thoroughly kaolinised, and show no distinct extinction angles, so that it is impossible to determine the variety of felspar present. The inclusions of quartz in some of the felspathic matter shows that micro-pegmatitic intergrowth of the two minerals has taken place. Some of the felspars show idiomorphic outlines. Abundantly scattered through the slide in grains, granular aggregates, and in clusters of idiomorphic and hypidiomorphic crystals is a slightly brownish monoclinic pyroxene, augite. This mineral occurs partly included in the kaolinised felspars, partly in the quartz, although some fragments show irregular outlines moulded on the idiomorphic felspars. A few shreds of light-green pleochroic uralite are noticeable, forming at the expense of the augite. A noticeable feature is the presence of abundant yellowish sphene. This mineral is highly idiomorphic, and occurs in small scattered crystals and groups of crystals, and in larger crystals throughout the slide. The crystals are usually wedge-shaped, and vary in size from ·002 inch to ·02 inch. The sphene is pleochroic, crystals being untwinned, and appearing honey-yellow by reflected light. In one instance an inclusion of apatite was noticed. Sphene is included in felspar and quartz, and is frequently partly surrounded by augite crystals, which are moulded upon it. Apatite is not uncommon, occurring in slender prisms with hexagonal cross-sections;

it is included in each of the previously described minerals. A few grains of magnetite are distributed through the slide, and in one instance a rim of the same mineral partly surrounds an augite crystal, suggesting that it may be secondary.

At the slate contact on the beach north of Trial Harbour, the granite is white in colour, and of medium grain-size, even when actually in contact with slate. In some places abundant fragments of slate are included in the granite, but are converted almost completely (when viewed in hand specimens) to fine crystalline aggregates of black biotite mica. At such places the granite itself usually carries abundant biotite.

It would appear, then, that at the actual contact the composition of the granite has been slightly modified, and that certain new minerals have been formed owing to the assimilation of a certain amount of the slate. This process has not been extensive, or its effects would be more noticeable in the exposed granite.

Speaking broadly, one of the commonest results of the granite intrusion appears to have been the silicification of the sedimentary rocks. In addition, however, other minerals are developed at different points, among those observed being biotite, tourmaline, andalusite, hornblende, actinolite, garnet, idocrase, diopside, tremolite, epidote, sphene, chlorite, phlogopite, serpentine, albite, with magnetite, pyrite, and pyrrhotite.

It will be seen that many of these minerals are silicates of lime and magnesia: these "lime-silicate hornstones" are so extensively developed as to form quite a feature of the contact metamorphic aureole: they will be dealt with later on.

The slates near the contact are usually very dark in colour, weathering black, and so the contrast with the white granite is marked. The rocks are always hard, and usually show very few signs of decomposition, appearing fresh immediately below the thin black weathered crust.

Reference has been made[99] to the fact that the granite-slate contact is well exposed on top of the cliffs overlooking Trial Harbour. At this point threads and tongues of granite extend for short distances into the surrounding slates, which are consequently much altered. Some of them appear to be more like igneous than sedimentary rocks, owing to the crystalline structure induced by the intense alteration they have undergone. On fresh faces the

([91]) *Vide supra*, p. 112.

rock is dark bluish-black, and shows abundant small crystals of biotite in a quartzose groundmass, and occasionally crystals of black hornblende up to three-sixteenths of an inch in length are noticeable. A little scattered pyrrhotite is present. The rock appears to be massive on fresh faces, and shows no signs of banding, but on weathered surfaces a distinct banded structure is noticeable. This may be due to a slight schistosity developed by the igneous intrusion, but is more likely due to a slight difference in the composition of different layers of the original sediment, resulting in the formation of slightly different contact minerals, which in turn have weathered at different rates. The examination of a thin section of this rock shows that the recrystallisation of the original constituents has been complete. The rock consists of aggregates of hypidiomorphic hornblende, with a little biotite and magnetite in a groundmass of quartz grains which form a typical mosaic. The hornblende is very fresh, and occurs in well-formed greenish-brown crystals which are strongly pleochroic. It is abundant through the slide. Biotite is scarce, occurring in ragged reddish-brown pleochroic aggregates, which are usually closely associated with granular magnetite. There are a few small granular aggregates of a colourless mineral with high refractive index and strong double refraction, apparently monoclinic pyroxene. Quartz mosaic forms the whole of the groundmass.

On the summit of the coastal cliffs, about 8 chains south-east of the previously described occurrence, along the contact, is a development of an interesting rock which merits special description. The granite from the actual contact at this point has already been described,[100] and has been shown to contain quartz, felspar, augite, sphene, apatite, and magnetite. The sedimentary is very hard and dark coloured, and on fresh faces shows abundant dark-brownish patches in an indistinguishable dark-bluish groundmass. On weathered surfaces, however, the appearance is striking. Standing out in relief from a dark-grey surface are abundant brownish-black garnets varying in size from one-sixteenth to one-quarter inch in diameter, and showing trapezohedral crystal forms. Owing to their hardness and resistance to decomposition, they have remained unchanged, while the enclosing rock has gradually weathered away. A thin section of this rock was prepared, and discloses the nature of the groundmass. The idiomorphic garnets are set in a groundmass consisting essentially of granular

([100]) *Vide supra*, p. 113.

quartz, with smaller quantities of biotite, magnetite, spinel, tourmaline, and muscovite. The garnets contain abundant inclusions of quartz, magnetite, and biotite. They are sometimes intersected by veinlets filled with quartz or with biotite, and are usually surrounded by a rim of biotite. The biotite occurs partly in reddish-brown flakes and aggregates which are pleochroic, and in better formed greenish-brown crystals which are strongly pleochroic. The mineral is fairly abundant, being well disseminated through the groundmass. Magnetite grains are scattered right throughout the slide, but are sometimes assembled in streaks and patches through the rock. The other constituents are much less abundant. A little green spinel appears to be associated with garnet. Green tourmaline is scarce, but a few minute prisms and crystal aggregates occur. One or two shreds of muscovite are present. The groundmass of quartz forms a fine-grained mosaic with occasional veinlets filled with rather larger grains.

At sea-level the slates at the contact are fine-grained, hard, bluish-black rocks with few distinguishable minerals. Scattered pyrrhotite is noticeable in scattered grains and filling minute fissures through the rock. Cutting through the rock in various directions are veinlets up to 1 inch in width, filled with crystalline black tourmaline. A thin section of this rock from the contact shows abundant magnetite in fine grains arranged in lines, which give the slide a banded appearance. The groundmass of the rock is an extremely fine quartz mosaic. A little actinolite is scattered through the rock, and grains of pyrrhotite are noticeable. A vein traversing the slide is filled with hornblende, with which is associated garnet and a little idocrase with a few scattered aggregates of pyrrhotite. The hornblende occurs in light-brown pleochroic crystals, and the garnet and idocrase in granular aggregates of very irregular shape.

The slate blocks included in the granite are very similar to the rock just described, the main difference being that they usually contain abundant brown biotite.

Similar rocks are exposed for about 10 chains along the shore (about 5 chains from the nearest point in the contact), with minor variations such as the development of more abundant garnet or biotite, when a change occurs, and bands of a very light-coloured hard rock make their appearance in the dark contact slates. This rock weathers to a yellowish colour. Microscopically examined in thin section, the rock is seen to be composed of a confused aggregate of crystal grains and irregular masses. Quite irregular

shreds of a brownish amphibole are present, and abundant through the slide: they may have been developed at the expense of monoclinic pyroxene, which is noticeable in grains through the slide. Rutile is fairly abundant in brown grains and crystals. The colourless patches forming the groundmass show mosaic structure, and appear to be composed mainly of quartz, with perhaps some clear albite: the individual grains are of microscopic size. Several irregular veinlets traverse the section, filled partly with quartz, partly with vesuvianite. A few scattered grains of magnetite are noticeable. The rock appears to be a thoroughly reconstituted sedimentary rock, which has been altered by the intrusion of the adjacent igneous rocks. It is succeeded to the south by black serpentine, very rich in magnetite, and bands of yellowish-green diopside rock, which have been described elsewhere.([101])

From this point southward for about three-quarters of a mile along the coast, serpentine is exposed, with occasional projecting tongues of sedimentary rocks and bands of diopside rocks: this section has been described in detail.([102])

The sedimentary rocks exposed in the side cutting on the Trial Harbour Road, near the head of the Serpentine Creek Falls, which are associated with diopside rocks at the serpentine contact,([103]) are intensely altered. The sediments are now hardened and silicified, and the general colour is light-greenish, with some dark-reddish bands. The original bedding-planes of the sedimentaries are still distinguishable by slight differences of composition. A noteworthy feature is the occurrence of pink garnet, in veins of irregular course and variable width up to 1 inch, cutting across the bedding-planes of the sediments. In the flinty groundmass are distinguishable aggregates of light-greenish diopside, and a little actinolite. Irregular quartzose veinlets traverse the rock. Granite is exposed but a few chains to the north, and the belt of sedimentaries is continuous, being a good deal decomposed in the immediate vicinity of the granite.

Serpentine is developed at the site of the old township of Remine, but at a rocky point along the coast, about one-half mile south of the old township, sedimentaries once again make their appearance. These rocks are apparently portion of the Pre-Silurian series so extensively developed in the district.

([101]) *Vide infra*, p. 125. ([102]) *Vide supra*, pp. 54, 55.
([103]) *Vide supra*, pp. 53, 54.

As exposed on a rocky point to the south of Remine, and apparently near the junction with the serpentine, the rocks are black and fresh right to the surface. They are extremely hard and flinty, and obviously represent alternate bands of slate and sandstone, intensely hardened and probably silicified. The slates are black and compact, while in the sandstones abundant grains of glassy quartz are visible through the rock-mass. A slight displacement of some bands by faulting is noticeable.

These rocks are apparently interbedded with a series of rocks of very different appearance. On weathered surfaces they are reddish-brown, but the weathering affects only the surface crust. On fresh surfaces the rock is very pale greenish-grey, and appears to be compact, showing a few scattered aggregates of pyrrhotite. In appearance it resembles a rock described from the serpentine contact to the north of Trial Harbour.([104]) Microscopical examination is necessary to show the structure of the rock, which effervesces with acid. In thin section it is seen that the rock is composed essentially of minute prismatic crystals of diopside, which show rather irregular outlines, and form a felted aggregate: there is also tremolite present in minute crystals of similar habit to that assumed by the pyroxene. A fairly large proportion of the groundmass of the slide is occupied by brownish allotriomorphic plates entirely moulded on the pyroxene and amphibole. These plates could not be determined as a definite mineral: they have a high refractive index, medium double refraction, and are non-pleochroic. They exhibit no cleavages, and the extinction is very indistinct, the plates showing aggregate structure. The material is apparently a secondary product, composed probably of some lime mineral which has been formed by the weathering of some of the primary calciferous minerals. In one part of the slide is an aggregate of idocrase crystals, though the mineral is not abundant. There is a little calcite forming irregular plates, and this also may be a secondary mineral. A little clear quartz occurs as an interstitial mineral, filling spaces between pyroxene or amphibole crystals: this has evidently been one of the last minerals to crystallise, or it may perhaps be secondary: the amount present is small. A few aggregates of pyrrhotite, partly oxidised to limonite, are noticeable. It is not easy to say positively what the rock really is. It may be called a lime-silicate rock, and in the writer's opinion represents an original calcareous sedimentary which has been completely altered and reconstituted under the action of heat and pressure exerted by the granite in the contact metamorphic zone.([105])

([104]) *Vide supra*, p. 49.

There are also lens-shaped bands of a different rock, weathering brown, but light in colour on fresh faces, with irregular pale-pink and greenish included aggregates. This rock is strikingly heavy. Microscopical examination shows it to be a lime-silicate hornstone, with garnet, diopside, idocrase, and a little quartz. The rock is described in detail elsewhere.([106])

On the south side of this point typical quartzites occur, with abundant fine-grained pyrrhotite in the groundmass. In these rocks are sometimes noticed small lens-shaped inclusions of a greenish flinty rock, perhaps narrow slate bands which have been metamorphosed.

The general strike of these beds is north-west.

Along the coast to the south is a small beach, succeeded by a rocky point, where there is exposed a considerable development of very hard-banded rocks of a general light colour. Some of these rocks are beautifully polished by the action of blown sand. They consist of closely-compacted bands of dark, blue-grey, white, and greenish material. The latter shows a finely crystalline structure, the white and dark bands being compact and merging into each other. A careful examination of freshly-broken specimens shows that the bands occur in a definite sequence, and from their structure are evidently of different composition. The greenish material occurs in vein form, with fairly sharply defined, though somewhat irregular, walls. It is bounded always by white flint, which merges outward into dark blue-grey material of the same description. The width of these greenish veins varies from a fraction of an inch to about 1 foot. Sometimes several narrow bands occur close together, with an intermediate band of white silicified slate. Where they become wider, the bands usually include irregular strips, sometimes lenticular, of white siliceous slate. Sometimes the greenish bands are themselves traversed by veinlets up to $\frac{1}{2}$-inch wide, filled with granular pink garnet. The nature of the greenish material proves, on examination, to be lime-silicate rock. It is described elsewhere.([107]) Some of the flinty bands are reddish in colour, and are traversed by irregular veinlets of light-green monoclinic pyroxene.

([105]) It has been deemed advisable to describe this rock here for the sake of convenience, rather than with the lime-silicate rocks at a later stage.

([106]) *Vide infra*, p. 128. ([107]) *Vide infra*, p. 127.

The beds, as a whole, are a good deal contorted, but the general strike is about north-west.

The occurrence of the greenish lime-silicate rock in vein-like masses and irregular patches in the hard, flinty, silicified slates, causes curious weathering effects. Owing to the more rapid decay of certain of these bands and masses, and the comparatively great resistance to decay offered by the other portions of the rock, the surface is not only deeply grooved and carved into ridges and pinnacles, but the whole rock is honeycombed. Many of the cavities are coated with an oolitic iron-stained incrustation.

Similar rocks outcrop for about 3 chains beyond the rocky point described, and extend inland some distance. They form a well-defined hill a short distance back from the shore. Here the lime-silicate bands are brick red, owing to a surface incrustation of limonite. The surface debris is becoming cemented by the iron leaching out of the rocks in surface waters.

A short distance south along the coast, the rocks described above are succeeded by slightly different contact rocks. They belong to the same series, but the contact effects, although still very marked, are not quite the same. They obviously represent slates and sandstones, and are well banded, with a south-easterly strike. The rocks consist of hard, white quartzites and reddish slates; the latter have been silicified and intensely indurated. In a fine-grained reddish groundmass (quite similar to that possessed by some of the rocks to the north of Trial Harbour, near the granite contact) are sometimes seen rounded patches of quartz, almost invariably associated with pyrrhotite. It would appear that at least a partial recrystallisation of the rock has taken place. These rocks were not examined microscopically. A few chains south a continuation of these beds outcrops, in the form of white quartzites and indurated flinty blue slates. It is worthy of note that these beds are intersected by quartz veins, seldom more than 2 inches in width, a few of which contain limonite in cavities which evidently represent the decomposition products of pyrite. These rocks outcrop on the coast. A few chains inland rises a steep hill composed of sandstones and grits, which may be of Silurian age ([108]). These appear to be horizontally bedded, and show few signs of alteration, unlike the rocks described above.

([108]) *Vide supra*, p. 105.

Sand-dunes occupy the coast and adjacent strip of country southwards for about ½-mile to the mouth of the Little Henty River.

On the Zeehan-Trial Harbour Road, about a mile south-west of Comstock, a short distance west of a sharp elbow bend in the road, there is exposed in the side-cutting of the road a belt of contact rocks which merit special mention. They are exposed for nearly a mile along the road, being bounded on both sides by gabbro-amphibolite. The rocks are usually much weathered, and near the surface have decomposed, yielding a red, clayey soil, evidently very rich in iron, which supports a luxuriant growth of thick scrub. Where fresh specimens of the rock are obtainable, they are seen to be greenish in colour, and to be indistinguishable from the fine-grained gabbro-amphibolite which occurs at its western edge, near McIvor's. In hand specimens the rock is dense, and no constituents can be determined. With the aid of the microscope, however, the rock is seen to be an andalusite slate. In thin section, andalusite is seen to be abundant in long prismatic crystals, with almost square cross-sections. These crystals contain usually small amounts of inclusions, which extend down the central portion of the crystals, appearing as a central line of inclusions in the longitudinal sections, and a small square surrounded by fresh material in the cross-sections. In other words, the inclusions frequently form a core to the andalusite crystals. These inclusions appear to be not carbonaceous matter, as one would expect with this mineral, but a light-coloured material, which appears to be semi-opaque, and shows low order interference colours between crossed nicols. This is probably kaolin. The same material is common throughout the slide, forming aggregates, in which small particles of clear mineral are visible. These aggregates probably represent the decomposition products of andalusite crystals. In the longitudinal sections this change appears to extend from the ends of the crystal towards the centre, as it is noticeable that in some cases there is a clear area in the centre of the section, while the alteration products have the appearance of tapering wedges driven in from each end of the crystal. The meeting of these "wedges" forms the core of the crystal referred to above. In places the crystals are minute, and have a tendency to form sheaf-like aggregates simulating sillimanite, but possessing all the optical properties of andalusite. Rounded aggregates of transparent green chlorite are scattered through the slide.

A few fragments of actinolite are present in the groundmass, which also carries some carbonaceous matter and scattered grains of magnetite. A little clear albite is distinguishable, and occasional grains of yellowish epidote.

From the preceding descriptions it will be seen that the contact effects induced by the granite in the surrounding sedimentaries vary a good deal from point to point. In certain localities, however, the alteration has been very different, and has resulted in a tourmalinisation, or silicification and tourmalinisation of the sediments. Perhaps this effect is most typically developed at Mayne's Mine. Here the original slates and sandstones have been very widely replaced by quartz and tourmaline, and the resulting rocks are very striking in appearance.

It should be borne in mind that in the particular case under review, the alterations have largely been effected by introduced vapours and solutions, and are not merely the effects of heat and pressure on the sedimentaries which have been intruded by the igneous mass. Another point should be emphasised here: it is not proposed to discuss the economic aspect of the deposits, which will be fully dealt with in another part of this report.

The rocks resulting from the alteration vary considerably—from white sandstones with mere traces of tourmaline, to dense tourmaline rocks with very little quartz.

In some of the least-altered rocks, tourmaline occurs in narrow veinlets, cutting through the rock, and it is noticeable that the tourmaline has impregnated the sandstone to a small extent on either side of the fissure, perhaps to the extent of $\frac{1}{2}$-inch only. That quartz has been introduced with the vapours which have caused the formation of the tourmaline is evident, for on breaking specimens along fissures, the walls are sometimes seen to be encrusted with minute singly and doubly terminated prisms of clear glassy quartz.

At times when a fissure crosses the original bedding-planes of the sedimentary rock, the different layers of the rock have been replaced to different extents: thus some bands appear to be unaltered (although even in these cases probably a silicification has taken place), while others are completely replaced by tourmaline. This type of alteration may extend but a few inches from the fissure, but in extreme cases the whole of the resulting rock for considerable distances is altered, the resulting rock being a striking banded black and white rock. It seems clear that the composition of the sedimentary has determined

the type of alteration. Argillaceous bands have caused the formation of tourmaline, arenaceous bands being represented by quartz bands, the resulting banded rock being composed entirely of these two minerals. Microscopical examination of thin sections did not give much additional information. The only minerals present are quartz and tourmaline. The quartz occurs in interlocking grains of irregular shape, sometimes with hypidiomorphic outlines. In some instances the central portions of grains are seen to be crowded with inclusions, while the outer rims are clear, the whole being optically continuous. The portion with the inclusions appears to represent the original sand grain, the clear portion an addition of secondary silica. The tourmaline is brown in colour, and occurs in short prismatic crystals and crystal aggregates, with usually a very small amount of interstitial quartz. In localities where the sedimentaries have been contorted, the contortions are faithfully reproduced in detail in the resulting replacement rock. Thus, specimens were collected showing sharp folds, which have been exactly reproduced in every particular, alternate bands consisting of quartz and tourmaline.

These rocks have been referred to elsewhere as banded quartz-tourmaline replacement rocks.

The rocks were recorded by Mr. Waller,([109]) and have been described from the Stanley River by the writer,([110]) and also from North Heemskirk,([111]) where they are abundantly developed round the northern boundary of the Heemskirk granite *massif*, and as derivatives from these rocks are abundant in the Tertiary stanniferous river gravels being worked in both districts just referred to.

Faults on a small scale are sometimes perfectly reproduced in these banded rocks.

A variation in the banded quartz-tourmaline rock is one in which the rock has a general mottled appearance. Irregular angular fragments of white quartzite are included in a groundmass of black tourmaline. A close examination shows that some of the included fragments are banded quartz tourmaline, and that some have been completely replaced by tourmaline. The cementing material usually carries a little quartz as well as tourmaline, and varies from place to place. The included fragments are always angular, with sharply-defined bound-

([109]) Report on the Tin Ore Deposits of Mt. Heemskirk, p. 6.
([110]) Geol. Surv. Tas. Bulletin 15, p. 36.
([111]) Geol. Surv. Tas. Report 6, p. 8.

aries; in some cases a little tourmaline has been developed within, but near the outside of the quartzose fragments, giving them a zonal structure on freshly-fractured faces. This rock may be described as a "quartz-tourmaline replacement breccia," meaning not a quartz-tourmaline rock which has been brecciated subsequent to formation, but a breccia (in the instance described originally composed of fragments of slate and sandstone) which has been subjected to the action of heated vapours and solutions carrying silica and boron in solution, and which has consequently suffered replacement, the original quartz of the rock remaining unaltered, while the argillaceous material has caused the formation of tourmaline. The original breccia was probably a fault breccia.

From the same locality as the above rocks garnet was recorded by Mr. L. K. Ward ([112]):—"Yellow crystals (grossularite?) occur at Mayne's Tin Mine, south of Mt. Heemskirk. The forms developed are the trapezohedron or a combination of this form with the rhombic dodecahedron . . . Clear blood-red crystals also are found at Mayne's Tin Mine." No crystals of the mineral were obtained by writer from this locality, although reddish aggregates in some of the altered sandstones certainly suggested the development of garnet. The mineral here is apparently a secondary mineral developed by the contact-metamorphic action of the adjacent granite.

(2)—*Lime-Silicate Hornstones.*

The rocks either entirely composed of, or very rich in, minerals which are silicates of lime or magnesia, or both, with iron sometimes entering into their composition, are so widely distributed as to form a noteworthy feature of the contact metamorphic aureole of the Heemskirk *massif*. They form a series of rocks known as lime-silicate hornstones. They are perhaps most extensively and typically developed in the vicinity of Trial Harbour. Serpentine occurs at the site of the old township of Remine, and granite about a mile to the north-west along the coast. In contact with the granite are altered slates which have already been described: between these slates and the serpentine is a belt of lime-silicate hornstones, which also occur in the serpentine here.

([112]) Quoted by W. F. Petterd: "The Minerals of Tasmania," 1910, p. 81.

Similar rocks occur about three-quarters of a mile south-east of Trial Harbour along the coast, with a series of altered slates and sandstones.

About 1 mile east of the harbour, near the border of the serpentine, outcrops of lime-silicate rocks were noted, although their extent could not be determined on account of the thick scrub.

About 1 mile east of Mayne's Mine, in the Burnt Bridge Creek, is an exposure associated with gabbro-amphibolite.([113])

In the western portion of Section 6667-M, H. D. Marsh, north of the Trial Harbour Road, and to the north of this section, similar rocks occur. They are associated with intensely indurated slate, and it is worthy of note that the granite approaches to within a few hundred yards of the gabbro-amphibolite. There may be a continuous belt of similar rocks through to the north, for lime-silicate hornstones occur again to the north at the Tenth Legion Mine (Section 6715-M, 80 acres). Here they are within a few chains of the granite contact.

Closely associated with the serpentine developed near Trial Harbour are bands and irregular masses of a lime-silicate rock which merits detailed description. Near its northern extension as exposed along the shore-line in the vicinity of Trial Harbour, the serpentine contains apparent inclusions of a yellowish rock, readily distinguishable from the dark-coloured surrounding serpentine. This rock is greenish-yellow on freshly broken faces, and appears to have a fine granular structure, crystal faces being sometimes distinguishable in the groundmass. The rock is strikingly heavy, and, as in the case of the serpentine enclosing it, carries very abundant magnetite. This mineral is distributed through the rock-mass in grains, irregular-shaped granular aggregates, and in veinlets. Some of the masses of magnetite are rather coarsely granular, and are sometimes associated with green phlogopite mica. Large crystal plates of greenish chlorite are also present. The weathering of the rock is characteristic, for on all outcrops the veinlets and irregular masses of magnetite stand out in relief from the yellowish surface of the rock.

A microscopical examination of a thin section of this rock shows that it is composed almost entirely of the colourless monoclinic pyroxene diopside. There are scattered grains and aggregates of magnetite, which also occur filling vein-

([113]) *Vide supra*, p. 103, also *infra*, p. 130.

lets running irregularly through the slide. In the section examined a veinlet of appreciable width cuts through the slide and is filled with magnetite and light-green serpentine: the magnetite coats one or both walls of the fissure, the central portion of it being filled with serpentine. This fissure cuts through various grains of pyroxene, and has obviously been formed and filled subsequently to the consolidation of the rock. The diopside viewed in ordinary light appears to be granular, but examined between crossed nicols is seen to be composed of comparatively large flakes with irregular boundaries, and in one part of the slide shows a tendency to assume a radial structure. These large crystal plates do not extinguish uniformly, but include numerous irregular grains of the same mineral extinguishing in groups independently of the host; there is apparently an intimate intergrowth of different crystals. No minerals other than diopside, magnetite, and serpentine are to be seen in the thin section examined.

Another section cut from a similar rock occurring a few chains further south along the coast-line, just north of the mouth of the Montagu Creek, fails to disclose any essential differences in the nature of the rock. The only minerals shown in this slide are diopside and magnetite. In some instances intergrowths of different crystals of diopside occur similar to those described above, but frequently the larger crystals are hypidiomorphic, and extinguish normally between crossed nicols. Some of these crystals are twinned, and fine examples of twinning lamellæ are noticeable. Diopside, as well as occurring in distinct crystal plates, is abundant in the form of finely granular aggregates in different parts of the section. Magnetite occurs in scattered grains and aggregates.

On the Trial Harbour Road, near the falls on the Serpentine Creek, contact metamorphic slates occur: these are very hard and flinty, and are traversed by irregular veins of garnet and of actinolite, aggregates of diopside being sometimes noticeable. These rocks are exposed in the side cutting of the road, and are seen to merge into decomposed iron-stained clays, beyond which diopside rocks are exposed for about 6 chains.

These rocks vary a little from point to point, but the essential features are similar to those already described. They are pale yellowish-green to greyish-green in colour, and finely granular to crystalline in structure. Crystals of pyroxene up to one-half inch in length are sometimes seen; the rocks may vary in the one specimen from being so fine-

grained as to be regarded as compact, to a fairly coarsely crystalline rock. The crystals occur in vein-like masses in the granular rock. Magnetite is always present. A microscopical examination was made of a thin section cut from a medium-grained specimen of this rock. The rock is seen to be composed entirely of diopside and magnetite. The diopside is colourless, and occurs in hypidiomorphic crystals and rounded grains. In the particular slide examined magnetite is not very abundant, occurring in irregularly-shaped grains throughout. Obviously, there is no essential difference between this rock and those described from the beach north of Trial Harbour.

Exposed along the coast south of Trial Harbour are contact metamorphic sedimentary rocks which have already been described. At a rocky point about a mile north of the Little Henty River is a very interesting occurrence of lime-silicate rocks in these altered sediments. Reference has been made to these rocks, and a description given of the sedimentaries,([114]) which belong to the Pre-Silurian series so extensively developed in the district.

The lime-silicate rock here occurs in bands and lenticular masses, which appear to have been introduced into the slate series. These bands are of a general greenish colour, with an ironstained crust on weathered surfaces. They vary in texture from very fine-grained, in which no constituents can be determined, to crystalline in which the component minerals are distinguishable. The width of these tabular vein-like masses of lime-silicates varies considerably. They are sometimes but a fraction of an inch, and occur up to about 12 inches in width. The walls are always well-defined, and the effect on the wall-rock is marked. The slate is hard and flinty, and usually of a dark blue-grey colour, but where traversed by these green veins the rock appears to be further hardened, and certainly is bleached white. Where several of these vein-like masses approach one another, the intervening strips of slate are converted to white cherty bands. In most of the widest bands there are residual fragments, sometimes continuous narrow bands, sometimes lens-shaped masses, of this altered slate. The impression gained by an examination of the occurrence is that the lime-silicates have been introduced by solutions following fissures in the slates, usually following bedding-planes, sometimes cutting across them. Veins of granular pink garnet are sometimes noticed traversing rather irregularly the greenish material. The dis-

([114]) *Vide supra*, pp. 118–120.

tinguishable minerals in the crystalline bands are greenish pyroxene, pale-green translucent tetragonal prisms of idocrase, granular pink garnet, white to brownish calcite, and a little wollastonite(?). The peculiar pistache-green of the granular groundmass in places suggests epidote.

Microscopical examination of a thin section of one of the finer-grained greenish bands confirms the presence of lime-silicates. The rock consists essentially of brownish granular epidote. At intervals through the slide are aggregates of the same mineral in hypidiomorphic crystals. A little monoclinic pyroxene diopside is distinguishable. In one portion of the slide are brownish crystals of garnet in a groundmass of calcite. These two minerals are intergrown: associated with the garnet are idiomorphic prismatic crystals of idocrase, also in a groundmass of calcite. The epidote groundmass of the slide shows an almost indefinable banded structure, and is traversed by narrow darker stripes, apparently of the same mineral, which run approximately parallel. The rock is a lime-silicate hornstone.

A few chains along the coast to the north-west of the previously described occurrence is a bold outcrop of hard black slates and sandstones previously referred to.[115] In these rocks are lens-shaped bands of a rock somewhat resembling the lime-silicate rock described above, and closely resembling it in mode of occurrence. It occurs in more or less tabular masses, which appear to be intrusive. The rock is dark reddish-brown on weathered surfaces, which are very rough owing to the decomposition and removal of certain constituents. On fresh faces it is light in colour, of a general pale flesh-pink shade, with greenish aggregates. It is hard and tough, and strikingly heavy. A thin section cut from this rock was examined microscopically. The rock is seen to be composed of garnet, diopside, tremolite, idocrase, and quartz. Diopside is abundant in crystals of somewhat irregular shape, which are frequently intergrown; associated with it is a little colourless amphibole. Garnet is fairly abundant in well-formed crystals and granular aggregates. It contains many inclusions of the other minerals. Idocrase, although not very abundant, shows idiomorphic outlines. Interstitial quartz is not uncommon. The groundmass in places is crowded with decomposition products, in which calcite seems to be fairly abundant.

Towards the eastern edge of the serpentine, in the vicinity of the nickeliferous opaline serpentine previously described,[116] and about north of the hill of supposed

[115] *Vide supra*, p. 118. [116] *Vide supra*, p. 56.

Silurian sediments, is a fairly extensive development of lime-silicate rocks. These occur apparently on the borders of the serpentine, at their junction with the slates. As exposed in a creek-bed towards the top of the ridge, and a few chains south-east of the highest outcrop of the big chalcedonic ironstained formation described elsewhere,[117] the rocks show a dark yellowish-brown weathered crust. They are exceptionally tough, and on fresh faces are pale greenish-grey. The rocks show a general crystalline texture, with veinlets in which the light-coloured mineral is fairly coarsely crystalline. A few aggregates of magnetite and sporadically disseminated pyrrhotite are noticeable throughout the rockmass.

In thin section the rock is seen to be composed almost entirely of diopside. This mineral occurs both in granular aggregates forming the groundmass of the slide and (more frequently) in hypidiomorphic prismatic crystals, sometimes of considerable size. Epidote is also present, closely associated with the diopside. Masses of calcite occur at intervals, partly moulded on and partly including the previously mentioned minerals. Scattered irregular aggregates of pyrrhotite are noticeable, and disseminated grains of magnetite. One portion of the slide is slightly stained by limonite derived from the partial decomposition of some of the pyrrhotite.

A little lower down the spur the nature of the rocks varies slightly. They are yellowish-green on fresh faces, and are composed essentially of granular diopside, with scattered aggregates and streaks of magnetite. They are in general similar to the diopside rocks described from the coast at Trial Harbour, where they are closely associated with serpentine. The extent of the rocks in this locality could not be determined on account of the undergrowth; they occur very close to the contact of the serpentine with the sedimentary rocks.

On Section 1392M, south-east of Mayne's Tin Mine, is an occurrence of wolfram and bismuth ore, described below. The workings here expose a belt of lime-silicate rocks differing somewhat from those previously described. The dominant mineral appears to be tremolite. The rock varies in colour from very pale greenish-grey to darker green, and is usually of a crystalline structure, showing abundant fine prismatic crystals of a light colour. A little magnetite occurs in places, and sometimes pyrite as well. Microscopically the rock is seen to be composed almost

[117] *Vide infra*, p. 422.

entirely of colourless crystals of tremolite, which have irregular outlines, as the crystals are a good deal intergrown, and are partly altered to talc. Scattered grains and aggregates of magnetite and pyrrhotite are noticeable throughout the slide.

Somewhat similar rocks were traced down the creek for about 2 chains, into very thick scrub. Here the rock carries a crust of limonite to a depth of half an inch, but on fresh faces appears to have a quartzose groundmass, through which are scattered abundant pale greenish aggregates, the latter occupying more than half the bulk of the rock. Veinlets of quartz traverse the rock. A little pyrite is noticeable. The microscopical examination of a thin section shows that aggregates of slightly brownish monoclinic pyroxene are scattered through a quartzose groundmass. Although in most cases well-defined crystal forms of pyroxene are not distinguishable, in some portions of the slide groups and columnar aggregates of hypidiomorphic crystals occur. A good deal of the pyroxene is slightly clouded by decomposition products. The quartz of the groundmass occurs partly as fissure fillings, irregular fissures running approximately parallel through the slide, and also in the form of a mosaic of interlocking grains of all sizes. In some of the veins showing the coarser quartz crystals, idiomorphic crystals of pyrite are to be seen. A few minute veinlets are seen to be filled partly with quartz and partly with calcite.

About 1 mile north-east of the previous occurrence, in the bed of the Burnt Bridge Creek, the Pre-Silurian sediments are much altered. Breccias are intercalated with sandstones and slates, and at least one intrusion of gabbro-amphibolite has been recorded. About 3 chains below this igneous rock are exposed in the bed of the creek several tabular masses of a very hard dense rock, of a very pale-green colour, which appears to have a crystalline structure. It closely resembles rocks which occur along the coast both north and south of the Trial Harbour serpentine. A thin section was prepared, and examination shows that the rock is a lime-silicate hornstone. It consists largely of granular aggregates of diopside and epidote, with very fresh vesuvianite in aggregates. A small amount of calcite is present, and a little clear quartz. The former mineral has probably been set free by the decomposition of some of the lime-bearing minerals. Portion of the groundmass of the slide consists of a very finely granular aggregate, which cannot be resolved definitely. The extinction of portions of this groundmass in distinct patches suggests that it has been

derived from some mineral now thoroughly decomposed. It is worthy of note that no garnet was observed in the single slide examined.

This lime-silicate rock occurs in narrow bands apparently interbedded with metamorphosed slates and sandstones.

Near a bridge over the Agnew Creek on an old track branching off the Trial Harbour Road, near the junction of the present pack-track to the Federation Mine, is a development of lime-silicates connected with a contact metamorphic deposit described in another part of this report. The metallic minerals present are magnetite, pyrrhotite, pyrite, chalcopyrite, and perhaps a little blende. The most abundant gangue mineral is a greenish amphibole, with biotite and fluorite in places. A thin section cut from a band, in which the only distinguishable minerals in hand specimens are a greenish pyroxene or amphibole and scattered pyrrhotite, was examined microscopically. The structure of the rock is very similar to that of a tremolite rock described above from Section 1392M. Amphibole varying from colourless to pale greenish occupies the bulk of the rock, with talcose aggregates in places, and a little brown biotite. Scattered grains of magnetite and pyrrhotite are present, and narrow veinlets filled with pyrite cut across many of the prismatic amphibole crystals.

Another section of fine-grained rock indistinguishable in hand specimens is seen to be composed of idiomorphic crystals of tremolite in a fine-grained talcose groundmass, with abundant fluorite. Distinguishable scales of talc are scattered through the groundmass, and sometimes occur in aggregates.

The country-rock is dark greenish-blue slate, and a thin section shows that much actinolite is developed in the groundmass of the slide, which is traversed by veinlets filled with abundant flakes of brown biotite. Fluorite is present in aggregates in portions of the slide.

About one half-mile north-east of the above deposit, between the exposed edges of the granite and the gabbro-amphibolite, are much altered slates with lime-silicate hornstones. Outcrops are scarce, and the locality is covered with very thick scrub and undergrowth. In addition, many of the rocks are much decomposed at the surface. At one point a greenish rock outcrops, which appears to be composed largely of epidote. A thin section cut from this rock shows that the bulk of the rock is composed of yellowish pleochroic epidote. This mineral occurs in masses of columnar crystals, crossing each other at all angles, the crystals occurring in definite aggregates which usually show

a radiating structure. Interstitial spaces sometimes occur between crystals, and these spaces are filled with clear quartz. In some of them a little colourless idocrase occurs, which has evidently crystallised later than the epidote, but earlier than the quartz.

A somewhat similar rock outcrops on the southern boundary of Section 6667M, towards the south-western corner of the section, but is too much weathered for exact identification. It is certainly a lime-silicate rock.

A short distance to the north, near the centre of Section 6667M, lime-silicates occur in the gangue of an ore-body which consists essentially of blende and magnetite. Lime-silicates also occur in the country-rock outside the main ore-body. The ore-body is described elsewhere,([118]) the chief metallic minerals being magnetite and sphalerite, with accessory pyrite. The gangue minerals are mainly diopside, serpentine, chlorite, and talc. Phlogopite also occurs in greenish hexagonal plates, sometimes of considerable size, both in the ore-body and in the serpentine which occurs in the wall-rock. The latter is exposed in the open-cut for several feet, but contains lenses of metallic minerals. A microscopical examination of specimens is necessary to distinguish the nature of the gangue and wall-rock in places. A thin section was cut from a specimen of ore showing both magnetite and sphalerite (blende), and only a small amount of pale greenish gangue. A little pyrite is seen to be present in addition to the two metallic minerals mentioned. The gangue consists mainly of diopside, which occurs partly in groups of hypidiomorphic prismatic crystals, but more commonly in aggregates composed of fine scaly individuals. Scattered through this fine-grained groundmass are larger colourless crystal plates of chlorite, this mineral also occurring in aggregates in parts of the slide. A few scaly aggregates of talc usually associated with aggregates of chlorite are present. The slide is traversed by a veinlet which cuts through many of the larger diopside crystals, and is filled mainly with serpentine, also partly with pyrite.

Another thin section was cut from a band in the ore-body composed essentially of a light greenish mineral, apparently pyroxene, and disseminated magnetite and sphalerite. The metallic appear to be mainly moulded on the non-metallic minerals. Of the latter, by far the most abundant is diopside, which occurs in large hypidiomorphic prismatic crystals and in aggregates composed of small

([118]) *Vide infra*, pp. 184-185, 412-415.

individuals. The larger crystals are frequently twinned. Tremolite occurs also in prismatic crystals, showing hypidiomorphic outlines, but is not very abundant. Some of the pyroxene crystals are partly altered to a light-green uralite. Some of the tremolite also has been partly altered. A few aggregates of greenish chlorite are noticeable in the groundmass, and scales and rod-like forms (cross-sections) of talc are also sporadically distributed through the slide.

No essential difference is exhibited by a slide cut from a very close-grained greenish-grey specimen with finely disseminated magnetite, sphalerite, and pyrite. Abundant crystals of diopside of quite irregular shape occur throughout the slide, with a few quite irregular patches of clear serpentine. The metallic minerals tend to form veinlets in the slide, and these are sometimes intersected by narrow veins of clear serpentine.

Bands of a greenish serpentinised rock are exposed in the cutting on the southern side of the ore-body. A thin section was cut from a specimen of this rock, which is of a dark-green colour, and shows scattered crystals of green phlogopite mica. Under the microscope the rock is seen to be composed almost entirely of a very pale greenish serpentine, through which are disseminated crystals of magnetite and pyrite. Pale greenish crystals of phlogopite occur partly altered to scaly aggregates of talc; the latter mineral also occurs without any distinguishable mica. Plates of chlorite showing little colour by transmitted light are present in the serpentinised groundmass.

In the same cutting, some yards away from the ore-body, the country-rock is a tough, close-grained, greenish-grey rock in which no constituents are distinguishable in hand specimens. In thin section this rock is seen to be composed of granular diopside, with a few clear patches of serpentine of irregular shape. Through the slide are a few aggregates, whose individuals are almost of microscopic size, of a mineral with a high refractive index, which is apparently isotropic; this is, apparently, garnet.

About a mile to the north of the deposit described above is a large deposit of magnetite on Section 6715-M, 80 acres, formerly known as the Tenth Legion Mine. This property really belongs to the Comstock district, and was not examined in detail. It is worthy of note at this stage, however, that associated with the magnetite are various lime and magnesium silicates, the principal ones noticed being diopside, serpentine, phlogopite, tremolite, and chlorite. These minerals occur in varying proportions, but the resulting lime-silicate rock is apparently fairly exten-

sively developed. The granite contact is distant about 30 chains to the west of this deposit: the bulk of the country-rock in the vicinity is quartzite.

About 8 chains north-west of the old tunnel (now partly collapsed) in the western portion of the above section, are some old workings now collapsed. A shaft has been sunk, a shallow adit driven, and some trenches cut: the country-rock exposed is quartzite. On the dump-heaps, however, are vughs of crystalline quartz with associated crystals of sphalerite: fragments of talc are attached to some of these geodes. On the tip also are crystalline aggregates of phlogopite mica, with decomposing white crystals, apparently of tremolite; green chlorite also occurs, in which are crystalline aggregates of quartz, sometimes forming small prismatic crystals projecting into geodes.

On a flat a few chains to the west of these old workings are more lime-silicate rocks, with highly altered slates and sandstones. The strike of the beds is approximately north and south, and their dip is east at a steep angle. Although in general their strike corresponds, the lime-silicate rocks appear to be intrusive into the sediments, *i.e.*, they are crystalline, of rather irregular thickness, and have no sharply-defined lines of division: they sometimes occur as crystalline masses of irregular shape (mainly diopside) in a close-grained sedimentary rock, and several instances were noticed of veinlets of diopside cutting across the line of strike of the sedimentaries, these veinlets being connected with " interbedded " masses of the same mineral. Some of the bands are light-green in colour, and somewhat resemble basic igneous rocks: they were not examined microscopically, but no other mineral than diopside is distinguishable. The slates and sandstones are intensely altered, but this is not surprising, as granite outcrops a few chains to the west. Some of the fine-grained sedimentaries vary a good deal in appearance: some are very light-coloured on the outcrops, others black, the latter occurring as bands and irregular masses in the former. The effects noted must be regarded as contact metamorphic phenomena, resulting from the intrusion of the neighbouring granite.

Summary.—Before attempting to discuss the mode of origin of the lime-silicate rocks, it seems advisable to briefly review the leading features of the occurrences described above in detail.

On the beach north of Trial Harbour diopside rocks appear as inclusions in, or intrusions into serpentine:

abundant magnetite is present, and phlogopite mica and chlorite were observed. Microscopically the rock is seen to be traversed by a veinlet of serpentine and magnetite, the vein cutting through diopside crystals. A tongue of metamorphosed slate, with garnet, biotite, and actinolite, projects into the serpentine at this point.

A few chains south along the beach similar diopside rock occurs in contact with sedimentary rocks in which is developed tremolite: vein-like masses of serpentine with abundant magnetite appear to be included in the diopside rock at this point.

On the Trial Harbour Road, near the Serpentine Creek Falls, diopside rocks are again in contact with metamorphic sedimentaries in which garnet, actinolite, and diopside are developed. The diopside rocks are often granular, but contain veinlets and irregular aggregates of diopside crystals.

South of Trial Harbour bands and lenses of lime-silicate rocks are developed in the sedimentaries, with a similar strike, being apparently intercalated with the sediments, which are altered at the contact. The lime-silicate bands contain diopside, idocrase, garnet, epidote, wollastonite, and calcite.

In the same locality, but a few chains to the north-west along the coast, are similar bands and lenses intercalated with silicified black slates and quartzites: the minerals recognised in the lime-silicate bands were garnet, diopside, tremolite, idocrase, quartz, and calcite.

Towards the south-western edge of the serpentine, about a mile from the coast, are abundantly developed lime-silicate rocks consisting essentially of diopside and epidote, with calcite, magnetite, and pyrrhotite.

South-east of Mayne's Mine, on Section 1392-M, is a band of rocks in the old sedimentaries, in which lime-silicate minerals are developed: no serpentine is noticeable in the vicinity. The rocks contain abundant tremolite, with diopside, talc, and calcite, and sometimes abundant chalcedonic quartz.

About a mile north-east are tabular masses, apparently interbedded with metamorphosed slates and sandstones, of lime-silicate rock containing diopside, epidote, idocrase, and a little quartz and calcite. Gabbro-amphibolite is exposed within about 3 chains of this occurrence.

In a magnetite-pyrrhotite deposit on the Agnew Creek are developed tremolite, biotite, and talc: fluorite is developed in this rock.

About half a mile to the north-east quartz-epidote rocks occur, and lime-silicate rocks which are a good deal weathered: these are very close to, if not at, the gabbro-amphibolite junction, and are associated with highly altered sedimentary rocks.

A few chains further north, in a magnetite-blende deposit, are diopside, tremolite, serpentine, chlorite, phlogopite, and talc. Some of the wall-rocks carry diopside and garnet only.

Exactly similar minerals (except garnet, which was not noted) occur in a large magnetite body on Section 6715-M. This is not far from either gabbro-amphibolite or granite. In the same locality tabular masses of diopside rock are intercalated with highly altered sediments, some veinlets filled with diopside cutting across the bedding-planes of the quartzites.

Mode of Origin.—In discussing the mode of origin of these rocks, it may be well first of all to consider the exposures on the coast at Trial Harbour. As described in detail above, the rock occurs (*a*) as lenses in serpentine in which is included a well-defined band of metamorphosed slate, (*b*) as a band (which may enclose vein-like masses of serpentine very rich in magnetite), with serpentinised peridotite on one side and intensely altered sedimentaries on the other.

(*a*) Lenses in serpentine were noticed in one place only, near the most northerly extension of the serpentine on the beach north of Trial Harbour.

(*b*) The occurrence between serpentine and sedimentaries (not always with included serpentine) appears the more normal, as at least three such instances were noted. It is a striking feature that magnetite is always exceptionally abundant in the serpentine most closely associated with these rocks. Little indication is obtained from the microscopical study of the rocks as to their mode of origin. The fact that in one thin section a veinlet of serpentine with secondary magnetite cuts through perfectly fresh crystals of diopside, the rock itself being closely associated with serpentine, indicates that the serpentinisation of the surrounding rock may have taken place subsequently to the crystallisation of the diopside. If this be so, it would appear likely that the diopside rocks must be contemporaneous with or earlier than the original peridotite, and if so, the granitic intrusions cannot be called on to explain the mode of origin of the rocks. Obviously, the evidence for this is not strong, and depends upon the correlation of

the serpentine forming the vein-filling described above, with the serpentine of the surrounding rockmass. The serpentine is evidently not derived from the pyroxene of the rock itself, for this shows no signs of decomposition, and the walls of the fissure are very sharply defined, and cut through crystal plates which are perfectly fresh: the material has obviously been introduced from without. The presence of irregular veinlets of magnetite, occurring in a similar fashion, strengthens the suspicion that the surrounding rock may have supplied the material for both minerals: serpentinisation of the peridotite must have been attended with a considerable increase in bulk, and the pressure exerted on the adjoining rockmass would probably have been sufficient to cause a fracturing, and so give entrance to the minerals referred to.

A piece of evidence which appears worth recording (although negative) is that the serpentine in the vicinity of the diopside rocks is sometimes intersected by numerous veins filled with chalcedonic silica, which is believed to be derived from the " after-action " of the basic magma: in no instance was a chalcedonic vein seen to penetrate the diopside rocks.

It must be borne in mind that the granite contact is distant but a few chains from these occurrences. The contact metamorphic effects on the sedimentaries are intense, and it is open to question whether these rocks would not have shown some signs of alteration, had they been formed prior to the intrusion of the granite: some indication of the formation of amphibole at the expense of the pyroxene might perhaps have been expected, but none was noticed. In some slides examined there was certainly no mashing: in one, however, where the crystals have very irregular outlines, and are extensively intergrown, portions of the slide show such a fine groundmass of pyroxene grains that there is a little doubt; in the same slide there is a tendency to shadowy extinction in some crystals, but the structure is indefinite.

Viewing the question from another standpoint, it is pertinent to ask, in view of their constant association in the field, what relation do the altered sedimentary rocks bear to the diopside rocks? The strike of the bands of diopside rocks is approximately similar to that of the sedimentaries. With regard to the structure of the latter and their relations to the serpentine, it is unfortunate that lack of outcrops, excepting along the coast and the road-cuttings, prevents accurate mapping of the exact boundaries of the serpentine.

On the hill to the north of the road and old township site, and overlooking the latter, no sign of serpentine was seen: intensely altered slates outcrop on the hilltop. It appears that the bands of sedimentary rock referred to are not isolated, but projecting tongues of the sediments, the line of contact betwen the two being very irregular and serrated. Some of the smaller masses of diopside rock, on the other hand, certainly are surrounded by serpentine, but the relation of the more extensive developments is uncertain, although it is clear that they are bounded on two sides by serpentine, and on a third by sedimentary rocks. It is just possible that they may extend back a short distance into the sediments, beyond the serpentine contact, but no sign of them was seen when attempting to trace the boundary of the two rocks, and the writer believes that they do not extend any distance back from the contact, and they may be cut off by the serpentine.

Attention has up to the present been confined to a consideration of the occurrences at Trial Harbour in association with the serpentine. As has been pointed out, the interpretation of the evidence presented there is not a simple problem, as certain of the features appear to be contradictory. It is natural, then, to consider carefully whether any other occurrences in the district may not throw light on the problem. The question then arises at once, "Can all the occurrences of lime-silicate rocks which have been described be correlated?" If so, the additional evidence yielded by other occurrences should assist in solving the problem.

On reviewing the general features of the various occurrences described above, several facts stand out clearly:

(*a*) The mineralogical composition of the various rocks at once suggests a correlation of the occurrences. Although rather extreme types exist, intermediate types form connecting links. Unfortunately, no analyses are available, and, in consequence, the comparison of different rocks must be based on the mineralogical composition.

(*b*) The structure in most of the localities described is similar. The rocks usually occur as tabular or irregular masses, or in both forms. These vein-like occurrences are never of very great width, bands being frequently measured by inches. Under the microscope the structure of rocks from different localities is remarkably similar. The rocks are always holocrystalline, the groundmass being sometimes granular, sometimes crystalline, both forms being frequently observed in the same rock.

(*c*) In their relation to the sedimentary rocks, the various lime-silicates have many points in common. The general structure of the various exposures has been noted above. A striking feature is the agreement of the line of strike of the tabular and lens-shaped bodies with that of the enclosing sedimentaries. Nor is this true in a general sense only, for the lime-silicates of different localities are intercalated with the sedimentaries in such a way as to strongly suggest that the mode of origin in different localities has been the same. Also the occurrence of veinlets connected with the lime-silicate bands, and filled with similar minerals, but cutting across the line of strike of the beds, was noted in more than one locality. The alteration of the "wall-rock" in the vicinity of the lime-silicates, and the development of nests of crystals of diopside in the sedimentary, are also features shared by several of the occurrences in different localities. In their relation to the sedimentary rocks, the structure of the lime-silicates is suggestive of intrusions of igneous rock. An important fact which should be recalled at this stage is the occurrence in one locality of certain sedimentary beds, actually interbedded with the slates and sandstones, and coinciding with them and with the lime-silicate bands in strike, which have an appreciably high lime and magnesia content. Although distant from $\frac{1}{2}$-mile to $\frac{3}{4}$-mile from the lime-silicate bands, the occurrence of these thin-bedded limestones is important.

(*d*) The field relation of the lime-silicate rocks to the basic igneous intrusives is interesting. The Trial Harbour occurrences have been dealt with, and it has been pointed out that in one instance vein-like masses of serpentine appear to be included in a band of diopside rock, although the normal occurrence is that of bands of diopside rock of varying width, appearing as lenses and tabular masses, usually associated with sedimentary rocks, partly or wholly included in serpentine. The other localities from which the rocks have been recorded indicate that the basic rock is invariably near at hand, although it may not be actually in contact with the lime-silicates at the surface. In nearly all cases either serpentine or gabbro-amphibolite outcrops quite near at hand; in the others, the basic igneous rock must occur at no great depth below the surface.

(*e*) The field relation of the lime-silicate hornstones to the acid igneous rocks is worthy of notice. Surface observations indicate that the lime-silicates are more closely associated with the basic than with the acid igneous rocks.

In some of the instances quoted above, however, the rocks do outcrop near the granite contact. In no instance were they seen to be in contact with the acid rocks, although sometimes within a few chains of them. It must be borne in mind, however, that no single occurrence can be regarded as beyond the influence of the granitic intrusion. Even where furthest from the actual granite contact the lime-silicates occur in intensely altered sedimentaries. Although closely associated with the basic rocks, it has already been noted that the basic rocks themselves are never far distant from the granite, and never far enough to be regarded as beyond its influence. The relation of acid to basic igneous rock is explained elsewhere.

Taking into consideration all the facts noted above, there can be little doubt about the consanguinity of the various occurrences of lime-silicate rocks: hence any discussion of the mode of origin of the rocks must take into consideration the facts presented by the different occurrences described, and cannot be confined to the Trial Harbour rocks, which are so closely associated with the serpentine.

The mode of origin cannot be finally decided until analyses of the various rocks are available, and it is a matter for regret that these particulars are not available at the present time. It is proposed, consequently, to summarise the discussion of the mode of origin of the lime-silicates.

The mineralogical composition of the rocks clearly indicates that they are of secondary origin, and not primary igneous rocks. It would seem, then, that two modes of formation are open to consideration:—

(*a*) The recrystallisation of calcareous sedimentary rocks which have been subjected to intense contact-metamorphic action.

(*b*) The crystallisation of the lime and magnesia-bearing minerals from solutions which have traversed older rocks, and which have derived their lime and magnesia either from the source whence the solutions originated or from the rocks traversed by the solutions.

Neither theory can be dismissed as impossible, in view of the evidence available, which, however, does not appear to be conclusive.

(*a*) This theory has a good deal to commend it. It has been clearly shown that the lime-silicates are closely associated with sedimentary rocks; that certain beds of

this sedimentary series are calcareous, and that the sedimentary rocks as a whole have suffered intense metamorphism in the vicinity of the known occurrences of the lime-silicates. The coincidence of the line of strike of the bands of lime-silicates with that of the recognisable sedimentaries would thus be explicable. The development of lens-shaped masses and of irregular aggregates of lime and magnesia minerals would occur in impure calcareous beds.

(*b*) In considering the possibility of the crystallisation of the minerals from introduced solutions, it is necessary to account for the solutions, and for their lime and magnesia content. In connection with intrusive igneous masses, such as the acid and basic rocks described, it is now recognised that during the final stages of consolidation heated waters are frequently liberated, which may traverse both the igneous rock itself and the adjacent sedimentaries. Such solutions might be derived either from the acid or basic magma, but the effects are always more intense in the case of the former. Were such magmatic waters set in motion, it is improbable that the contained lime and magnesia, if present at all in appreciable quantities, would be sufficient to form the minerals noted. On the other hand, if such solutions traversed the basic rocks, the high content of lime and magnesia would be readily accounted for, as it could be derived from the walls of the fissures forming the paths by which the solutions escaped. In a similar manner, if the sedimentary rocks are themselves lime and magnesia bearing, they would furnish the migrating solutions with the materials necessary for the formation of the observed minerals. In this case, also, the observed position of the lime-silicate bands coincides with that in which such mineral aggregates would be formed, for solutions would naturally follow the bedding-planes of the sedimentary rocks.

Thus, it would appear, taking a general view, that either of the theories mentioned might be called on to account for the lime-silicates. It will be necessary, then, to examine the occurrences rather more minutely to try and obtain a clue.

The occurrence in serpentine in one instance, without apparent sedimentaries, suggests the introduction into that rock by solutions. The fact that wherever the lime-silicates occur in serpentine, the latter rock is exceptionally rich in magnetite, which is sometimes scarce in the diopside rocks, is significant. If solutions traversed the serpentine and took into solution lime and magnesia from the

serpentine wall-rock, to form new minerals, it is conceivable that conditions might not have been favourable for the solution of the iron, which would then separate as secondary magnetite. Thin sections actually show that most of the magnetite in this serpentine is secondary. It is doubtful whether the serpentine filling a minute veinlet traversing one thin section of diopside rock examined, can with any degree of certainty be correlated with the serpentine of the adjacent rock-mass, and particularly in view of the field occurrence, the serpentine cannot be regarded as later than the diopside rocks.

The apparent inclusions of vein-like masses of serpentine rich in magnetite, in diopside rock, can be readily explained if it be assumed that solutions traverse roughly parallel fissures in the serpentine, and alter some of it, leaving residual masses unreplaced, but with concentrated magnetite content. This occurrence is not easy to explain on the assumption that calcareous beds of the sedimentary have been recrystallised under contact-metamorphic action.

The small irregular veinlets filled in some places with diopside, in others with lime garnet, cutting across the bedding-planes of the sedimentary rocks are easily explicable if lime-bearing solutions have been introduced.

A feature worthy of note is the comparative scarcity of pure lime-silicates (one slightly doubtful occurrence of wollastonite only being noted), the abundance of magnesia-bearing minerals, and the comparative scarcity of aluminium-bearing minerals. These facts seem scarcely compatible with the idea of thermal metamorphism of pure limestone beds or of impure calcareous beds (when aluminous lime and magnesia silicates would have been formed more abundantly). The metamorphism of dolomite would have produced the abundant diopside which is present, if beds of dolomite had been present. These facts appear rather more readily interpreted if the assumption be justified that the rocks have been formed by solutions which traversed the serpentine and derived much of their mineral content from it.

The constant association with basic rocks is significant, and can scarcely be regarded as an accidental occurrence, since no single exception was noticed.

The presence of lime-silicate minerals in ore-deposits has been noted. Reasons are given elsewhere for connecting these ore-bodies genetically with the granite. The metallic minerals have been derived from the acid magma, which produced the granite as one consolidation product, and

have been carried to their present positions by solutions. The gangue minerals are typical of such deposits.

Considering all the evidence, it seems clear that some at least of the lime-silicate hornstones have been produced by magmatic waters, derived from the acid magma which have during their migration traversed the basic rocks and derived their lime and magnesia content from the basic rocks themselves. Some of the occurrences could well be the result of the contact-metamorphism of beds rich in lime and magnesia, intercalated with the Pre-Silurian slates and sandstones. Until further evidence is forthcoming, however, the writer prefers to regard the various occurrences as being genetically connected, and to have derived their lime and magnesia from the basic rocks.

In putting forward this theory to explain the mode of origin of the various minerals rich in lime and magnesia, the writer does not claim originality. Although he has attempted to investigate the matter impartially, the evidence adduced has but tended to confirm the opinion expressed ([119]) by Mr. L. K. Ward, formerly Assistant Government Geologist of Tasmania, who investigated this question. Mr. Ward described occurrences from South Heemskirk, Colebrook Hill, Gormanston Creek (North Dundas), and Anderson's Creek (Beaconsfield), and, after a careful investigation of the different rocks in these localities, concluded ([120]):—

"It is to the chemical reaction of the emanations from the acidic magma hearths upon the walls of fissures which traverse the basic rocks that the author would ascribe the greater part of the lime and magnesia contents of the contact-rocks here described."

Thus, it will be seen that the writer has arrived at the same conclusion as Mr. Ward, with regard to the mode of origin of the lime-silicates, after a closer examination than the latter was able to give to this particular district.

(2)—The General Sequence of Events Leading to the Present Geological Structure.

(1) *The First Period of Sedimentation.*—On a floor not exposed in the district, but consisting probably of Pre-

([119]) "The Origin of Certain Contact Rocks with a High Content of Lime and Magnesia," by L. K. Ward, B.A., B.E.; Section C, Vol. xiii., Proc. A.A.A.S., pp. 176-187.

([120]) *Op. cit.*, p. 184.

Cambrian rocks, a thick series of sediments was laid down, which now represent the oldest rocks exposed in the district. The nature of the sediments indicates that deep-water conditions prevailed for a long period, alternating with shallow-water conditions for shorter periods. There are evidences that very deep-water conditions prevailed at intervals, when the fine-grained calcareous bands were formed. During this period of sedimentation igneous activity must have prevailed, not necessarily in the limited area described, the record of this activity being preserved in the interbedded tuffs and breccias of the series. These sediments were laid down at some undetermined period between the Upper Pre-Cambrian and the close of the Ordovician, and have been described in the text as Pre-Silurian.

(2) *The Folding of the Region in Pre-Silurian Times.*—The present crushed and altered state of the sediments described clearly shows that a period of intense crushing and folding must have taken place before the deposition of the Silurian sediments. At this time the fissile structure of the slates was developed, and the whole of the rocks were intensely crushed. This process has been very widespread, and is not confined to this district.

(3) *The Second Period of Sedimentation.*—There is a little doubt about this chapter of the geological history, depending on the correctness of the assumption that an area of sandstones and grits near the mouth of the Little Henty River belong to the Silurian system.

There was probably a considerable time-break between the folding of the region and a depression of part of the area below sea-level. During shallow-water conditions in the Silurian ocean the second period of sedimentation persisted for a short time compared with that of the first period.

(4) *Period of Igneous Activity.*—In Devonian time, following some time after the previous sedimentation, there came a period of intense igneous activity, which must have been associated with earth movements. A huge mass of igneous rock material was forced upwards as a molten magma, but remained at rest deep below the crust, sufficiently long for magmatic differentiation to cause a separation into two sub-magmas. A partial relief of pressure resulted in the rising of the basic sub-magma to a higher position in the crust, where it came to rest, still deep below the surface. The magma rose to different heights, but did not actually reach the surface. As it very gradually cooled

differentiation caused another partial separation into a basic and ultra-basic magma, one merging into the other, but before this separation was complete the mass solidified. Closely following the consolidation, the huge mass of acidic material, far exceeding in bulk that of the basic rock, was intruded into the overlying rocks, bulging, shattering, and altering them. This magma took the form of a huge dome-shaped mass, and came to rest at a considerable depth below the crust. The mass was still at a very high temperature, and remained so long enough for differentiation of the mass to proceed, and this process resulted in the formation of several rock-types, all closely related, yet possessing distinctive features. As the mass gradually cooled and solidified, various portions of the still molten material were ejected. It was during this period that the whole of the primary ore-deposits of the district were formed.

(5) *Period of Gradation.*—The intense igneous activity of Devonian time was followed by a long period of tranquillity, during which the land surface was considerably modified by the degradational forces which were constantly at work. Although in the district examined there is no record of the formation of any rock (with the exception of small patches of recent sediments), from the occurrences to the east it appears that the overlying rocks were removed and the granite itself more or less deeply dissected before Permo-Carboniferous sedimentation set in. From the glacial till developed to the east at the Oonah Hill, Zeehan,([121]) and the Permo-Carboniferous coal measures to the south-east at Eden,([122]) it seems possible that this area too may have been below sea-level during Permo-Carboniferous time, and that another period of sedimentation may have ensued, followed by an uplift: if so, the rocks formed have been entirely removed, and any faulting which may have thrown down these beds is masked.

It is possible that at some time during this long period of degradation, the land surface was worn down to base-level over an extensive area, and denuded again after another uplift: the evidence for this is not strong, but the level of the summit of the Heemskirk Range, and its approximately equal height with other West Coast mountain peaks, suggests that some such action may have taken place, and that these peaks now represent residual fragments of the old peneplain. If such be so, it is obvious

([121]) *Vide* Geol. Surv. Tas. Bulletin 8, p. 42.

([122]) *Vide* "Report on the Mineral Districts of Zeehan and Neighbourhood," by W. H. Twelvetrees, 1900, pp. 105-106.

that an enormous amount of denudation has since taken place. There is clear evidence that at a later period the land surface was worn down to base-level, and an extensive peneplain formed, above the general level of which the Heemskirk Range stood out as a monadnock. This peneplanation of the surface was extensive, and not confined solely to this particular district.

(6) *Period of Uplift.*—The long period of gradation described above was succeeded by a period of uplift, when the whole of the land surface was raised above sea-level. It may have been at this period also that faulting determined the general configuration of the coast-line. This uplift rejuvenated the rivers, whose beds had become very flat at the close of the peneplanation of the old land surface, and the regraded streams at once proceeded to deepen their channels, and another period of gradation, which continues at the present time, was initiated.

V.—ECONOMIC GEOLOGY.

(1)—The General Relationships of the Ore-deposits.

The occurrence of tin ores in the South Heemskirk district in close association with acid igneous rocks is quite in accord with known occurrences in other districts, and an examination will show that the resemblances are not merely superficial, but are such as to indicate a genetic connection between ore-deposits and rock-types, in this as in other West Coast mining districts.

Summaries of the relationships of the tin ores to the acid rocks of Devonian age in different districts have recently been published,[123] and will not be repeated here.

Concisely stated, tin ore in the South Heemskirk district occurs in lodes and in veins both within the borders of the intrusive granite *massif* and in the adjacent sedimentary rocks. The minerals present (both metallic and gangue) clearly indicate that granite and tin ores are genetically connected, and the conclusion arrived at is that both the tin ore and the granite have been derived from a common magma.

As has been pointed out by Mr. L. K. Ward for the North Dundas district,[124] the occurrence of ores of metals other than tin, and the mineral associations of these occurrences, suggest a relationship between the tin ores of Heemskirk and the ores of other metals in neighbouring districts. Thus the blende and galena which are associated with a little cassiterite at Sweeney's Mine, the galena and fahl-ore with small amounts of cassiterite at the old Globe Mine, with tourmaline, fluorite, and quartz in each case, are very suggestive occurrences.

The presence of contact deposits of magnetite and hæmatite round the borders of the granite is noteworthy, and suggests a possible correlation with the Meredith Range *massif*, similar iron ores occurring round its southern borders on the Stanley River Tinfield.[125]

The question of the inter-relationship of the different types of tin veins cannot be regarded as settled as a result of the present examination. No definite intersections of different types were available for inspection, and hence there is no proof of the relative ages.

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[123] *Vide* Geol. Surv. Tas. Bulletin 15, p. 61, and Bulletin 6, p. 41.
[124] *Vide* Geol. Surv. Tas. Bulletin 6, pp. 41-43.
[125] *Vide* Geol. Surv. Tas. Bulletin 15, pp. 65-104.

Again, with regard to the possible merging of different types at a depth, no definite statement can be made. In the deepest workings below the present surface, no appreciable alteration in the mineralogical composition of the veins is observable.

With regard to the relationship of the ore-deposits of the South Heemskirk Tinfield to those of surrounding districts, it is interesting to note that the Heemskirk granite *massif* represents the consolidation product of an igneous magma which was responsible for the introduction not only of the tin ores of the South Heemskirk district, but also of the iron, zinc, and lead ores of the Comstock district, and the silver-lead ores of the Zeehan field. Messrs. Twelvetrees and Ward have shown[126] that three distinct zones are recognisable—(*a*) granite zone, (*b*) contact metamorphic zone, (*c*) transmetamorphic zone—which may be subdivided into a pyritic belt and a sideritic belt. The reader is referred to the publication quoted for a full account, but the opinions expressed therein have more recently been summarised by Mr. L. K. Ward thus:—[127]

" The tin-bearing lodes of the Heemskirk district exhibit some variety of composition. They are marked in almost every case by the presence of pyrites, and less often by the existence of small amounts of bismuthinite, molybdenite, and wolframite with the cassiterite. Of the gangue minerals tourmaline is the most characteristic and most widely distributed. Fluorite is not abundant.

" Lying to the eastward (and southward) of this area, in which cassiterite is the most constant metallic mineral, are the magnetic masses of the Comstock district. The magnetite is found in very large bodies which are seldom free from admixture with other metallic minerals. Although often nearly perfectly pure, the magnetite is found associated with galena, blende, chalcopyrite, and pyrite, and one instance is known in which cassiterite accompanies it.

" Still further to the eastward lie the large pyritic lodes of the western portion of the Zeehan field. Pyrites is the most abundant mineral, and blende and galena are associated with it. At one point there is a notable development of stannite, with which are associated pyrite, chalcopyrite,

[126] *Vide* Geol. Surv. Tas. Bulletin 8, pp. 63-67.

[127] "An Investigation of the Relationship between the Ore-bodies of the Heemskirk-Comstock-Zeehan Region, and the Associated Igneous Rock," by L. Keith Ward, B.A., B.E., in Proceedings of Australasian Association for the Advancement of Science, Vol. xiii., Section C, pp. 153-154.

galena, bismuthinite, wolframite, tetrahedrite, siderite, and sporadic traces of fluorite.

" The eastern limit of the area under consideration—the Zeehan field proper—is characterised by lodes of which a considerable portion consists of siderite, with which are found galena, blende, and smaller quantities of tetrahedrite and chalcopyrite.

" Between these broad groups lie many associations which clearly mark transitional stages. Certain metals have been proved to exist in almost every type, and as the work of developing the mines proceeds fresh discoveries are continually being made of the presence of small proportions of certain metals in lodes which were formerly not known to contain them.

" The gangue minerals in the lodes are also found to transgress the limits of the main groups referred to above.

" There are no known instances in which a lode characteristic of one zone or group is actually intersected by a lode belonging to another zone. This evidence, negative though it may be, is certainly most suggestive, since a very large number of lodes have been worked from time to time and thus exposed for examination. It appears that the members of the different groups belong all to a series (or, at most, two series), of which the different components were formed during a single stage in one metallogenetic epoch.

" All these phenomena strongly support the view that the ores which have been mentioned are derived from a common source, and that the differences between them are only quantitative variations in the proportions of the constituent elements."

Mr. Ward comments on the zonal arrangement of the ores about the granite, and then proceeds to show that both igneous rocks and metallic ores have been derived from the same igneous magma. Applying general principles discussed to this particular area he states:[128] " The author holds the belief that the several ores of this area were not derived from a single point of origin, but that they were derived from several centres of segregation within the heart of the acidic magma. . . . . Of the immediate causes of precipitation, the fall in temperature would seem to have always been the chief. . . . . [129] The feature of greatest prominence which is revealed by the geological examination of the whole area is that concerned with the zonal distribution of the different types of lode-matter about the exposed granite. Yet, from what has

[128] *Op. cit.*, p. 161.

[129] *Op. cit.*, p. 162.

already been stated, the lodes of the Zeehan field do not proceed from the centre of the Heemskirk *massif*, but from some hidden source below the field itself." The author proceeds to discuss the[130] "nature of the zonal distribution of ores, and the significance of the granite at a distance from the position of the source of the lodes situated (in Zeehan) on the fringe of the area discussed," pointing out that both acidic and basic rocks underlie the eastern portion of the area, that the igneous magma rose to a greater altitude in the Heemskirk area than in the vicinity of Zeehan, where there is still a great thickness of overlying sedimentary rocks not removed by denudation as those formerly present to the west have been: this means that the contact metamorphic zone dips underground with the surface of the granite, and "thus the geological plan gives precisely similar information to that which would be afforded by a vertical section. . . . So the nature of the variations in the lode-matter, as observed in a horizontal direction, is sensibly identical with that which would be visible in a vertical direction could we but follow a single lode downwards towards its source, if the materials supplied to the several fissures throughout the area have been approximately the same. The general result appears to have been that cassiterite ores have been precipitated within the igneous boundaries by the ascending vapours and solutions which, as they traversed the successively cooler zones, have deposited in turn magnetite or mixed magnetite and sulphides, then pyritic zinc and lead ores, and finally sideritic lead ore. Inequalities in the surface of the granite mass have caused the precipitation of these different ores at different levels, and subsequent denudation has exposed the deposits of different zones of precipitation at the level of the present surface in zones of distribution which conform to the boundaries of the granite."[131]

The articles quoted above are heartily commended to the reader who wishes further information on this interesting question of the zonal distribution of the various ores of the Heemskirk-Comstock-Zeehan region. The above quotations clearly show the relationship of the tin ores to those of the adjacent area, and the writer's observations confirm those of the previous investigators whose work much simplified his task.

This report deals with the granite zone, with part of the contact metamorphic zone, and part of the pyritic zone (the Comstock mines were not examined).

[130] *Idem.* [131] *Idem.*

With regard to the comparison of tin ores in the South Heemskirk district with those of adjacent tinfields, little need be said at this stage beyond stating that many of the deposits are distinctly comparable, not only in their mode of occurrence, but also in their mineralogical composition and structure, with those of the Stanley River district to the north, and of the North Dundas district to the east. Further comparisons of particular types are made below.

(2)—The Relationships of the Ore-deposits to the Several Rock Groups.

It is instructive to notice the relationship which the ore-deposits bear to the different rock groups represented on the field. The rock groups to be considered are the basic igneous rocks, the acid igneous rocks, and the sedimentary rocks.

The only primary ore-deposits which occur within the borders of the basic rocks are those of nickel, and lenses of magnetite. Tin ore has been located near the boundary of the basic rock, but there is nothing to suggest a close genetic connection therewith.

Within the boundaries of the acid igneous rocks, however, are lodes, veins, and at least one well-defined pipe of tin ore, also tin-wolfram, tin-bismuth, zinc, and silver-lead. Referring to the acid group in more detail, it is noteworthy that the deposits are not confined to either the normal pink granite, white granite, fine-grained nodular tourmaline granite, or aplite. Deposits of the same type occur in all varieties, although the three latter rocks appear rather more favourable for tin ores than the coarse-grained pink variety of granite, which, however, contains deposits of zinc and silver-lead. Since ore-deposits of exactly the same type, with no variation in mineral constitution, occur in all the varieties of granite described, since a vein may extend from one variety to another without interruption, and since deposits with different mineral groupings occur in the same variety of granite, it is clear that the particular acid rock type of this district cannot have any definite connection with the type of deposit formed.

It appears that all deposits so far located occur within a limited distance of the edge of the granite, but this statement is made with reserve because the western edge of the granite is below sea-level.

Turning to the sedimentary rocks, it is found that comparatively few tin-ore deposits have been located, but that these do not differ essentially from those found within the granite borders. Quartz and tourmaline are still the main gangue minerals, as they are in the granite.

Clearly, then, the nature of the wall-rock does not influence the type of tin ore deposit formed.

In the sedimentary rocks (slates and sandstones) near the granite-contact, *i.e.*, within the contact-metamorphic aureole of the granite, several deposits of magnetite occur, sometimes with sulphides (blende and pyrite), and usually with lime-silicate gangue minerals. These deposits do not occur within the borders of the granite. Their mode of origin will be referred to in another part of this report. The nature of the country-rock has probably influenced the mineralogical composition of these deposits.

In the same zone is a deposit ([132]) which carries minerals characteristic of contact-metamorphic deposits, but in addition wolframite and bismuthinite—unusual minerals in a contact deposit. The composition of the gangue minerals of this deposit suggest that the country-rock has had some influence on the nature of the deposit formed.

Reviewing the structure of the ore-deposits in the different rocks, as is to be expected, no difference can be detected in the various acid igneous rocks. The same vein-type is occasionally continuous from one rock to another without variation.

When contrasting tin ore deposits in granite and in sedimentary rocks near the granite-contact, it is clear that the structure of the lode-formation, in some cases at least, has been determined by the country-rock. This is well shown, for instance, in the case of Mayne's Tin Mine, where the ore-bearing vapours and solutions have ascended by fissures which extended to considerable depths, and were probably continuous through slate and underlying granite, or at least had connection with fissures in the granite which themselves were in communication with the deep-seated source of the metallic ingredients. As the vapours ascended by these feeders, however, the bedding-planes of the sedimentaries, and perhaps certain planes of weakness as well, afforded opportunity for the vapours to attack the country-rock surrounding the fissures, with the result that this rock was mineralised, and irregular vughs formed, often with rich tin ore. The country-rock

([132]) *Vide infra*, pp. 180, 181, 399–401

has been tourmalinised and silicified as a result of pneumatolytic action. Not only is the general nature of the ore-deposit modified by the structure of the sedimentary rock, but the exact type of sedimentary rock has a definite relation to the minerals developed by the pneumatolytic agencies at work, the argillaceous bands being more favourable for the development of dense green tourmaline, with which the richest tin usually occurs.

Some outcrops in the contact sedimentaries appear to be tin ores generally similar to those occurring in the granite, but no definite opinion can be expressed in the absence of exploitation work.

(3)—Primary Ore-deposits.

The most important primary ore-deposits of the district discovered up to the time of the writer's examination are undoubtedly those of tin, making the mining field essentially a tin field. At the same time, ores of other metals have been discovered, and it has been deemed advisable to deal with these under separate headings for convenience, although in some cases little more than passing reference is required.

A.—Tin Ores.

In describing the tin ores it is desirable to classify them, and this is best done on the basis of the mineralogical composition of the deposits. This method has been successfully applied by Mr. G. A. Waller ([133]) to the tin ores of the district, and the present classification is based on that initiated by this writer, and elaborated by Mr. L. K. Ward.([134])

(1)—*Quartz-Tourmaline-Cassiterite Type.*

The vein-type is more abundantly represented in the South Heemskirk tinfield than the others to be described, and becomes of commercial importance in several localities.

([133]) *Vide* "Report on Tin Ore Deposits of Mt. Heemskirk," by G. A. Waller, 1902.

([134]) *Vide* Geol. Surv. Tas. Bulletins, No. 6, pp. 47-54, No. 8, p. 47, *et seq.*, and other publications of the Geological Survey of Tasmania

The type has been defined for this district, as follows, by Mr. Waller, who calls the veins quartz-tourmaline veins.(135)

"These veins consist essentially of a tabular mass of quartz or quartz-tourmaline, containing in the centre a vein from which the country-rock on either side has become mineralised. Either the vein-rock or the vein-stone may carry tin, but usually the vein-stone is the richer of the two. Tin appears to be associated with both black (iron) and green (alkali) tourmaline; but I think that of the two, the green is the more favourable. This is also the case at Mt. Bischoff. A little iron, copper, and arsenical pyrites is often present, either in the vein-stone or in the vein-rock, and in all probability these minerals will be found in all the veins in depth, their absence from the upper portions of the veins being due to the oxidising and leaching action of surface waters. To this list must be added small quantities of bismuth sulphide, wolframite, and rarely molybdenite."

Explaining the meaning of the phrases "vein-rock" and "vein-stone," Mr. Waller says (136): "When they [quartz-tourmaline reefs] occur in granite, they consist of a tabular mass of quartz, quartz-tourmaline, pinitoid or greisen (which I propose to call the vein-rock), with a central vein filled with black or green tourmaline, quartz, and frequently tin oxide (the vein-stone)."

From his examination of the district, the writer found the above description to apply to many of the tin ore deposits, and to represent both the mineralogical composition and also the structure of the veins.

There are, in the writer's opinion, two minerals besides those mentioned, which should be included in the type description. These are fluorite and hæmatite.

Although not very common in the district, fluorite is well developed in one vein which belongs to this class (that exposed in the Long Tunnel on the Federation Mine), and so must find a place in the description of the vein-type.

Hæmatite is abundantly developed in one vein (at the Whip Shaft workings, Federation Mine), which, although it has affinities with the quartz-quartzose type described below, apparently belongs to this class. The hæmatite is massive, and is closely associated with quartz in the groundmass, through which are radiating aggregates of tourmaline and some cassiterite. There can be little

(135) *Op. cit.*, pp. 8, 9. (136) *Op. cit.*, p. 6.

doubt about its primary nature. Crystals of quartz from the same formation, which are associated with cassiterite, contain inclusions of red hæmatite, showing that the mineral was developed before the completion of the crystallisation of the quartz.

A similar class of ore to that from the Whip Shaft workings is found in Yates' level, and exposed in a surface trench above Fowler and Dunn's open-cut, both occurrences being included in the Western Workings of the Federation Mine, and within a short distance of the Whip Shaft. In these occurrences quartz appears to be absent. The stone consists of tourmaline (black and green) in a groundmass of hæmatite, with a small amount of cellular limonite, probably representing an oxidation product of pyrite present in the primary ore. The tourmaline is in aggregates of small prismatic crystals radiating from a common centre, aggregates being semicircular in cross-section. The hæmatite is in dense masses of quite irregular shape. Its physical characteristics are normal, with one notable exception. The mineral is *distinctly* magnetic. It certainly is more than *feebly* magnetic, and even resembles magnetite, although not quite as strongly attracted by the magnet as that mineral. Although this property might be due to a certain proportion of finely-divided magnetite intergrown with the hæmatite none of the former mineral could be isolated, and the writer is of opinion that the mineral is hæmatite, and, further, that this mineral is primary. It is interesting to compare this occurrence with one recently noted at North Heemskirk,(137) although in the latter the magnetic hæmatite occurs in a contact-metamorphic deposit in sedimentary rocks, and of different mode of origin to that of the tin veins under discussion, although both are genetically connected with the granite.

Confirmatory evidence of the occurrence of hæmatite in a quartz-tourmaline-cassiterite vein was obtained by the writer at North Heemskirk in the case of Long's Iron Blow, where not only massive hæmatite, but definite crystals of the same mineral occur. This occurrence has been described by the writer elsewhere.(138)

The definition was framed to suit the occurrences of this particular district, but it has since been shown that the mineralisation of the country-rock is not general enough

(137) *Vide* Geol. Surv. Tas. Report 6, p. 59.
(138) *Op. cit.*, pp. 51-53.

to be included in the definition of the vein-type. This exception was pointed out by Mr. L. K. Ward ([139]), after a detailed examination of the occurrences of tin ore at North Dundas.

The minerals mentioned by Mr. Waller are all present in veins in the South Heemskirk Tinfield, but it must be understood that in no case were *all* the minerals of the type seen to be present in the one deposit.

In the discussion of this vein-type the question as to the distinction between veins and dykes demands attention, as many tabular deposits of quartz and tourmaline do not show the variety of minerals (consisting only of the two non-metallic minerals mentioned). and do not exhibit the central seam so typical of the veins. This question has been fully discussed under the heading of "General Geology,"([140]) the results of microscopical examinations of thin sections given, and the opinion expressed (as the result of this investigation) that there is no essential difference between quartz-tourmaline veins and quartz-tour maline dykes, although the extreme examples of each class may be differentiated without trouble. It is pointed out that cassiterite may reasonably be expected in these "dykes," as well as in the more typical quartz-tourmaline-cassiterite veins.

Some of the veins appear to be of very simple composition, containing only quartz, tourmaline, and cassiterite, but Mr. Waller's caution must be kept in mind—that the sulphides may have been oxidised and removed from the upper portion of the veins. This is certainly true in some cases, but there appear to be some veins which do not, even where exposed as primary ore, carry any sulphides.

One example of this vein-type which has some rather unusual features is worthy of special note. There is a central vein which is quite distinct from the vein-rock on either flank, and different from the vein-stone of any other example noted. Regarded independently of the main formation in which it occurs, it might be taken to belong to the quartz-quartzose type described below, which had been introduced into a vein (previously consolidated) of the quartz-tourmaline-cassiterite vein-type. Further work in opening up the particular deposit (which occurs on the Federation Mine) may prove this to be the case, but

([139]) *Vide* Geol. Surv. Tas. Bulletin 6, p. 53.
([140]) *Vide supra*, pp. 76-82.

it seems advisable until such information becomes available, to class the whole formation with the quartz-tourmaline-cassiterite veins. The central portion of the deposit (vein-stone) consists of quartz and cassiterite, with a little secondary limonite in places. The vein-rock bordering this vein-stone is quartz-tourmaline, with rather more quartz than usual, but otherwise no uncommon features. The vein-stone shows distinct crustification, quartz and cassiterite forming alternate layers, and evidently the minerals have been successively deposited, probably from gases which were under sufficient pressure to force aside the walls of the fissure far enough to give room for crystallisation. The outermost layer, which itself is bounded by quartz-tourmaline, is composed of finely granular white quartz. This is followed on either side by a layer of fine, brown cassiterite. On this are layers of closely-packed prisms of quartz, which form the foundation on either side for small prismatic crystals of cassiterite, which occur in radiating nests and sheaves. They are brown in colour, translucent, and show terminal faces. The succeeding layers are of prisms of quartz, and intergrown with them are abundant cassiterite crystals, which again assume the prismatic habit, crystals being up to 5/16th inch in length, and showing perfect terminal faces. This is the innermost layer, but sometimes quartz disappears, and the inner lining is composed entirely of crystals of tin oxide. In some instances finely-divided tin oxide forms the base on which the larger and more perfectly formed crystals rest, and occurs in concentric layers of hemispherical form. The occurrence of the cassiterite in this form is not common, but may be compared with the botryoidal cassiterite at the Wakefield Mine, and at Mayne's Mine.

The occurrence of a central vein of quartz and cassiterite, free from tourmaline, in a vein which appears otherwise to be of the quartz-tourmaline cassiterite type, was not noticed elsewhere in the district. The width of the central vein varies from 2 to 5 inches, and it has been traced on the surface for at least 20 feet. The main outcrop is more extensive, but no central quartz-cassiterite vein is noticeable. The occurrence, considered in conjunction with that of veins of white quartz in the quartz-tourmaline stone beyond the boundaries of the main central vein, may perhaps be interpreted to mean (as suggested above) that these veins belong to the quartz-quartzose class, and have

been introduced into a normal quartz-tourmaline-cassiterite vein.

Along the same line of outcrop, near Munro's shaft, on the highest portion of the Federation lease, is another interesting occurrence, which may be noted here. There are on the surface abundant boulders, evidently derived from this outcrop, of lode material, consisting of tourmaline, limonite, and quartz. The tourmaline is green in colour, and very dense, showing no sign of crystalline structure. It is occasionally traversed by veinlets of crystalline quartz, which forms a lining of prismatic crystals to occasional vughs in the dense tourmaline. Massive limonite is abundant, and this mineral sometimes takes the columnar form: this mineral is obviously secondary. A thin section of some of this very dense tourmaline was examined microscopically, and it was found that the mineral occurs partly in irregular aggregates, frequently stained with limonite, and in abundant minute needle-like prisms, which often are grouped radially about some nucleus, and which frequently penetrate the grains of quartz which are present in the groundmass. Adjacent quartz grains are frequently penetrated by these tourmaline needles, indicating that the quartz first crystallised, and the tourmaline needles are developed later, and are partly replacing the quartz. A few minute veinlets of secondary silica were noted.

The extensive ore-body developed on the Federation Mine at the Black Face, described in detail elsewhere, is a variation of this vein-type. The exact conditions governing the formation of the large ore-body are not quite clear, but apparently the intersection of two or more fissures has resulted in a departure at this point from the normal vein structure.

Mention has been made ([141]) of the variation noticeable in the mineralogical composition of some of the quartz-tourmaline-cassiterite veins as the distance from the granite increases, and the opinion expressed that some of the quartz veins of the sedimentary rocks may be but special cases of this particular vein-type.

This vein-type is economically the most important represented on the field. Examples are to be found on the Federation, Prince George (R. Clarke's), Cliff, Healey and McIvor's, Kelvin (Williams, O'Brien, and Buckley's), and other mines.

([141]) *Vide supra*, p. 80.

Occurrences in this field are to be correlated with representatives of the same vein-type in the North Dundas Tinfield ([142]) and the Stanley River Tinfield.([143])

(2)—*Quartz-Quartzose Type.*

It is not certain that a separate type should be formed for the veins about to be described, as they are undoubtedly closely allied to the quartz-tourmaline-cassiterite veins, and perhaps a more detailed examination, especially when more work has been done, will show that they should merely be regarded as extreme types of that class. However, as several distinct formations were noticed having similar features, it seemed advisable to describe them independently.

The vein-stone is of crystalline quartz, usually showing comb-structure, and sometimes closely associated with cassiterite. In a few examples the central vein is not at all distinct. The quartz crystals may be translucent or transparent. This vein-stone emerges into the vein-rock, which is quartzose. It consists of a granular quartz matrix, through which are scattered irregular grains of glassy quartz up to one-quarter inch in diameter. This matrix may also carry a little cassiterite. Pyrite is sometimes present in the vein-rock in small cubical crystals up to one-sixteenth inch across, showing sharp crystal outlines, and not infrequently striated faces. It is not certain that tourmaline should be included in a description of the vein-type. Certain formations which appear to belong to this type may at certain points on their outcrop carry veinlets and small vughs of tourmaline (usually green), indicating a merging into the previously described type, but the writer prefers to regard tourmaline as being absent from the typical quartz-quartzose vein-type. Wolframite was noticed in one instance, in small crystals (up to one-eighth inch in length and one-sixteenth inch diameter), associated with fluorite and fine scales of mica, which could not be definitely determined.

No other minerals appear to be present, unless perhaps hæmatite be included. The mineral is present (as a primary mineral) in one vein, which, however, does not certainly belong to this type. Although very quartzose, this particular vein carries a little tourmaline, and more likely belongs to the quartz-tourmaline-cassiterite type.

([142]) *Vide* Geol. Surv. Tas. Bulletin 6, pp. 52-54.
([143]) *Vide* Geol. Surv. Tas. Bulletin 15, pp. 63-65.

The vein-stone may attain a width of 5 inches, and the vein as a whole reaches 30 feet in width in exceptional cases.

The walls are not sharply defined, and it would rather appear that there is a merging into the country-rock. This point could not be determined with certainty, however, as in several cases where exposures were available for inspection, the granite was very decomposed.

The amount of work done on formations of this type is not large, although several give indications of developing into economically important veins.

Several examples occur on the Federation Mine. The white trench near the old horse tram exposes one vein, which is cut through by two narrow quartz-tourmaline veins of later date. The Whip Shaft lode belongs here or to the quartz-tourmaline-cassiterite type; it is really an intermediate vein. Still another is exposed on the surface at the Air Shaft workings: tourmaline makes its appearance in small amount towards the edges of the formation in one exposure.

The White Face is apparently a formation of this type, and a formation on the Cliff Mine forms an intermediate type between this and the preceding one.

A very interesting vein on the Federation Mine is associated with quartz-tourmaline rock on either side, and may be a vein of this type introduced subsequently to the formation of the quartz-tourmaline vein. This vein is described fully elsewhere.(144)

Other outcrops of veins belonging to this class were noticed in different parts of the granite area on which no work whatever had been done.

(3)—*Pyritic-Cassiterite Type.*

This vein-type has been previously described from the district by Mr. Waller under the heading of "Pyritic Veins."(145) As this description is not quite complete, it may be well to quote Mr. L. K. Ward's definition of the type, compiled after a careful study of the occurrences at North Dundas.(146)

"The metallic minerals of the vein-type are pyrrhotite, pyrite, arsenopyrite, chalcopyrite, with a certain amount of galena, sphalerite, and bismuthinite. Wolframite is present in most deposits. The tin ore occurring with these

(144) *Vide* pp. 156–157, 276. (145) *Op. cit.*, p. 9.
(146) *Vide* Geol. Surv. Tas. Bulletin 6, p. 48.

is cassiterite, but stannite has been observed in some rare cases. Of the gangue minerals, the most abundant is quartz, and with it occurs dolomite. In smaller proportions the following minerals are also present:—Tourmaline, chlorite, epidote, and fluorite. Apatite has also been recorded. The prevailing structure of the vein-filling is massive."

In the South Heemskirk district the type is not as well developed as that previously described. No deposits which belong undoubtedly to this type were available for inspection *in situ*, although ore on the dump-heaps of two properties indicates that at least this number of members of the vein-type exist.

A vein which should be included in this class, although it does not conform strictly to the type as described above, is one which occurs at Mayne's Mine (Section 124M) in sedimentary rocks within a few chains of the exposed border of the granite. The only minerals present are pyrite, tourmaline, and cassiterite, with some kaolin, which is probably secondary. The occurrence is described below.(147) The general appearance is that of a body of massive green tourmaline traversed by veins of pyrite, which give it a general banded structure, the bands corresponding with the line of strike of the formation. There is no marked vein-stone or vein-rock in the sense described above. The tourmaline appears to be massive, but under a powerful lens is seen to be composed of minute prismatic crystals: it is green in colour, none of the black variety being noticed. The tourmaline occupies the bulk of the vein (about 6 feet in width where exposed), although pyrite is abundant, and occurs in cubical and pyritohedral crystals, in some cases encrusting opposite walls of open fissures, with a strike corresponding to that of the main formation. Cross-fissures filled with pyrite are also noticed in places. Cassiterite is present in a very finely-divided form, but is not usually visible to the naked eye. Irregular masses of kaolin are present in places. No other gangue minerals were noticed, and even quartz is not visible: micro-slides were not examined, so quartz may be present in small amount. A striking feature is that there are no well-defined walls: the lode material appears to merge into tourmalinised slate. Judging by its mineralogical composition the formation is evidently related to the pyritic-cassiterite veins. In mode of origin it appears to have been formed by the replacement of a band of country-rock by the mineralising solutions. It is rather doubtful whether the open fissures with pyrite may

(147) *Vide infra*, p. 378.

not have been filled with some other mineral now removed by oxidation, although there is no evidence to support this theory, and the pyrite itself is fresh within a few feet of the surface.

Several narrow veinlets on the same property are doubtless to be correlated with this formation, and that exposed in the No. 3 Adit on the adjoining property (the Kelvin Mine) is apparently quite similar in mineralogical composition, though its structure cannot be determined in the present condition of these workings.

The old Globe Mine (also known as the Mt. Agnew Mine) produced both copper and silver-lead ore of good grade. Very little information is available concerning this property, and none concerning the ore *in situ*, but the property is described in another part of this report.

The metallic minerals present are galena, tetrahedrite, chalcopyrite, sphalerite, pyrite, and cassiterite.

The gangue minerals, in the relative order of abundance as far as can be judged from the dump-heaps, are quartz, tourmaline, siderite, and fluorite. The nature of the ore is described below, and it is shown that sometimes vughs occur, but that the ore is frequently banded. The tetrahedrite carries high silver values, and it occurs partly lining vughs, where it is particularly associated with galena, sphalerite, and pyrite, with a siderite gangue, partly in veins with the same minerals, partly disseminated through a crystalline groundmass of quartz, through which are scattered siderite and pyrite. Chalcopyrite does not appear to be very common, and cassiterite was not noticed in hand specimens: green tourmaline is abundant.

With regard to the classification of this deposit, it is rather doubtful whether it should really be included in Mr. Ward's pyritic-cassiterite type. Pyrrhotite is absent, although pyrite is not uncommon in cubical and pyritohedral crystals. At North Dundas pyrrhotite is the most abundant of the metallic minerals, although pyrite is present and in some places predominates. Arsenopyrite, bismuthinite, and wolframite have not been noticed, but it is noteworthy that the two latter minerals are apparently absent from the North Dundas deposits. Dolomite may be present with the siderite, and chlorite is possibly present with the massive green tourmaline: epidote has not been noted.

It is unfortunate that the shoot of ore was not available for examination, to enable some definite statement to be made with regard to the distribution of cassiterite in this

interesting deposit. The mineral appears to be very scarce. From information gathered from a gentleman familiar with the property, the writer believes that the tin oxide occurs in definite shoots which seem to be of very limited length.

A study of the minerals present shows that several of them belong essentially to high-temperature deposits, while others belong to the class recognised as being formed usually at lower temperatures.

Tourmaline, fluorite, quartz, cassiterite, and smaller quantities of galena, chalcopyrite, sphalerite, and pyrite are typical of cassiterite veins formed at high temperatures.([148]) Siderite may also be present in such deposits. It is worthy of particular note, however, that pyrrhotite is absent.

On the other hand, the abundant galena, sphalerite, chalcopyrite, tetrahedrite, with quartz and siderite (and more rarely fluorite), are characteristic of deposits formed at intermediate depths and at lower temperatures than the minerals noted above.([149]) This association is significant, and suggests that we are here dealing with a vein-type intermediate between the true high-temperature tin deposits of Mt. Heemskirk and the moderate-temperature silver-lead deposits of Zeehan. Although its situation within the igneous rock suggests a high temperature, the mineral association indicates rather that the deposit as exposed represents an overlapping of the two zones. The deposit must have been formed after the consolidation of the crust of the granite, by solutions emanating from some reservoir deep within the heart of the rock, containing material still fluid, these solutions depositing first their tin content, and afterwards their silver-lead-zinc-copper-antimony content in the cooler outward zone; under such conditions it will readily be seen that no hard and fast line could be drawn between the two zones, but that at a certain locality there would be an overlapping, and this particular locality has been exposed by the workings in question. If the formation were followed in depth, doubtless the sulphides would gradually decrease in quantity, and the deposit be found to resemble more closely a typical tin vein.

One point is worthy of note with regard to the mineralogical composition. The tetrahedrite present has been regarded by Mr. Waller as a secondary mineral.([150]) The

([148]) *Vide* "Mineral Deposits," by Waldemar Lindgren, 1913, p. 616.
([149]) *Op. cit.*, p. 514.
([150]) *Op. cit.*, p. 10.

writer, however, after a close examination of various specimens illustrating its mode of occurrence, has come to the conclusion that the mineral is primary. The occurrence of a typical moderate-temperature mineral in a stanniferous tourmaline vein would be explained by the theory mentioned above.

Another deposit which possesses some rather unusual features, but which has some features in common with the occurrence described at the Globe Mine, is that being exploited at Sweeney's Mine, on the southern slopes of Mt. Agnew. A description of the property is given elsewhere.[151] It is situated about $1\frac{3}{4}$ mile south-west of the old Globe Mine described, and well within the borders of the granite, the nearest point on the contact being nearly 1 mile to the south-east at the Kelvin Mine. The granite of the district is the normal coarse-grained pink granite, carrying a few scattered aggregates of tourmaline.

The minerals present in the deposit are sphalerite, pyrite, galena, stibnite, chalcopyrite, cassiterite, quartz, siderite, and fluorite, with tourmaline and chlorite in the wall-rocks.

The mode of occurrence of the ore is described in a later part of this report,[152] and it is seen that very little work has been done, and the true structure of the ore-body is not apparent. The ore exposed in a surface trench on the summit of the hill carries abundant sphalerite, some pyrite, stibnite, and traces of chalcopyrite and cassiterite, with quartz the only distinguishable gangue mineral.

Lower down the hill the exposed ore shows abundant sphalerite and pyrite in a quartzose groundmass in hand specimens. A thin section was examined microscopically, and showed that the groundmass is composed of crystalline quartz, which shows hypidiomorphic outlines, but which is idiomorphic to most of the other minerals present. The exception is pyrite which in a few cases occurs in idiomorphic crystals. These have obviously been the first to crystallise out from solution, followed closely by quartz. Pyrite and sphalerite are abundant, and are closely associated. The pyrite includes idiomorphic crystals of quartz, and some masses are partly moulded on the latter mineral, showing that the pyrite has crystallised later than the quartz. The same applies to the sphalerite. The two metallic minerals appear to have crystallised contemporaneously on the whole, although some of the pyrite has crystallised later than the sphalerite, since it completely

(151) *Vide infra*, pp. 361–368. (152) *Vide infra*, pp. 362–364.

includes some masses of the latter mineral. The order of crystallisation is somewhat unusual.

Other ore from the same locality is of a general green colour, and shows pyrite and sphalerite in a quartzose and chloritic groundmass. Microscopical examination of a thin section shows the presence of pyrite, sphalerite, quartz, and chlorite. As in the previous case, quartz is idiomorphic, and has been the first mineral to crystallise. Crystals are included in the pyrite, and also determine the shape of the sphalerite masses, which are moulded partly on the quartz. Sphalerite has followed the quartz in crystallisation, and has been succeeded by pyrite, which includes some of it. Chlorite aggregates are abundant in the groundmass, as though replacing some earlier-formed mineral, but there is no indication of what this mineral was.

What appears to be truly primary ore is that from the lower adit—handsome ore consisting of sphalerite, pyrite, and stibnite, in a groundmass consisting essentially of brown siderite and amethyst fluorite. The two latter minerals occur almost to the exclusion of the quartz in the groundmass, which, however, is present in small quantity. A thin section under the microscope shows that the quartz is in highly-idiomorphic crystals, and has evidently crystallised first. The pyrite and sphalerite appear to have crystallised to some extent contemporaneously. Fragments of sphalerite are included in the pyrite masses, which, however, show idiomorphic outlines to other masses of sphalerite. The siderite and fluorite are partly intergrown, and appear to have crystallised contemporaneously, but subsequently to the other constituents, which all present idiomorphic outlines to them. Inclusions of idiomorphic crystals of quartz are common, particularly in the siderite. Of very particular interest and importance in this slide is the presence of granular aggregates of cassiterite. Individual grains are very minute, but they are fairly well disseminated through the slide. They usually occur in association with the quartz, and may have crystallised earlier than that mineral, although the order is not easy to definitely decide. Stibnite does not occur in the only slide available of this ore, but from the occurrence of the mineral in hand specimens, it is clearly earlier than the sphalerite, and may even be earlier than the quartz.

In the description of the mining property, the occurrence of veins of cassiterite has been described.[153] The

(153) *Vide infra*, pp. 363, 364.

cassiterite is associated with both sphalerite and galena, the latter in minute quantities only. These veins appear to be independent of the main formation, but their relation to it is not well exposed.

A typical pinitoid vein cut in the lower adit is described below.

In the zone of kaolinised granite adjacent to the ore-body, which is itself impregnated with pyrite and a little sphalerite in places, occur extremely interesting nodular masses at intervals, composed of tourmaline, siderite, a little quartz, and sometimes fluorite. The nodules are of rather irregular shape, up to 4 inches diameter, and are not visibly connected with veins traversing the granite. The tourmaline is black, and occurs in radiating masses up to 3 inches in length. Crystals intersect at different angles and are closely associated and intergrown with translucent brownish siderite. This mineral has crystallised slightly later than the tourmaline, but there can be no doubt about its primary nature. As isolated fragments reached strongly for manganese as well as for iron, fragments of the mineral were separated with some difficulty from the accompanying tourmaline, from different specimens collected, and submitted to the Government Assayer, who reported for a specimen which showed a trace of manganese by qualitative tests—

Iron	37·5 per cent.
Manganese	0·35 per cent.

This would be equivalent to 77·6 per cent. carbonate of iron; the remaining impurity is probably calcium, which was not determined.

Another sample isolated from a nodule in which it occurred with tourmaline, and which gave decided reactions for manganese, as well as for iron, by qualitative tests, was also submitted to the Government Assayer, who reported—

Manganese	16·6 per cent.

This would be equivalent to 34·7 per cent. of manganese carbonate.

Thus, the mineral is a manganiferous siderite.

Where fluorite occurs, it is amethyst in colour, and is present in aggregates included in the siderite. A small amount of amorphous quartz is usually present, forming a coating to the tourmaline crystals, and sometimes filling interstitial spaces between adjoining needles.

The boundaries of these nodular masses are ill-defined, and siderite is sometimes developed in the enclosing rock.

In considering the mineralogical composition of the ore as throwing light on the genesis of the deposit, it is at once evident that the association of minerals present is not that which is to be expected in a normal tin vein. The presence of abundant sphalerite, with galena, pyrite, and siderite, at once suggest a comparison with the ores of this composition a few miles to the east. On the other hand, the cassiterite and fluorite and tourmaline in the wall-rock, suggest a direct comparison with the normal tin veins.

It is worthy of note that a small cassiterite content, and in the same vein fluorite, are present in the pyrite-stannite-chalcopyrite type of vein developed at the Oonah Mine, Zeehan. This vein also carries smaller amounts of bismuthinite, tetrahedrite, wolframite, antimonial lead ores, zinc blende, quartz, and siderite.([154])

It is interesting to compare the vein with the pyritic-cassiterite vein-type of Ward (quoted above), in which the minerals present are pyrrhotite, pyrite, arsenopyrite, chalcopyrite, galena, sphalerite, bismuthinite, wolframite, cassiterite, and rarely stannite, with tourmaline, chlorite, epidote, fluorite, and sometimes apatite.

The vein under review appears to form a connecting type between the lead-zinc and the tin veins. In the writer's opinion it is to be classed as a variation of the pyritic-cassiterite vein-type. The absence of pyrrhotite and of tourmaline from the ore, however, which are probably essential constituents of the vein-type, render such a classification somewhat doubtful.

The minerals present in the ore are all classed by Emmons ([155]) as belonging to the "Deposits of the Deep Vein Zones," although all with the exception of cassiterite may also belong to the class of "Deposits of Moderate and Shallow Depth: Igneous Rocks Near-by," and, in fact, in several cases are more typical of the latter class.

There can be no doubt of the genetic connections of the ore-deposit with the granite in which it occurs, and the fact of its occurrence in this rock, and the alteration of the wall-rock clearly proves that at least the outer crust

([154]) *Vide* Geol. Surv. Tas. Bulletin 8, pp. 52, 53.
([155]) "A Genetic Classification of Minerals." by William H. Emmons: Economic Geology, Vol. III., No. 7, 1908.

of the granite had consolidated at the time the ore-deposit was formed.

It appears to the writer probable that in the deposit in question, there is not one simple type, but rather an overlapping of types. At the time the deposit was formed there was a considerable cover of sedimentary rocks, since removed by denudation. It is probable, too, that the surface of the granite itself stood at a higher level than it does at the present time. In the deeper zone, which was at higher temperature, the cassiterite was deposited when such a temperature was reached that it could no longer be retained in solution. As the ascending solutions reached the cooler outward zones the sulphides of zinc, lead, &c., were deposited. Clearly, such zones in nature are never sharply defined, and at one locality there may be expected a merging upwards into sulphides of zinc, lead, &c., and downwards into tin, carrying smaller quantities of the other metals. It is this particular locality which appears to be represented, the upper zone having been removed by denudation. It may be expected, then, that if the ore be followed downwards, tin may become more abundant, the sulphides of the base metals tending to decrease.

(4)—*Pinitoid Veins*

Mr. G. A. Waller recognised this vein-type in the district, and described it as follows ([156]):—

"These veins have the same general character as the quartz-tourmaline veins. They also contain a central vein of tourmaline, or cassiterite and tourmaline, but the vein-rock is much softer, and contains less quartz. The felspar of the granite has been altered to a massive substance, which has been termed pinitoid. This is not a definite mineral, but a complex substance containing probably several minerals, all of which approximate to muscovite in composition. A slice of very similar stone from the Ben Lomond district examined under the microscope revealed the presence of a good deal of crystalline mica, together with the amorphous pinite, or massive mica. The vein-rock generally contains the original quartz of the granite unaltered, but sometimes the quartz also has been replaced. The vein-rock, as well as the vein-stone, is sometimes very rich in tin. The accessory minerals

([156]) "Report on the Tin Ore Deposits of Mt. Heemskirk," by G. A. Waller, 1902, p. 9.

mentioned as occurring in the quartz-tourmaline veins will probably also be found in the pinitoid veins, but up to the present I have only observed the presence of a little pyrite."

The writer can add little to this description. Some cases were noticed in which the original quartz of the granite appears to be unaltered, but in others not only the felspars (which appear to be attacked first), but the quartz also, has been replaced. A good example of the type is to be found at Sweeney's Mine.

In the lower adit a vein of cassiterite was intersected, enclosed in altered granite The rich tin-bearing stone is almost free of pyrite, although this mineral is abundantly developed in the adjacent stone on either side. The cassiterite is extremely fine, and dark-brown in colour. It occurs in a soft, greenish groundmass, in which no constituents other than a small amount of finely-divided pyrite are distinguishable in hand specimens. A thin section of this rock shows that it has been converted to massive mica or pinite, in which are occasional shreds and crystals of white mica, a few scattered aggregates of quartz, and a few minute shreds of green tourmaline. Cassiterite is present in minute grains and granular aggregates, distributed through the groundmass. It is well disseminated through the slide, but does not occur in veins, outside of the central vein, traversing the rock. Inclusions of cassiterite occur in the white mica, as well as through the groundmass of the rock. No pyrite occurs in the slide examined.

The relation of this vein to the main formation on this property (described in the preceding section) cannot be stated with certainty, but it certainly appears to be later and to intersect the pyritic formation. Further work, if carried out on the property, should make this relationship clear.

Examples of the vein-type are to be found on other properties, but particular reference may be made to the old Montagu Mine (Section 6660-M, E. Mulcahy and M. Bullen), on which several pinitoid veins occur.

In the stanniferous pipe on the Federation Mine (described more fully below), a similar massive micaceous aggregate, or pinite, is abundantly developed, although the structure is very different from that of the typical pinitoid veins.

Examples of quartz-tourmaline-cassiterite veins were noticed, in which a small amount of pinite was developed,

and this at once raises the question as to whether a fresh vein-type should be formed on account of the pinitoid developed. Up to the present the veins which appear to belong to this class have not been shown to carry the variety of sulphides found in veins of the types previously described, but this may be on account of the small amount of work done on the veins. No work has been done on a pinitoid vein which can be regarded as below the influence of ground-water, and consequently the apparently simple composition of the vein-type may be due to the oxidation and removal of sulphides which exist in the primary ore.

The two types of veins are related, and it may be that the pinitoid veins should be regarded as merely a variation of the normal vein-type. Until further work has been carried out, however, it is deemed advisable, as a matter of convenience, to retain Waller's classification, and class certain of the stanniferous formations as belonging to the pinitoid vein-type.

(5)—*Greisen Veins.*

The vein-type classified by Mr. Waller as greisen is not very important in the South Heemskirk Tinfield, although in some of the tin-mining centres of the State it appears to predominate over other types.

Mr. Waller thus defines the vein-type ([157]):—

"The felspar of the granite has been altered to a white crystalline lithia-mica, so that the resulting rock (greisen) consists of a mixture of granular quartz and white mica. Tourmaline and quartz are present in the central vein, and both the vein-stone and the vein-rock may carry tin."

The examples quoted by the above author are probably the best to be observed in the district, viz., at the old Orient Mine. In the North Heemskirk district a good example occurs on the western slope of Donnelly's Look Out, exposed in a small side-cutting of the track.

Little is to be seen at the Orient Mine, as the workings are mostly collapsed, but specimens of typical greisen were noticed on the dump-heaps.

At the Federation Mine, too, about 2 chains west of Munro's shaft, narrow veins of greisen were noticed in the exposed granite surface, containing a central vein of black tourmaline, and from 2 to 3 inches of vein-rock, in which

([157]) *Op. cit.*, p. 9.

the felspars had been completely replaced by white mica: this merged in either side into normal granite

The stone exposed at the old Orient workings was not tested for tin, but it is at least not very rich if that available on the dump-heaps is typical.

On the whole, the vein-type has not up to the present been proved to be of great economic importance in the district.

A close examination of various occurrences throughout the district shows that mica is sometimes present in small quantities in veins which would be classed with the quartz-tourmaline-cassiterite veins if classified by the content of minerals other than mica, and by their structure. This indicates at once that no very hard and fast line can be drawn between the two types. While the extreme developments of both the greisen vein-type and the quartz-tourmaline-cassiterite vein-type may be readily distinguished, and for this reason a classification such as that suggested is advisable, still, it seems clear that intermediate types do exist, and no arbitrary line of division can be drawn between them. The presence of muscovite in the massive pinitoid veins, and of small amounts of pinitoid in at least one greisen vein, indicates that here, too, there is a merging of types. The presence of a small amount of pyrite in all types is worthy of note.

(6)—*Pipe Formations.*

A very interesting occurrence in the district, and one unlike any other which has been described from Tasmania, so far as the writer is aware, is that of at least one pipe-deposit, which has been worked for some distance and found to carry rich tin. This pipe occurs on the Federation Mine, and the work done is described in detail in another part of this report.([158]) It is proposed at this stage to consider the general features of the pipe, and discuss its mode of origin.

The pipe is far from regular in its strike, dip, or cross-section. The strike of the main pipe varies from N. 16° W. to N. 58° W. (while one branch strikes N. 47° E.). The dip varies from vertical to within 9° of horizontal. The cross-section is usually oval, sometimes more nearly lens-shaped, tapering out to nothing, the cross-section varying from 25 feet by 15 feet near the sur-

([158]) *Vide infra*, pp. 261–267.

face, to 5 feet by 1 foot in the face at the deepest point exposed. It has been followed for a total length of 115 feet, and carried rich tin for the whole distance. A branch pipe from the main was followed horizontally for 30 feet, and also yielded rich tin. Both main and branch pipes continue in the respective faces where work has ceased.

Although the central (softest and richest) portion of the pipe has mostly been worked out, most of the workings were fortunately accessible.

The pipe material at the surface was thoroughly kaolinised. Typically, however, as exposed in the deeper workings, it may be classified as (*a*) true pipe-material, and (*b*) wall material, the two classes depending on the amount of alteration which the granite has undergone.

(*a*) The true pipe-material, occupying the central portion of the pipe was very soft, and contained the richest tin. It is greenish-grey in colour, has a waxy lustre and white streak, and feels greasy to the touch. It is composed of an aggregate of minute scales, and when scales can be isolated they are semi-translucent. It is attacked by, but not completely soluble in, acids. Unfortunately, no analysis of the material is available. It appears to be a form of massive mica, allied to paragonite, and similar to the aggregate which has been termed "pinitoid" by Mr. Waller.([159]) Until further information with regard to its composition is available, it seems advisable to use the more general name "pinite." Scattered through this groundmass are abundant crystals of cassiterite and pyrite. The occurrence of these minerals is described elsewhere.([160]) Quartz and tourmaline were not noticed in this true pipe material.

(*b*) This material is bounded by generally similar, although harder, wall material. The dimensions given for the pipe do not include the wall material, which has in most cases not been broken down, as it was too hard to pay for breaking-down and sluicing by the crude methods employed by the tributers who worked this portion of the property. The thickness of this material is seldom exposed, and it grades into normal granite, but it apparently varies from 1 to 6 feet. The line of division between true pipe material and wall material appears fairly well defined. The latter consists essentially of similar pinite to that contained in the central portion of the

([159]) *Op. cit.*, p. 9. ([160]) *Vide infra*, p. 263.

pipe. This substance, however, appears to be rather more coherent and in somewhat larger scales. Crystals of cassiterite and of pyrite quite similar to those in the true pipe material are abundant, though somewhat less so than in the softer material. The most striking difference is the abundance of quartz and tourmaline. The quartz is always crystalline, and occurs abundantly through the groundmass, in geodes forming prismatic crystals, and occasionally in ill-defined veins. Tourmaline is quite abundant in places. It is black, and occurs in radiating aggregates of fibrous crystals, varying from a fraction of an inch up to 2 inches in length. The mineral sometimes occurs in nodules, composed of radiating fibres. Geodes of both quartz and tourmaline crystals are not uncommon, the former up to 2 inches in length. The crystals are mutually intergrown, and must to some extent have crystallised simultaneously. Crystals of cassiterite are sometimes included in quartz, and cassiterite, tourmaline, and quartz are at times all included in pyrite. The order of crystallisation appears to be (1) cassiterite, (2) tourmaline and quartz, (3) pyrite. The wall material merges into granite, which is usually more or less decomposed, as exposed in the workings. It is the variety described as "white" granite, being medium-grained, and carrying abundant nodules of quartz and black tourmaline. Cassiterite becomes less abundant with increasing distance from the central pipe.

A thin section was prepared from hard, altered granite at a point where the wall-rock was merging into granite. In hand specimens fairly abundant quartz is noticeable in a greenish pinitoid groundmass. Minute crystals of pyrite are present in places, but no cassiterite is visible. Microscopical examination shows that grains of quartz, usually with quite irregular outlines, are abundant. A few idiomorphic crystals of clear secondary quartz are present, but the whole of the groundmass of the slide is composed of scaly aggregates of a mineral resembling mica; the scales are very minute, and exhibit only aggregate structure. The mineral is evidently a secondary product, resulting from the replacement of the felspar and mica of the original granite. Until more detailed information is available from analyses, this micaceous aggregate is termed pinite. This section shows that the aggregates are replacing the quartz of the granite, some grains being almost completely replaced. A small quantity of very fine granular cassiterite is present.

The examination of this slide strengthens the impression gained by the general examination of the pipe, that the soft stanniferous lode-material results from a replacement of the granite. As described in a later part of this report,([161]) one offshoot from the main pipe has been followed for 30 feet, and continues in the face. The general structure of this offshoot is similar to that of the main pipe which has been described, the central portion being completely altered, and carrying very rich tin, merging into harder stanniferous wall material, which, in turn, merges into granite. The association of a quartz-tourmaline vein in this connection will be referred to below.

The form of the pipe deserves further comment, as it gives a clue to the mode of origin. The tortuous course of the main pipe is fully described below, and need not be referred to further at this juncture. The cross-section, however, is worthy of notice. The portion worked by open-cut methods near the surface is said to have been funnel-shaped, and to have measured as much as 25 by 15 feet. It is somewhat doubtful, however, whether this represented the size of the true pipe, as the wall material would be altered and softened near the surface by the action of surface waters, and was doubtless worked with the true central pipe material, both carrying rich tin. Although not noticeable in the portion of the pipe which was vertical, as it became more nearly horizontal in course the pipe showed well defined "wings," *i.e.*, it gradually tapered out along the greatest diameter of the general elliptical section. The idea conveyed by this structure is that the pipe really represents a bulge along a fissure. Exactly the same structure is noticeable in a small pipe appearing in the wall of the offshoot, which has been worked to the west of the main pipe.

An important consideration in discussing the mode of origin of this deposit is the association with the pipe of quartz-tourmaline veins. These veins are described elsewhere.([162]) They belong to two classes—the greisen type, and the quartz-tourmaline-cassiterite type. The sole instance of the former vein, however, is somewhat of an intermediate type, or is at least a greisen vein allied to the quartz-tourmaline-cassiterite veins. This vein, striking N. 27° E., and with a vertical dip, adjoins the pipe as exposed in the open-cut, and merges into granite without sharply defined walls; the vein carries cassiterite. The

([161]) *Vide infra*, p. 264. ([162]) *Vide infra*, p. 262.

winze connecting with the pipe workings was sunk on this vein, and at one point an interesting intersection takes place with another greisen vein of about 9 inches, which is almost horizontal. The exposure is not complete, and it is impossible to say which is the later, and whether any displacement has taken place.

In the tributers' tunnel below, a quartz-tourmaline-cassiterite vein has been cut, which strikes N. 6° W., and dips east at 70°.

In the face of the western branch pipe, a quartz-tourmaline vein from 1 to 3 inches in width, partly surrounds the true pipe material. In the section exposed, it is arched; on the upper side is a firm brown kaolin, iron-stained from decomposing pyrite and carrying tin, but separated from the quartz-tourmaline by a seam of white kaolin.

Well-defined fissures occur in the granite at different points, intersecting at various angles, many of them subsequent to the formation of the lode-material. Thus, in the intermediate drive is a well-defined almost horizontal fissure, forming the roof of the drive. In the face of this drive several more nearly vertical fissures occur, the main one striking N. 13° E., and being vertical. In one case the boundary between altered pinitoid granite and the normal granite is marked by a fissure, but this is rather the exception, judging by the few exposures available.

It is reported that during the work on the pipe one quartz-tourmaline vein was found to cut through the pipe, and that where exposed the surface of the vein material was studded with tin. This occurrence was, unfortunately, not seen by the writer, being worked out prior to his visit.

With regard to the mode of origin of this interesting deposit, it is clearly genetically connected with the adjacent tin-bearing veins of more normal type. It was formed after the consolidation of the outer crust of the granite by the action of highly-heated vapours and solutions rising through fissures in the granite, which may have been caused by the contraction of the igneous rock on cooling. The irregular form of the deposit is doubtless due to the intersecting fissures. The more recent fissures already described may, perhaps, give a clue to the structure of the pipe, although the fissures which exist at the present time have certainly been formed since the formation of the tin-bearing pipe. It is not unlikely that the contraction caused by the cooling of the outer crust would cause not only vertical, but also more or less horizontal

fissures. Solutions rising along a vertical fissure intersected by a horizontal one would follow the path of least resistance. This might cause them to travel laterally for some distance, when another intersection might cause a fresh deviation. The exact causes which have resulted in the localisation of the ore-forming processes to one particular portion of the fissure are not clear. Although the section of the pipe clearly shows that in some localities the solutions have followed fissures, in others such evidence is wanting, and in the writer's opinion the solutions have during their course found their way in places through solid granite, altering the original rock and depositing their burden of metallic compounds. The minerals present show that compounds of boron, fluorine, and sulphur were present, and these " mineralisers " have played an important part in the action.

Stanniferous pipes such as that described are not known to occur elsewhere in Tasmania, and do not appear to be common in tin-bearing areas elsewhere, and it is therefore of interest to note that pipes which appear to have many features in common with the one under consideration are known to occur in New South Wales, and have been described by Mr. L. A. Cotton, B.A., B.Sc.(163) " Smith's Pipe " was 3 feet in diameter, and was worked vertically for 8 feet, when it dipped steeply to the north: it was then worked for 90 feet and abandoned.(164) " The central core of the pipe was composed of a highly felspathic material and contained abundant cassiterite. The present walls of the pipe are soft and kaolinised. This change is connected with the genesis of the deposit for the kaolinisation passes gradually from the centre outwards into solid undecomposed granite a few feet distant." Another pipe described by Mr. Cotton is " Hong Hay's Pipe," which was worked for about 50 feet. The central core was exceptionally rich in tin.(165) " The pipe is oval in shape, being about 3 feet 6 inches in the long and 2 feet 6 inches in the short diameter. It occurs in a hard, fine-grained modification of the acid granite, which is here strongly jointed in two directions. The master-joints bear N. 49° W., and the subsidiary ones N. 55° E. None of these joints were altered by impregnations at a distance of 3 yards from the pipe.

(163) " The Tin Deposits of New England, N.S.W." Part I., by L. A. Cotton, B.A., B.Sc., in Proc. Linnean Society of N.S.W., 1909, Vol. XXXIV., Part IV., pp. 774-776.
(164) *Op. cit.*, p. 774.
(165) *Op. cit.*, p. 775.

The pipe dips at 49 degrees in the first 12 feet in a direction S. 35° W., and then at 35 degrees for the next 40 feet of descent. It then takes a very steep dip in the same direction. The central part of the pipe is reported to have been highly felspathic, soft, and easily mined. The present walls of the pipe consist of a white, fine-grained, friable casing of a felspathic nature containing in places a good deal of cassiterite."

These descriptions are sufficient to show that there is a great similarity between the pipes and the one under consideration. Mr. Cotton also points out that the pipes of the New England district differ from those described from the Transvaal,(166) which are characterised by intense alteration of the granite in which they occur. " In many of these pipes a characteristic zone of tourmaline borders the outer edge of the pipe, while the central portion consists chiefly of quartz and mica."

Thus the Transvaal pipes differ also from the Federation one, although the presence of quartz and mica, and the formation of a tourmaline ring suggests some points of resemblance. The work quoted, which deals with the South African occurrence, was not available to the writer.

It is interesting to note in passing that in the article quoted above, Mr. Cotton proposes the following classification for the tin deposits of the New England (N.S.W.) district:—(1) Quartz-quartzose Veins, (2) Quartzose, (3) Greisen, (4) Quartz-greisen, (5) Quartz, (6) Quartz-felspar, (7) Chlorite Deposits, (8) Arsenical Lodes, (9) Pipe Deposits, (10) Cassiterite Veins in Slate, (11) Stannite Deposits. Although some classes are not represented in the South Heemskirk Tinfield, others have points in common, the most marked difference being the almost complete absence of tourmaline, which is unusually abundant right throughout the district under consideration.

B.—WOLFRAM AND BISMUTH ORES.

Adhering strictly to a genetic classification of the ore-deposits, it is doubtful whether the ores to be described in the following section should be differentiated from the tin ores. In defining certain of the latter it has been stated that wolframite is present in the vein-type in small quantities. It will readily be seen that by a variation in the

(166) Quoting Kynaston, H., and Mellor, E. T.: " The Geology of the Waterburg Tin Fields." Memoir No. 4, Geol. Surv. of Transvaal, Department of Mines.

type, the cassiterite content may decrease and the wolframite content increase to such an extent that economically the ore may be considered as a wolfram rather than as a tin ore, although strictly belonging to the type described for the latter. This is particularly true in the case of the ore exposed by a trench on Section 5426M, to the south of the Federation Mine, and west of the Cumberland Dam embankment. This is a tin-wolfram ore, and belongs to the quartz-tourmaline-cassiterite vein-type.

The minerals present are wolframite, cassiterite, and possibly a little pyrite, with abundant quartz, and some green tourmaline.

Wolframite is apparently not well disseminated through the ore, but occurs rather as rich patches in the form of vughs: the formation is partly cut across by a trench, and no wolframite was seen in this trench *in situ*, but rich specimens occur on the dump-heap. Some specimens would assay about 20 per cent. wolfram. The mineral occurs in well-formed crystals, the examination of different specimens showing that combinations of prism, pinacoidal, and dome faces are represented: crystals sometimes attain a length of 1 inch. Cassiterite is not always noticeable, and is subordinate in amount to the wolframite, occuring to the extent of about ½ per cent. Geodes were sometimes noticed lined with clear prismatic crystals of quartz associated with a little green tourmaline, the quartz crystals being in turn encrusted with cassiterite.

The wolframite is invariably associated with crystals of quartz. The latter occurs in prismatic crystals up to about 1 inch in length, usually if not invariably singly terminated, and forming either confused crystalline masses, or linings of geodes. Sections of crystals indicate that crystals have grown by several successive additions of silica, forming a continuous crystal, the additions being rendered distinctly visible in partially weathered specimens. A small amount of fine granular quartz forms interstitial material in the masses of crystalline quartz.

One large specimen of ore lying on the heap apparently gives the clue to the structure of the main tin-wolfram vein. This shows a central seam of green tourmaline and cassiterite, with no distinguishable wolframite, flanked on either side by crystalline aggregates of quartz with disseminated sheaves of green tourmaline crystals, and containing geodes of quartz with a little tourmaline and crystals of cassiterite and wolframite. The bulk of the material exposed in the trench is white quartzose material of medium grain-size, with larger irregular quartz grains and a little

disseminated green tourmaline traversed by veinlets of green tourmaline; there are also present nodules of massive green tourmaline pierced by sheaves of radiating brown tourmaline, sometimes accompanied by quartz. In several instances the green tourmaline aggregates show outlines which strongly suggest that they replace felspars of the original granite.

The formation is evidently one which has been formed by processes exactly similar to those which have operated in the formation of the quartz-tourmaline-cassiterite veins: solutions have ascended by a fissure or possibly more than one fissure (now represented by tourmaline veins), carrying with them metallic compounds which have been deposited partly in the central vein, partly in adjacent rock. The solutions appear to have been somewhat poorer in boron compounds and richer in silica than those which have operated in some of the tin veins of the district.

The occurrence of fairly abundant wolframite in a creek bed on the western slope of the range, on the Federation Tin Mine, is referred to elsewhere. This has been derived from a formation not yet certainly located *in situ*, but not far distant; the association of cassiterite and quartz-tourmaline vein-stone is significant, and there can be little doubt that the wolframite occurs either in a shoot of ore in one of the located quartz-tourmaline-cassiterite veins, or in a similar vein not yet discovered.

In a later part of this report a description is given of the work done on the old Empress Mine (Section 5093M), and of the "White Face" on this section.([167]) Here, in a quartz-quartzose formation, wolframite occurs in scattered crystals and nests of crystals, with cassiterite. Gangue minerals are quartz, mica, and fluorite. The mode of origin is quite similar to that of the cassiterite, and the occurrence does not call for special comment. To the writer's knowledge the presence of wolfram in this ore had not previously been reported, and although it does not appear to be present in payable quantities in the ore already exposed, any samples taken should be tested for wolfram as well as for tin, as richer shoots may occur. As discussed elsewhere, this deposit belongs to the quartz-quartzose type, which may perhaps be an extreme variation of the quartz-tourmaline-cassiterite vein-type.

Two shoots of bismuth ore occur on the Federation Mine, which have very promising features, and promise to become of commercial importance as producers of bismuth. These occur in the group of workings known as the Western Work-

([167]) *Vide infra*, p. 343.

ings, and in the No. 1 Adit and the old Cumberland adit, now known as Yates' Level. There does not appear to be any connection between the two occurrences, although they are not far apart, and are undoubtedly genetically connected. Little detailed information is available concerning the nature and structure of the ore-bodies in which the bismuth occurs, in the present state of the workings, but it appears in each case that the shoots of ore occur in normal tin veins of the quartz-tourmaline-cassiterite type. In one shoot a little bismutite (bismuth carbonate) was reported to occur, and in both cases bismuthinite (bismuth sulphide) is present. The gangue minerals are quartz and tourmaline. Some cassiterite is present in each case. The ore is partly oxidised, and the limonite present suggests that pyrite may be found in the primary ore. In the writer's opinion these shoots are but local variations in normal quartz-tourmaline-cassiterite veins, in which one of the accessory minerals of the typical vein becomes unusually abundant, and consequently economically important. The shoots may merge into normal shoots of tin ore, but only prospecting can determine their extent, and this is recommended.

Another occurrence to which reference must be made belongs apparently to a different class of deposit to those mentioned above. Very little work has been done upon it, and in consequence a detailed discussion of the ore-body is not possible. This work is described in another part of this report.([168])

Although described under the heading of wolfram ores, the ore should strictly be termed a tin-wolfram-bismuth ore, as all three metals are present; the tin content, however, appears low, and wolfram and bismuth appear to have been the metals sought in the work which has been carried out.

The metallic minerals present are magnetite, pyrrhotite, pyrite, chalcopyrite, wolframite, bismuthinite, and cassiterite. The gangue minerals noted are tremolite, diopside, quartz with some secondary talc and calcite. Lime-silicates also occur in the country rock in the vicinity, this rock being composed of slates and sandstones of Pre-Silurian age. The result of a microscopical examination of thin sections of these rocks is recorded elsewhere.([169])

The deposit is a contact metamorphic ore-body, genetically connected with the intrusion of the granite *massif*, which underlies this particular area. The occurrence of cassiterite, wolframite, and bismuthinite in such a deposit is unusual. The occurrence of these minerals with quartz

([168]) *Vide infra*, pp. 399–401. ([169]) *Vide supra*, p. 129.

crystals is suggestive, and it is possible that the minerals may have been introduced by pneumatolytic agencies after the formation of the main contact ore-body. So little evidence is available as to the occurrence of these minerals *in situ*, however, that the matter cannot be finally decided. It is worthy of remark that no tourmaline was noticed, and this mineral would be expected had the metals referred to been introduced by vein-forming processes such as those which operated in the formation of the tin deposits of the district. The presence of tin, wolfram, and bismuth in the dense pyritic body recorded in describing the property, is noteworthy: the relation of this pyritic mass to the main formation on which work has been carried out, is not clear in the present dilapidated state of the workings.

C.—MOLYBDENUM ORES.

Up to the present molybdenum ores have not proved to be of economic importance in the South Heemskirk Tinfield, although molybdenite has been located at several points, and discoveries of richer ores may be made, particularly as the present high price of the mineral justifies the prospector in keeping a sharp lookout in localities where it is known to exist.

Molybdenite is known to occur in the district on Section 4323M near the coast, 6922M charted in the names of Lipscombe and Hutchinson, about 1 mile west of Gap Peak, these two localities being well within the granite area, and at the Kelvin Mine (Section 6095M) in the sedimentaries within a few chains of the granite contact. In addition to the above, isolated specimens have been obtained from the Federation Mine in stanniferous lode-material, from Sweeney's Mine in pink granite, and the mineral was noted *in situ* in the granite on the Trial Harbour Road, about 1 mile from Remine, at the contact of the granite with sedimentaries. On Sections 4323M and 6922M molybdenite occurs in small quantity only, disseminated through stanniferous lode-material. It is a primary mineral, introduced by the vein-forming processes, and thus forms one of the component minerals of the tin-veins.

At the Federation Mine the mineral was not seen *in situ*, and the writer was unable to discover the exact locality on the property from which a fine specimen of the mineral, now exhibited in the Geological Survey collection, Launceston, was obtained. On this property the mineral is certainly not abundant.

In a side-cutting for the road, on the descent to Trial Harbour from the main road, and within about a chain of the exposed contact with sedimentaries, flakes of molybdenite were noticed in the granite. The mineral here certainly appears to have been introduced after the consolidation of the granite by vein-forming agencies, for it is associated with narrow and very irregular aplitic-looking veins. These aplitic veins are from one-eighth to one-half inch in width, and merge into the granite, molybdenite occupying the central portion of the veins. They have no regular strike, but may follow one course for a few inches and then bend round almost at right angles, apparently dying out in a few inches. No microscopical examination of this rock was made, but it is possible that the apparent aplitic veins are not true aplites, but that the molybdenite-bearing vapours or solutions, in ascending through minute fissures in the consolidated and cooling outer crust of granite, not only deposited their metallic burden, but also slightly bleached and altered the granite forming the walls of these fissures. Unfortunately the molybdenite is not sufficiently abundant at this point to be of economic importance, but the occurrence is interesting, and at once suggests that prospecting in the vicinity may disclose localities in which the vein-forming solutions have been more active, and in which more of the mineral has been deposited.

The occurrence of molybdenite at the old Kelvin Mine, Section 6095M, is distinct from any of those described above. It is to be regretted that the ore was not available for inspection *in situ*. As described elsewhere, it occurred on the dump-heap of an old adit, now completely collapsed, but the specimens available did not indicate that the mineral was present in payable quantities.

At Mayne's Tin Mine a specimen was obtained from the face of the No. 2 Open-Cut, showing a splash of molybdenite in quartz-tourmaline veinstone, which carries tin. No other occurrences of the mineral were noted on the property. This vein is in sedimentary rocks within a few chains of the granite contact.

D.—LEAD AND ZINC ORES.

Lead and zinc ores are known to occur in the district, but although small quantities of each appear to have been sent away, the ores have not up to the present been shown to be of great economic value.

Galena is present, with some tetrahedrite, chalcopyrite, sphalerite, pyrite, and cassiterite, in a gangue of quartz, tourmaline, siderite, and fluorite, within the borders of the granite at the old Globe Mine, on the southern slope of Mt. Agnew. Owing to its affinities with the tin-deposits of the district, this particular deposit has been described elsewhere,([170]) and the opinion expressed that it forms an intermediate type between the tin-veins and the silver-lead veins. Some silver-lead ore appears to have been hand-picked and shipped, but apparently the quantity was not large.

Galena also occurs in small quantities at Sweeney's Mine, but it is of no importance commercially. This property has also been described elsewhere,([171]) and the mode of origin of the ore-deposit discussed.

Sphalerite (zinc-blende) is present in both the ore deposits referred to above. At the Globe Mine it is an accessory mineral, of no importance as an ore of zinc. At Sweeney's Mine, however, it is more abundant, and forms in places the bulk of the deposit, which is being prospected as a tin mine. The ore is complex, containing abundant sphalerite and pyrite, with galena, stibnite, chalcopyrite, cassiterite, quartz, siderite, fluorite, and tourmaline. With the exception of sphalerite and pyrite (the latter being fairly abundant), the metallic minerals mentioned are present in small quantities only. Sphalerite in places forms the bulk of the ore. The mode of origin of the deposit has been discussed elsewhere, and the opinion expressed that it belongs to the high temperature deposits, and probably forms an intermediate type between the true tin deposits and the silver-lead type of the Zeehan field. Very little work has so far been done on the property to open up the deposit. From some of the surface exposures it appears that the ore may have a value as an ore of zinc if the demand arises, but no definite opinion can be expressed until further information is available as to the shoots of ore, their size, and the distribution of the minerals therein.

About one-quarter mile to the north-west of this deposit, and apparently on Section 5362M, is a narrow vein of sphalerite, width from 1 to 3 inches, exposed in the bed of a creek. It is of no commercial value, but is interesting and worthy of record as a local variation in a vein which should probably be classed with the tin-veins.

About one-quarter mile north-east of Sweeney's Mine another outcrop of sphalerite was reported as occurring in the bed of a creek, but the writer did not succeed in locat-

([170]) *Vide* pp. 162–164, 407-409. ([171]) *Vide* pp. 164–168, 361–368.

ing the outcrop in the thick scrub which covers the hill-slopes in this vicinity. This outcrop is probably on Section 5372M.

It is noteworthy that the three deposits referred to all occur within a short distance of each other, and that the Globe Mine, in the ore of which sphalerite is also present, is only a short distance to the east, while the mineral is not noticeable in any of the other veins of the district which are allied to the tin-veins. (The zinciferous deposits of the Comstock region, which carry magnetite also, are excluded and are discussed below.) This association is suggestive, and it is possible that all have been derived from a single magmatic reservoir in which the processes of differentiation had caused a greater concentration of zinc compounds than occurred in some of the other reservoirs which gave rise to the more normal tin-veins of the district.

As remarked above, these deposits of zinc ores are, in the writer's opinion, genetically connected with the tin veins of the district, and it is doubtful whether in a strict classification they should be separated therefrom. It has been noticed in the course of examination of Tasmanian mining fields by officers of the Geological Survey that any one component mineral of a particular vein-type may locally predominate over the economically important mineral, and may give the vein at that particular point a facies distinct from that of the type-vein. In this case, therefore, the deposits referred to above should probably be classed as variations of the pyritic-cassiterite vein-type.

In the adjoining Comstock district zinc ores have been profitably worked in the past, but it is not proposed to deal with these in this report. On the outskirts of the Comstock district, however, and really belonging to the Heemskirk district, is a deposit to which reference must be made. This is on Section 6667M, charted in the name of H. D. Marsh, and situated about 2 miles east of Mt. Agnew. The section has been described elsewhere,[172] and reference is also made to the ore deposit [173] from the point of view of an iron ore. The deposit is a contact-metamorphic one, consisting of magnetite and sphalerite, with a little pyrite, and diopside, serpentine, chlorite, talc, and phlogopite as gangue minerals.

The magnetite and sphalerite are irregularly distributed through the deposit, occurring sometimes in fairly pure aggregates of one mineral or the other, which may be several inches in width, and also closely intergrown. In the course

[172] *Vide infra*, pp. 412–415. [173] *Vide infra*, p. 189.

of the work carried out in the past, the purer zinc ore was hand-picked, and with satisfactory results so far as the grade of ore obtained was concerned. The Government Assayer's return for a grab sample taken by the writer from a heap of about 4 tons of picked sphalerite indicated 40·81 per cent. zinc and 20·4 per cent. iron. This shows that it has been possible to hand-pick the ore to a high grade, although in actual practice it appears to the writer unlikely that it will pay to work the deposit in this way, as a large amount of the ore consists of intimately-mixed magnetite and sphalerite. The ore exposed in the present face over a width of 10 feet assayed 7·39 per cent. zinc and 23·4 per cent. iron.

The mode of origin of this deposit is very different to that of the zinc ores described above, which are allied to the tin veins. Immediately following the intrusion of the huge granite mass into the overlying sedimentary rocks, but probably before its consolidation, mineralising solutions from the molten mass penetrated the adjacent rocks, carrying metallic compounds. Probably beds which offered special facilities to the solutions, which were at a high temperature and under very high pressure, were penetrated, whilst others escaped. The metamorphic effects on all the sedimentary rocks near the granite mass must have been intense, and it is not easy to distinguish between these effects and those of the mineralising solutions. It seems clear, however, that certain beds (perhaps more calcareous than the surrounding ones) were penetrated, and the rock-material actually replaced, its place being taken by compounds introduced by the solution from the intrusive magma in which magmatic differentiation had been active in effecting a partial concentration. Thus the ore-deposit was formed by the replacement of the material of the original sedimentary rock by metallic and non-metallic compounds derived from the adjacent intrusive igneous rock-mass. It is clear from the minerals formed as a result of this action that the deposit must have been formed at a high temperature. The magnetite is, of course, a primary mineral, and there is nothing to indicate that the nature of the deposit would change in any of its essential features if it were prospected at a greater depth.

E.—NICKEL ORES.

At one locality in the district (Trial Harbour) a deposit of nickel ore occurs, on which a small amount of work has been done.

Details of the work carried out are given elsewhere.[174] As remarked there, it is unfortunate that very little information is available concerning the results of this work.

The ore present is mainly pentlandite (sulphide of nickel and iron, Fe Ni S), with a small amount of pyrrhotite, these minerals being closely associated with magnetite. The minerals occur in serpentine on Section 892-M, 80 acres, originally granted as a nickel reward section: it is about one-half mile east of Trial Harbour.

Serpentine from the locality has been previously described,[175] and a microscopical examination has shown that abundant residual fragments of olivine are present, indicating that the serpentine has been derived from a peridotite: brucite [magnesium hydrate, Mg $(OH)_2$], and magnetite are present in the slide examined.

Secondary minerals are well developed in the serpentine exposed by the workings; these are described in more detail elsewhere,[176] but may for convenience be briefly enumerated at this stage. Those determined were arragonite, calcite, magnesite, dolomite, selenite, brucite, deweylite, chrysotile, opal, chalcedony, limonite, pyrolusite, and magnetite.

The secondary nickel mineral garnierite (hydrous silicate of nickel and magnesium) is also present.

A close examination of various specimens (which carry up to 20 per cent. nickel) shows that pentlandite is fairly well disseminated through the specimens. It occurs in minute grains, in granular aggregates, and in vein-like streaks, always closely associated with granular magnetite. The mineral is light bronze-yellow in colour, has a hardness of about 4, bronze-coloured streak, and metallic lustre. Some grains show cleavage faces: it is non-magnetic. A few particles of a mineral which could not be distinguished with certainty from the pentlandite were found to be magnetic: these are doubtless pyrrhotite: they also react for nickel as well as for iron. The pyrrhotite also appears to be intimately associated with the pentlandite.

The assay results of samples taken from the heaps of ore at the mouth of the adit and from the face of the drive are interesting:[177] they show that some of the ore is high grade, and that the serpentine is nickeliferous in places where no nickel minerals are noticeable in the rock.

As there is no well-defined ore-body exposed in the present workings it is important to try and determine what

[174] *Vide infra*, pp. 415–421.
[175] *Vide supra*, p. 54.
[176] *Vide supra*, pp. 41–47.
[177] *Vide infra*, pp. 418, 419.

factors govern the distribution of the ore in the serpentine rock.

There are no noticeable walls: the "ore" apparently merges into the serpentine, and it will be shown that in reality the terms are interchangeable, and that the nickeliferous rock is a variety of serpentine.

On examining the available workings (which are described elsewhere)[178] one is immediately struck by the abundance of secondary minerals developed in the serpentine. The rock is traversed in all directions by veinlets carrying these (mostly calcium and magnesium) minerals: many of them are stained with green garnierite (hydrous silicate of nickel and magnesium). In view of these facts, one is faced with the question as to whether the deposits of nickel ore can be of secondary origin. The garnierite certainly is secondary, but the writer is referring more particularly to the deposits of pentlandite: can the rich ore which does exist in places, be the result of the precipitation of sulphides from solutions which have gathered their nickel content (just as other solutions have gathered their magnesium and calcium content) from the serpentine rock? The question is an important one.

At one spot in the No. 1 Adit,[179] where pentlandite is fairly abundant in the serpentine, it is seen to occur also included in veins of green deweylite which traverse the rock. This occurrence in a mineral which is undoubtedly secondary does not at first sight appear to be consistent with a theory of primary origin for the pentlandite. A closer examination, however, shows that the deweylite sometimes replaces the serpentine, and hence the sulphide mineral contained in the serpentine would remain unaltered and entirely included within the secondary deweylite when that mineral replaced the serpentine.

On the whole, the evidence appears to point to the primary origin of the pentlandite, and the writer is of opinion that the nickel was present in the original magma, crystallising as pentlandite in the original basic rock (peridotite), and remaining in that form during the subsequent serpentinisation of the rock-mass.

Its close association with pyrrhotite, a primary mineral, and with crystals of magnetite, strengthen this conviction.

Recent authorities do not appear to regard pentlandite as a mineral which is deposited in zones of secondary enrichment, but rather as a mineral which usually crystallises from the magma as an original rock constituent, although

[178] *Vide infra*, pp. 415–421.
[179] *Vide infra*, p. 417.

it may in some cases be deposited from solutions injected into fissures in the solidifying rock, the metallic compounds having accumulated in these solutions owing to the action of magmatic differentiation.

In his "Genetic Classification of Minerals,"(180) William H. Emmons places pentlandite among the minerals which occur in igneous rocks, and doubtfully among those which occur in deposits of moderate and shallow depth, with igneous rocks near by: according to this authority it is not known to occur in deposits formed under any other conditions.

Thus the pentlandite may be regarded in this case as a true primary mineral, and one which is really a rock constituent just as the olivine is.

It remains to refer to the distribution of the pentlandite in the serpentine. The factors determining this distribution are uncertain; it is clear that a concentration has taken place in certain localities, while in others the mineral is almost if not entirely absent from the serpentine. This local concentration, however, does not appear to be connected in any way with vein-forming processes: there is no well-defined lode-channel which can be recognised and followed in prospecting operations. The uneven distribution of the ore has been determined by the operation of the processes of magmatic differentiation which were active in the molten magma. Under the action of these processes, certain of the more basic constituents, with certain of the metallic compounds present in the magma, tended to segregate, and while this action was still proceeding, cooling of the magma continued, and eventually the whole mass solidified. Thus the nickel ore is included in the rock-mass in bodies of irregular shape and size, and no forecast can be made as to the extent or distribution of the ore-bodies.

F.—IRON ORES.

The primary iron ores of the district are not of economic importance.

Irregular masses of magnetite occur in the serpentine, but not in sufficient quantities to prove of any value as a source of iron ore on a commercial scale.

At intervals round the edges of the granite *massif*, contact metamorphic deposits have been developed, and in most of these, magnetite is abundant. As magnetite carries up

(180) "Economic Geology," Vol. III., No. 7, Oct.-Nov., 1908, p. 620.

to 72 per cent. of metallic iron, it is highly prized by iron smelters as an iron ore, when deposits of sufficient size occur free from deleterious substances. Hence these magnetite deposits were examined. It was found, however, that with the exception of the deposit at the Tenth Legion Mine, Comstock (briefly referred to below), none of the contact ore-bodies was likely to prove of value as a source of iron ore.

On Section 1392-M, about three-quarters of a mile east-south-east from Mayne's Tin Mine, is an occurrence of wolfram-bismuth ore, associated with magnetite and pyrrhotite. The property is described elsewhere.(181) The magnetite in this deposit is associated with sulphides, and does not occur in sufficient quantity to be of any value. A few chains to the north-east of the workings is an exposure of a body of dense magnetite with limonite, on which is an old prospecting shaft a few feet deep. The quality of the surface material appears good, but it is probable that sulphides will be encountered at no great depth, although the magnetite itself is primary. The extent of the deposit could not be determined, as the outcrop occurs on a hillside covered with dense scrub. The situation is rather inaccessible with present facilities, and it cannot be said that this deposit presents sufficiently promising features to warrant exploitation as an iron ore.

On the Agnew Creek, north of the Trial Harbour Road, and near the pack track to the Federation Mine over the southern slopes of Mt. Agnew, is a contact metamorphic deposit in the slates, almost at the contact with the intrusive granite. A more complete description of this deposit is given elsewhere,(182) and although magnetite occurs in granular aggregates and more or less lenticular bands, it is associated with sulphides, and in small quantities only, and cannot be regarded as of economic importance.

On Section 6667-M, charted in the name of H. D. Marsh, and situated about 2 miles east of Mt. Agnew, and to the north of the Trial Harbour Road, is another contact metamorphic deposit which appears to have been regarded as a possible source of iron ore. The work done on this deposit is described in a later part of this report.(183) The width of the deposit as exposed varies from 8 to 15 feet. Magnetite is abundant, and is associated with sphalerite, a little pyrite, and lime-silicates. Pure masses of magnetite a few inches in width do occur, but as a rule more or less sphalerite is

(181) *Vide infra*, pp. 399–401. (182) *Vide infra*, pp. 409–411.
(183) *Vide infra*, pp. 412–415.

present. The small width of the pure magnetite bands, and the presence of sulphides of zinc and iron, preclude the possibility of the ore being utilised for its iron content.

On the same section, which is covered with very dense (and in places impenetrable) scrub, other magnetite-bearing deposits occur, as indicated by the erratic behaviour of the compass needle, and other deposits may possibly be located which will prove of more value than the one referred to above.

About a mile north-north-west of Section 6667-M described above, is an important deposit of iron ore at the Tenth Legion Mine. Since this mine belongs to the Comstock district, it is not proposed to refer to it in detail in this report. It has been previously described by officers of the Geological Survey, and the reader is referred to these reports for further information.([184]) At this mine there is a large deposit of magnetite with some lime-silicate minerals, but where exposed, the ore is free from sulphides, and carries no minerals which could be regarded as detrimental to its use as an ore of iron. The magnetite is certainly primary, and the formation is a contact metamorphic deposit. Small amounts of sulphides may be found below water-level, but there is no indication of their presence on the surface, and if a local demand arises for iron ore, this deposit is certainly worthy of attention.

(4)—Alteration of the Wall-Rock by the Mineralising Solutions.

In dealing with the alteration of the wall-rocks of the lodes by the mineralising solutions, it seems advisable for the sake of convenience to deal separately with the ore-bodies in igneous and in sedimentary rocks, since the effect produced has been different in each case. This is not surprising when the differences in the two classes of rocks are kept in mind, these differences being due to texture, mineralogical composition, and chemical composition, the two latter being of course to some extent inter-dependent. Variations in the nature of the mineralising solutions, and in the conditions under which those solutions have been in contact with the wall-rock, will in certain cases produce different effects on any given rock.

([184]) "Report on the Iron and Zinc-Lead Ore Deposits of the Comstock District," by G. A. Waller, 1903, pp. 3-10, 14-16. Also Geol. Surv. Tas. Bulletin 8, pp. 48, 49.

(*a*) *Ore-bodies in Igneous Rocks.*—This question of the alteration of the igneous rock when the latter forms the wall of the ore-body has in reality been referred to in dealing with the different types of ore-bodies. In the case of the granite, it has been seen that the alteration has been intense, and that much of the ore is in reality granite which has been altered by the mineralising solutions. This is the "vein-rock" of the tin veins. Vapours ascending by narrow fissures not only deposit their load of metallic and non-metallic compounds, but under the conditions of high temperature and probably high pressure, which existed at the time, the chemical activity of the solutions was intense, and the granite forming the walls of the fissure was attacked. The felspars and mica of the granite succumbed to these attacks, and were replaced in different cases by tourmaline, quartz, white mica, pinite, cassiterite, pyrite, and small amounts of other metallic minerals. The original quartz of the igneous rock usually remains unaltered. The amount of this alteration varies considerably in different cases. The simplest is that in which a silicification has taken place, with perhaps a slight tourmalinisation, in which even the felspars and mica have not been completely altered. In the extreme case, the bulk of the rock is formed of irregular masses of tourmaline and quartz, the former mineral occurring in radiating masses, the latter forming the groundmass, and the whole rock being altered to such an extent that no trace of the original structure of the igneous rock is retained. Various intermediate types are to be found, in which the alteration has been more or less intense.

Occasionally the felspars have been replaced by tourmaline needles in such a way that the crystal form of the felspar is retained, although the pseudomorph is composed of aggregates of tourmaline with small amounts of quartz: cassiterite may also be present. This structure, although noticeable in a few cases, is not so well developed as in the Stanley River district, where similar vein-forming processes have been active.([185])

The extent to which this alteration has extended in the granite on either side of the central fissure by which the vapours and solutions have been introduced, varies considerably: it may be only about an inch, or as much as 6 feet. In the true veins the alteration is usually more intense near the central fissure, and becomes less marked as the vein-rock merges into granite: in the case of those

([185]) *Vide* Geol. Surv. Tas. Bulletin 15, pp. 32, 104-106.

deposits which are more nearly related to igneous dykes, this difference is not appreciable, and when examined in detail it is seen that the boundaries of the deposit are well defined, and that the adjoining granite is little altered, *i.e.*, the true wall-rock in these cases has almost escaped alteration. Intermediate types exist, but the difficulty of distinguishing between veins and dykes has been discussed elsewhere.([186])

The presence of cassiterite and other metallic minerals has been mentioned. These minerals are present in varying amounts, and minerals developed in the wall-rock of one vein may be entirely absent from that of another. Of the minerals which accompany cassiterite, pyrite is the commonest: the others have been enumerated in describing the vein-types. The abundance of the metallic minerals in the wall-rock adjoining the veins varies directly with the distance from the vein. While there may be rich values in the wall-rock actually adjoining the central vein, these may die out altogether a few inches away in the granite, or they may extend for several feet. There is usually an appreciable development of cassiterite in the wall-rock, even when this does not show signs of intense alteration: this is shown by the results of assays of samples from different localities.

It is not unusual to notice that the granite in the neighbourhood of the tin veins is a good deal softened, and a close examination shows that this softening is due to a partial or complete kaolinisation of the felspars of the wall-rock, where these have not been replaced by the mineralising solutions. This alteration is undoubtedly partly due to the action of surface waters carrying carbon dioxide in solution, but it may also be due in part to the action of the mineralising solutions.

Mention has been made only of the alteration of the igneous rock in the case of simple fissures. It sometimes happens, however, that several parallel fissures have each allowed of the introduction of mineralising solutions. Alteration of the granite has proceeded outwards from each of these fissures as indicated above, with the result that a broad mineralised zone has been formed. It is interesting to note, however, that in some examples of this class of mineralisation, the alteration has been different from adjacent fissures: in one case tourmaline may be abundant and no mica noticeable, while in another mica may be abundant and tourmaline quite subordinate in amount.

([186]) *Vide supra*, p. 81.

This is not difficult to explain, however, for the minerals developed in any given rock by mineralising solutions must depend upon the composition of those solutions (as well as upon temperature and pressure), and a variation in the solutions from point to point is to be expected. It is this variation which has resulted in the formation of different minerals adjacent to different fissures.

(*b*) *Ore-bodies in Sedimentary Rocks.*—The alteration of the wall-rocks by mineralising solutions when the rocks are slates and sandstones, has been different to that of the igneous rocks.

In the case of veins of the various types described, the noticeable effects are silicification and tourmalinisation. The locality where these effects are best seen is at Mayne's and the Kelvin Mines. Here it is seen that the composition of the rock has largely determined the nature of the secondary alteration which those rocks have undergone. Where they have been fairly pure sandstones, the rocks have been hardened and silicified, and occasional vughs of crystalline quartz developed. When interbedded with more argillaceous bands, the latter are replaced by black tourmaline, while the arenaceous bands are silicified. The result of this action is that some of the wall-rocks are remarkably banded, alternate bands consisting of white quartz and black tourmaline. The extent of this alteration is very variable, and is determined, at least in part, by the intensity of the vein-forming action in the main fissures which have given action to the solutions. Thus in some instances narrow veinlets of quartz and tourmaline, less than one-half inch in width, were seen cutting across the bedding-planes of the sedimentary rocks, and extending outwards from these were bands of black tourmaline (replacing argillaceous strata), tapering out within a few inches of the fissure. With some of the more important quartz-tourmaline veins, however, the alteration extends for several feet into the surrounding rock. It is worthy of note that garnet is developed rather abundantly at some points in the vicinity of the ore-bodies in this locality, but this may be a contact metamorphic mineral, developed by the intrusion of the huge mass of granite a few chains away.

In addition to quartz and tourmaline, small amounts of cassiterite and pyrite are sometimes developed in the sedimentaries which form the wall-rocks.

With regard to the contact metamorphic deposits, several of which occur in the district, the alteration of the wall-rocks is different. The various deposits are described else-

where, and from what is said there, it will be seen that in most cases the " walls " of the deposits are indefinite, and it is not always easy to say exactly where the deposit ends and the true country-rock commences. In several cases these are replacement deposits, and certain bands of the country-rock are completely replaced, while others, alternating with the former, are little altered. Thus there may be a gradual merging into the country-rock. Again, these deposits usually occur in close proximity to the granite, and in a region in which the whole of the country-rock is metamorphosed, so that it is very difficult to determine which of the secondary minerals developed in the sedimentaries are due to the contact metamorphic effects of the granitic intrusion, and which are due to the action of the mineralising solutions. Chlorite is fairly abundant in one instance, while in most cases various lime-silicates (tremolite, diopside, lime-garnet, &c.) are present more or less abundantly, and it would appear that portion at least of the lime and magnesia entering into the composition of these minerals has been introduced by the ore-bearing solutions. Amphibole and biotite, which are also present in some cases, may have been developed by the mineralising solutions.

(5)—The Structure of the Lode Formations.

(*a*) *General.*—On the whole, the structure of the lode formations of the district is comparatively simple, and has occasioned the mining companies concerned little trouble. In a few exceptional cases, however, the structure is more complex, and the structural features have not been quite so readily interpreted.

It is proposed to first touch broadly on some of the general structural features, and then deal more in detail with particular vein-types.

With regard to continuity to depth, always a question full of interest to the mining community, and one of vital importance to the permanence of the field, indications are very favourable so far as the tin lodes of various types are concerned. From the discussion of the genesis of the deposits elsewhere in this report, it will be seen that the writer's opinion is that both granite and ore deposits are intimately related, in that both are believed to have been derived from the same intrusive igneous magma. The outer crust of the granite mass is held to have first consolidated, and into fissures formed in the cooling rock probably by

contraction, metallic compounds with vapours and solutions at a high temperature, and of intense chemical activity, were injected from reservoirs deep in the heart of the igneous mass, where they had collected under the action of differentiation processes. In many cases the vein-forming processes continued not only to the border of the igneous rock-mass, but still further outwards into the surrounding sedimentary rocks. From this general statement it will be seen that where tin veins occur in the sedimentary rocks adjacent to the igneous contact, as, for example, at Mayne's and the Kelvin Mine, the tin values may be expected to continue not only to the contact with the granite, but into the heart of the granite mass itself. It will be clear from what has been said that there will be a downward limit to the tin veins in the granite itself, but that this limit will be at a very considerable depth below the original surface of the granite; measured from this surface, the limiting depth would not be likely to be reached by mining operations. In the long period which has followed the cessation of igneous activity, the cover of overlying rocks has been partly removed by erosion, and in some cases the granite itself deeply dissected. The question then arises: " Has the granite been eroded so deeply that only the stumps of the tin veins are left?" The question is an important one, and deals directly with the structure of the tin veins. It is not possible to say with any degree of accuracy the amount of erosion which has actually taken place, but from a study of the area the writer is of opinion that the structure on the whole is favourable to the continuance of the tin ores to considerable depths below the present surface. The granite has been deeply dissected in places by the various streams, and where outcrops have been exposed by such dissection, there is no appreciable change in their character, from the exposures on the higher ground several hundred feet above.

The occurrence of minerals such as sphalerite and galena in some quantities in certain of the deposits as described elsewhere([187]) is to be regarded as a favourable indication as to the probable continuance of the tin ores to a depth, for the occurrences are interpreted by the writer to indicate a partial overlapping of the zones of high and moderate temperature minerals, as discussed in another part of this report. Should this interpretation be correct, the occurrences noted must be taken to mean that denudation has removed the bulk of the deposits formed in the upper zone

([187]) *Vide supra*, pp. 162-168, 182-184.

(situated mainly in the sedimentary rocks overlying the granite, these sedimentaries having also been largely removed), and that the mineral deposit is likely to continue to considerable depths below the exposed outcrops which have been located.

Thus the structure of the tin veins is apparently favourable for their continuance to depths beyond the reach of economic mining.

Another important aspect of the question of structure is the influence of faulting of the lodes. Little definite information is available on the subject, owing to the comparatively small amount of developmental work carried out. Up to the present time, however, none of the workings have disclosed any appreciable faults, although some of the surface outcrops appear to be displaced a few feet. This is the case on the Federation Mine, in the central and south-western portions of the property, where quartz-tourmaline outcrops can sometimes be traced for a considerable distance, when they apparently disappear, button-grass covering the surface, and fresh outcrops of similar material may reappear a few feet to one side or the other of the line of strike. These dislocations are of small extent on the surface, and so far as can be judged from information available, faulting has not occurred to such an extent as to impair the value of any of the known ore-bodies.

(*b*) *Veins.*—Dealing with the tin ores more in detail, the internal structure of the various types of veins has already been described, and the minerals occurring in the central portion or vein-stone, as well as in the ore bordering this central vein, which has been called the vein-rock.([188]) In most instances where the various types are developed in the granite the structure of the deposit as a whole is not complex, being that of a simple vein. In some examples several fissures more or less parallel, sometimes uniting, form a lode system rather than a vein. In such cases strips of granite between adjacent veins of the system may be so altered as to form lode material.

An example in which the mineralogical composition is that of the quartz-tourmaline-cassiterite veins, but in which the structure is not that of simple vein-stone and vein-rock, is to be found in the case of Gray's Lode, on the Federation Mine. This is referred to elsewhere, but as the occurrence is unlike any other so far opened up, it merits detailed description. The striking features are that rich tin occurs

([188]) *Vide supra*, pp. 153–171.

in a laminated quartz-tourmaline stone, and that throughout the whole of the sections exposed, although black tourmaline is abundant, no green tourmaline is to be seen—an unusual feature of the ore-deposits in this district. There are two trenches, each cut partly across the formation, one slightly lower down the hillslope than the other, the two being only a few feet apart.

In the lower trench the western zone for 6 feet is characterised by the presence of muscovite mica, and carries a series of parallel threads of tourmaline in a yellowish groundmass of greisen. These threads sometimes cross each other, but it is evident that impregnation has spread outwards from a central fissure to a rather variable extent. This greisen merges into a hard white quartzose variety of lode material with a little black tourmaline. The quartz often shows idiomorphic outlines. The tourmaline is present in scattered crystals and aggregates, in well-defined nodules, and filling minute fissures which cut through the rock in all directions. A study of these tourmaline-filled fissures shows that they generally intersect without displacement; sometimes, however, there is a noticeable displacement. Two veins may unite for a short distance and then separate again; at times there is a marked development of tourmaline, extending for several inches, at the intersection of two minute veinlets, showing that the action has been intense at this point. This fact is significant.

In the face of this lower trench is exposed soft, partially-decomposed, iron-stained granite of fine-grained texture, cut through by veinlets of black tourmaline.

In the upper trench, 6 feet further south, this section is practically continued, with a slight overlapping at the lower end, where the tourmaline-bearing white quartzose lode material is exposed, followed by decomposed iron-stained granite with tourmaline veins. Some portions are micaceous, and on the southern wall of the trench in particular is a mass of yellowish greisenised granite, cut through by abundant quartz-tourmaline veins, extending for 10 feet. From this point to the face there is abundant black tourmaline. This occurs in masses of irregular shape, up to 3 feet in width, with occasional masses of white quartz, which evidently represent a later filling of cavities in the earlier-formed tourmaline. These masses of quartz are lined with glassy prisms of quartz which project inwards, showing that they are true geodes. Many of the prisms are doubly terminated, resting loosely on earlier-formed crystals. It is noteworthy that some of the geodes are lined with chalce-

dony, showing a botryoidal habit, this in turn being in some instances encrusted with transparent quartz crystals. Most of the quartz crystals in these geodes are less than one-half inch in length, and less than one-eighth inch in diameter.

The quartz forming the base on which the crystals rest is penetrated by abundant finely crystallised prismatic needles of tourmaline. These show terminal faces, and have crystallised out on the inner lining of a cavity which has afterwards been filled with quartz, including the projecting crystals already formed. It is very noticeable that the masses of black tourmaline are edged on either side by white quartz with a very little disseminated black tourmaline. The quartz is crystalline in structure. On the edge of the quartz and tourmaline one geode was noticed with a little white mica and abundant crystals of cassiterite. A good deal of tin oxide was noticed, too, very finely divided, and forming threads and strings with quartz in the black tourmaline.

Beyond the white quartz on either side are bands of quartz-tourmaline stone, the two minerals being present in about equal proportions, the tourmaline in some cases evidently replacing the felspar of the original granite, and being pseudomorphous after it.

The quartz-tourmaline in turn merges into decomposed coarse-grained granite.

It will thus be seen that there is a decided crustified structure noticeable in this lode.

In one instance the quartz-tourmaline veins splits, and encloses a lens-shaped block of granite, which appears quite normal in character, although weathered.

The examination of a thin section of a piece of the richer tinstone (the material which has been called a " laminated quartz-tourmaline " on account of its banded structure) shows that only three minerals are present—tourmaline, quartz, and cassiterite. The tourmaline is in single idiomorphic crystals, and in groups of prismatic crystals, which tend to arrange themselves in radiating clusters. These crystals are both brown and blue in colour, and frequently show zonal banding. The tourmaline has evidently been the first mineral to crystallise, for the whole slide is traversed by numerous parallel veinlets of quartz, which cut through the tourmaline crystals. It is mainly in these veinlets that the cassiterite occurs. It is in fine grains and granular aggregates. The cassiterite may in a few cases replace the earlier-formed tourmaline in the vicinity of the quartz-filled fissures.

Regarding the structure of the formation as a whole and its mode of origin, it would seem that there have been several distinct periods of mineralisation, caused by vapours ascending through the same main fissure. These mineralising vapours being under very considerable pressure appear to have forced aside the walls, giving space for free crystallisation of the various minerals. This would account for the crustified structure noted. From the blocks of included granite and the ramifying nature of the quartz-tourmaline stone, it seems that mineralisation has taken place from several fissures, probably all connected, thus giving the deposit the character of a lode system rather than of a simple vein.

The structure of veins of most of the types described appears to be modified to some extent by intersecting fissures where such occur. Where a cross-fracture has intersected the main solution-bearing fissure, there has usually resulted a local bulge of ore at the intersection, which may or may not carry tin values above the average. It seems likely that the big body of ore developed on the highest portion of the Federation property, and known as the Black Face Lode,([189]) has been formed in this way at the intersection of two well-defined veins of the quartz-tourmaline-cassiterite type. Little is known of this large ore-body at depth, but it should repay prospecting, as it carries rich tin in places near the surface.

The structure noted above for the tin-veins in the granite does not vary in essentials for the different types of veins described.

The absence of a central vein from some formations, and the apparent merging in some cases from this variety to formations which are fairly homogeneous in mineralogical composition and texture, have been dealt with elsewhere.

In dealing with the tin deposits developed in the sedimentary rocks, the structure is not quite so simple as in the case where similar vein-types are developed in the granite. The reason for this is to be found mainly in the structure, and to a much smaller extent in the composition, of the sedimentary rocks. The only examples available for inspection were at Mayne's and the Kelvin Tin Mines, adjoining properties described in detail elsewhere, situated at the contact of granite and slate country. Owing to the very irregular nature of the work carried out, and the covering of some of the exposures with spoil heaps, full details of the structural features of the lode formations could not be

([189]) *Vide infra*, p. 272.

unravelled, although some interesting and important features were observed. The clue to the general structure of the deposits is given by a study of the wall rocks. The action noticed there repeatedly on a small scale has taken place on a larger scale under more favourable conditions, with the result that ore deposits of commercial value have been formed

The country rocks are slates and sandstones, and they are much altered in the vicinity, owing partly to the contact metamorphic action of the adjacent granite and partly to the action of the mineralising solutions. It not infrequently happens that a narrow vein of tourmaline or quartz and tourmaline cuts across the bedding-planes of the sedimentary rocks. When this happens the effect on alternate bands of the sedimentary is very different. Siliceous bands show little sign of alteration, but argillaceous bands are invariably altered, and partly replaced by tourmaline, in the vicinity of the main fissure. The extent of this tourmalinisation of the argillaceous bands varies considerably; in some cases the cross-fissures are of minute size only, and it is noticed that the tourmalinisation of the argillaceous bands extends for less than 1 inch along the bedding-planes. As the cross-fissures increase in size, the alteration of the argillaceous beds become more intense, and extends for a greater distance along the bedding-planes from the cross-fissure. A noticeable feature, too, is the development of irregular bulges and bunches of tourmaline at the point of intersection of cross-fissures with the bedding-planes of the sedimentaries. These features, in the writer's opinion, give the clue to the general structure of the ore deposits, which cannot be worked out in detail in the present condition of the old workings.

The occurrence of ore in the worked-out portions of the deposit appears to have been in the form of nearly horizontal veins of green tourmaline, which widened at intervals to form "vughs," which usually carried rich tin values. Some of these vughs are described as having been "large enough to turn a horse and dray in." Most of the tin won from the mining operations on the property appears to have been derived from these vughs, the cassiterite being mostly fine, but as much as 15 bags being won from one vugh. The vughs contained green tourmaline and kaolin with some limonite (probably derived from the decomposition of pyrite), the cassiterite being both botryoidal and as slime. Crystalline quartz also appears to have been present. From descriptions given of the work carried out, it would appear that vughs occurred not only on one, but on several, distinct

flat veins of tourmaline, that the nature of all was similar, and that all carried rich tin.

In addition to these flat veins with their vughs, nearly vertical formations occur, and have been partly opened up, which are really normal quartz-tourmaline-cassiterite veins There is a central seam of fairly massive green tourmaline with quartz and cassiterite, forming the vein-stone, bordered by vein-rock of quartz and black tourmaline, carrying also a certain amount of green tourmaline, with geodes lined with quartz, and sometimes carrying cassiterite. The width varies considerably, and bulges of considerable size occur at intervals. In the tunnel driven through the hill narrow veins occur similar in character to those mentioned above, and carrying cassiterite, forming, in the writer's opinion, the downward continuation of the same veins.

In view of these features of the particular deposit under review (which is described more fully in another part of this report,[190]) the writer submits that the general structural features of the deposit can be explained. Details remain to be worked out when further exposures are available.

The deposit is certainly genetically connected with the adjacent granite. The intrusion of the latter had heated the adjacent and overlying sedimentary rocks to a high temperature, and as the igneous rock-mass gradually cooled and consolidated, the adjacent sediments also cooled, and necessarily contracted. The strains set up by the contractional stresses resulted in a fissuring of the sedimentaries. During the final stages of consolidation of the granite, when vein-forming processes were active, mineralising vapours and solutions which had ascended through cracks in the consolidated outer crust of the granite penetrated the overlying sedimentaries also, along these previously-formed fissures forming the main tin-bearing veins. As the fissures in many cases intersected the original bedding-planes of the sedimentary rocks, certain of the beds of the latter in the vicinity of the main feeder (as the vertical fissure may be called) were attacked by the vein-forming solutions, and more or less completely replaced for considerable distances, forming vein-like masses corresponding approximately with the strike and dip of the sedimentary rock. The tendency of bedding-planes to form paths for the solutions in a series of sedimentary rocks has also been a factor in the formation of these flat veins, the sedimentary rock on either side of the bedding-plane being more or less completely

([190]) *Vide infra*, pp. 368-383.

replaced. But this process has been complicated by the occurrence of intersecting fissures, which appear to have had an important effect on the formation of the ore-bodies. In some cases fissures more or less approaching the horizontal, yet cutting across the bedding-planes of the sedimentaries, have intersected the feeders, and have been traversed by the mineralising solutions, forming offshoots from the feeder, with the formation in some cases of a " vugh " of ore at the intersection of the fissures, and of smaller vughs at the intersection of this flat fissure either with certain beds of sedimentary rock or with other more nearly vertical fissures.

The intersection of two fissures about vertical appears to have been responsible in some instances for the formation of pipe-like bodies of ore, or of bulges in the main feeder.

That some such process of replacement of the country-rock as that indicated has taken place in the formation of some of these bulges of ore is evidenced by the occurrence of unreplaced country-rock in blocks of irregular shape, faced with crystals of quartz and tourmaline, entirely surrounded by quartz-tourmaline lode-material.

Thus the writer would contend that the present structure of the deposit under consideration is due mainly to the structural features of the sedimentary rocks, and partly also to their chemical composition.

The processes enumerated above appear to have been operative also in the ore-bodies on the adjacent property, the Kelvin Tin Mine, so far as can be judged from the available exposures, and little need be added to what has been said in connection with Mayne's Mine. On this property there is at least one quartz-tourmaline-cassiterite vein which appears quite normal in character, and which appears to run continuously from the sedimentary into the igneous rocks. It has not been exposed at the actual junction, but the corresponding strike of various outcrops, both in slate and granite, indicates that the vein is continuous. A little prospecting work at the contact on the line of strike would yield some interesting and probably useful information.

With regard to the nature at depth of the deposits described above as occurring on Mayne's and the Kelvin Mines, it is interesting to note that if the deposits are exploited to a depth, it is not unlikely that granite may be encountered within the limits of economic mining. In the writer's opinion the main tin-veins will be found to be continuous from slate into granite, and to continue to considerable depths into the heart of the granite itself. This

opinion is based on the information available as to the mode of origin of the tin-veins discussed elsewhere. As to whether tin values are likely to prove high enough as depth is attained to pay for working, no forecast can be attempted. This is a matter which prospecting alone can decide. It may be stated, however, that there is no reason to believe that tin values will decrease within the depths which are likely to be reached by mining. It is possible that rich ore may be located at the line of contact between the two rocks, as the physical conditions may have been such as to allow of the entrance of mineralising solutions, which would then attack one or both of the rocks forming the walls, partly replacing them and depositing part of their metallic burden. On the other hand, at some points along the junction the slate has been intensely altered, and partly assimilated in the granite at the actual contact, and the " welding " of the two rocks (themselves so distinct in their mode of origin) is so complete that in the absence of a subsequent fissure the veins would be expected to pass from slate to granite through the contact without any appreciable enrichment of ore. The structural features of the deposits would not be expected to exhibit any marked changes in the sedimentary rocks, but in the granite the tendency would be for the structure to become simpler, and the veins to show normal characteristics.

(*c*) *Pipe-formations.*—Turning to the stanniferous pipes in the granite, of which only one example (on the Federation Mine) is available for inspection, the structure is seen to differ very materially from that of the tin-bearing veins described above. Details have already been given of this pipe, and reference made to its mode of origin and necessarily to its structure. Its most marked feature is its irregularity. Throughout the total length over which it has been prospected, it has been found to vary considerably in size and also in shape. But this variation is marked not only on the cross-section of the pipe, but laterally as well. Its course through the granite is essentially a tortuous one, and it is apparently impossible to predict what turns may be taken within a few feet. The mode of origin has already been discussed, and the opinion expressed that the pipe has been formed by chemically active vapours and solutions rising through previously consolidated and fissured granite. The presence of fissures intersecting at various angles seems to have been at least partly responsible for the structure of the pipe, and for the formation of the branch pipes which are known to occur. It seems possible, however, that in

some places the pipe results from the alteration of solid granite, and that fissures have played a very subordinate part, if any, in its formation. The shape of the cross-section, which not infrequently shows a marked tapering out on opposite sides, clearly indicates that fissures have played an important part in determining the structure of the formation, by affording a ready passage to solutions rising under pressure.

While there can be little doubt about the permanence of the deposit to considerable depths within the granite, no forecast can be made as to the structure of the pipe at greater depths than it has already been prospected. It is likely to continue irregularly through the granite, varying considerably in size from point to point. An attempt was made by the writer to determine whether there was not a series of fissures at whose intersection the ore-body was formed, so that by plotting these some forecast could be made as to the probable course of the pipe, but this was found to be impracticable, since, as stated above, in certain parts of its course there is no clear evidence of fissures having played an important part.

(*d*) *Contact Deposits.*—Little need be said with regard to the structure of the contact metamorphic deposits of the district, as so little work has been done upon any of them up to the present. Such deposits are notably irregular in structure, and may vary very considerably within a short distance. The structure of such deposits in sedimentary rocks near igneous contacts, is worthy of note. As they have been, unlike the normal tin veins, formed prior to the consolidation of the granite, it is to be anticipated that if followed to a depth they would be found to cut out when the contact between igneous and sedimentary rock was reached: in the case of the tin veins, the deposits are continuous.

Should prospecting be carried out on any of these deposits, their irregular nature should be kept in mind, and the deposits tested even beyond their apparent walls. Blocks of country-rock included within the boundaries of the deposits are sometimes encountered, giving a false impression of the width of the mineralised zone.

The internal structure of these deposits is also somewhat variable, as a general rule, but so little has been done to open up the deposits of this particular district that little detailed information is available.

(*e*) *Magmatic Segregation.*—The deposit of nickel ore at Trial Harbour has been described elsewhere, and little more need be said as to its structure. As pointed out previously, the deposit appears to be a magmatic segregation, and as such it must be expected that it will be irregular in its structure. The ore-body merges insensibly into normal serpentine, without any definite walls, and the writer would maintain that there is no *essential* difference between ore and serpentine, the term " ore " being used to designate serpentine in which the percentage of nickel (occurring in the primary mineral pentlandite) rises high enough to render the rock of economic value. One aspect of the question of the structure of the deposit then resolves itself into an enquiry as to the distribution of the pentlandite in the serpentine, and the causes which have operated to bring about a partial concentration into particular localities. It seems clear that this concentration has been brought about by the operation of forces of which little is known in reality, the forces of magmatic segregation. While the magma was still in a molten state, portion of the nickel originally disseminated through the magma became more or less concentrated by the operation of these forces, and as cooling proceeded the nickel entered into combination with iron and sulphur, and crystallised out to form pentlandite. From this explanation it will be clear that no definite forecast can be made as to the structure of the deposit. The boundaries of the nickel-bearing serpentine are sure to be very irregular, and will vary considerably. Little can be said as to its continuity to a depth. Bodies of payable ore may be found which will continue to considerable depths, or, on the other hand, they may cut out (merging into normal serpentine) at comparatively shallow depths, to be succeeded possibly by other bodies. Thus the structure is likely to prove very irregular, and there appear to be no determining factors to enable any forecast to be made upon which future prospecting work may be based.

(6)—The Secondary Alteration of the Lodes.

It is necessary to say but little under this heading, but there are certain features to which attention should be called in connection with the alteration which the lodes have in some cases undergone. The secondary alteration referred to is the alteration brought about by oxidising agencies, chiefly made effective by actual weathering and the circulation of surface waters. The changes are partly physical and partly chemical, the former being mainly dependent upon the latter.

Tin Ores.—As a result of the attacks of weathering agencies both on the exposed outcrops and on the containing granite, the granite usually weathers and disintegrates much more rapidly than the quartz-tourmaline veins, leaving the latter standing out in relief above the general surface. These exposed masses are then exposed more completely to atmospheric changes, and fissures gradually develop, owing largely to temperature changes. These fissures give access to surface waters which in their turn tend always to decompose the lode material. The result of this action is that fragments are constantly breaking away from the exposed outcrops, and collecting on the hill slopes, finding their way gradually to the watercourses, and thence seawards, some fragments suffering disintegration *en route*, the contained cassiterite being set free, others going to form alluvial deposits, or being carried to the sea, depending on the gradient of the streams. The manner in which the detrital material from exposed quartz-tourmaline outcrops collects on the hill slopes is shown in Photo. No. 3. It is worthy of note that in the granite area, the degradation of the igneous rock is usually more rapid than that of the quartz-tourmaline outcrop (although the latter is being degraded in the manner described above), the net result being that the lode outcrop usually remains exposed above the general level of the surrounding granite.

As described elsewhere, this is really due to the resistance offered by the essential constituents of the lodes, quartz and tourmaline, to the attacks of weathering agencies. It is usually found, however, that there is an appreciable softening of the material forming these outcrops. The tourmaline after long exposure tends to become dull in colour, and distinctly brittle.

One of the most noticeable and economically important of the changes resulting from the secondary alteration of the lodes, is the oxidation and removal of pyrite in the upper zones. This change becomes important because of the simpler nature of the residual lode material, resulting in the production of a higher grade tin concentrate. In the earlier history of the field the presence of pyrite in the ore was held to be almost prohibitive, and instances are on record in which shoots of ore carrying good tin values were neglected because of the presence of pyrite, and in which stanniferous pyritic ore has been dumped as useless, after mining, because of the pyrite. At the present day, although it is recognised that the presence of pyrite is not

an insuperable barrier, owing to improved methods of treatment, it certainly is an unwelcome constituent of the ore, as it adds considerably to the cost of treatment. Thus the fact that under certain conditions part or all of the pyrite may be oxidised and removed from the tin ores near the surface, becomes an important consideration. The presence of pyrite as an essential constituent of the various vein-types has been previously noted. It is not always noticeable near the surface owing to the secondary alteration, and the depth to which this alteration (*i.e.*, oxidation to limonite and complete or partial removal in solution) has been effective, apparently varies considerably in particular cases. In some instances pyritic ore occurs within a few feet of the surface, while in others there are clear indications that pyrite has been oxidised and removed from over 100 feet below the present surface. In the present undeveloped state of most of the properties, it is impossible to make any definite forecast with regard to the ores, but it is certain that the primary ore in some cases in which only quartz, tourmaline, and cassiterite have been observed, will be found to contain pyrite.

No change takes place in the cassiterite itself, and although solution and redeposition have been suggested, there is no evidence whatever for any such change having taken place. The oxidised outcrops may become somewhat richer, bulk for bulk, than the primary ore, because of the removal of the pyrite, although the actual tin content remains about the same: there may be a certain amount of mechanical concentration of the tin oxide, owing to the working down of some of the fine cassiterite set free during the weathering of the exposed outcrops, to lower horizons of the oxidised lode material. It is unlikely, however, that this process has been operative to any great extent.

An interesting development, noted in the case of one outcrop only (on the Federation Mine), is that of chlorite with limonite along the outcrop of a quartz-tourmaline lode formation.

In the case of the tin-bearing pipe described as occurring on the Federation Mine, the true pipe material appears to be much softened and kaolinised near the surface, owing to the action of surface waters. This alteration has been of advantage in working, the extremely soft nature of the material greatly facilitating its extraction. Even the primary pipe material, however, is soft, and offers no drawbacks to easy working.

Wolfram Ores.—Although secondary alteration of the wolfram ore in one locality has been recorded, none was observed by the writer in the course of his examination. In connection with the wolfram-bismuth ore on Section 1392-M, described elsewhere, Mr. W. F. Petterd states:—([191])

"Excellent pseudomorphs, partial and occasionally complete, of this mineral [scheelite] to wolframite are not uncommon at a locality about 1 mile east of south of Mayne's Tin Mine, Heemskirk. They are perfect crystals in form, sometimes only transmuted to a very limited degree; then again the whole substance of the crystals may be changed to the iron-manganese tungstate, in which case they assume the dull surface appearance so generally typical of pseudomorphous action. Some very nice crystals of the pure substance also accompany the rest. These are from opaque to semi-transparent, and of a pale-yellowish colour. With this find wolframite also occurs in excellent crystals both pure and partially so. . . . A yellowish-brown substance may occasionally be detected as minute blebs and veins on the scheelite in connection with this occurrence, which may be and apparently is the hydrated tungstic oxide meymacite (WO_3 $2H_2O$), which is formed by alteration."

In referring to the same find under the heading of wolframite, Mr. Petterd says([192]) that . . . "a very interesting find of partially pseudomorphous wolframite has been made. The crystals of the original mineral are extremely well-formed, of the normal character, and fairly large in size. The whole mass of the crystals is more or less altered to scheelite. Sometimes the planes are faced by a thin layer of the tungstate of lime of a glistening pale-yellow colour, and more rarely one-half of the crystals will appear to be thus transmuted."

It seems clear from this description that the wolfram ore in this locality has undergone secondary alteration. At the time of the writer's examination, however, no specimens of ore similar to that described could be obtained from the old workings, although the presence of wolfram was shown by assays.

In the case of the wolfram ore occurring on the Cumberland Dam plateau, on Section 5426-M, south of the Fede-

([191]) "Catalogue of the Minerals of Tasmania," by W. F. Petterd, 1910, p. 156.

([192]) *Op. cit.*, p. 200.

ration Mine, no secondary alteration of the wolfram is noticeable. Some of the wolfram crystals are dull after exposure to weathering agencies, but there is no marked alteration.

Nickel Ores.—The nickel ore of the district has undergone secondary alteration, with the result that garnierite has been formed, as noted elsewhere. The decomposition of the sulphides has resulted partly in the formation of selenite in small quantities, while garnierite has been formed by the interaction of nickel and magnesium silicate. The formation of encrusting masses of this green mineral has resulted in a certain amount of secondary enrichment of the deposit, as noted elsewhere. Some of the magnetite in the ore is derived from the olivine, being set free in the serpentinisation of that mineral. Limonite is formed in small quantities from the oxidation of the sulphides.

Iron Ores.—The secondary alteration of the primary iron ores is not very important. In the case of the contact metamorphic magnetite deposits, there is usually a small development of limonite, derived partly from the oxidation of contained pyrite, and partly from the decomposition of ferromagnesian minerals, the magnetite itself being little changed, even in surface outcrops. It has sometimes a slight encrustation of hæmatite and limonite.

(7)—Secondary Ore-deposits.

In addition to the primary ore-deposits of the various metals, which have been described in some detail above, there are in different parts of the district secondary deposits of ores to which reference must be made. These will for convenience be referred to under the headings of the different metals. In each case they have been derived from the primary ores: contrary to the experience of the adjoining district to the north, the secondary deposits of the South Heemskirk district have not proved to be of any great economic importance: those of tin have proved to be easily the most important. Although the output has not been large, they have kept a few men employed and have enabled a certain amount of prospecting work to be carried out which could not have been attempted had they been absent.

The title "secondary" as applied to the ores of tin and wolfram described in this section is used for convenience: while the minerals themselves (cassiterite and wolframite)

certainly are primary. Viewed broadly the " deposits " are of secondary origin in that they have been derived from true primary ore-deposits.

A.—TIN ORES.

The secondary deposits of tin ores of the district are not at present of much importance, although they have in the past given employment to a fair number of men, and have yielded a small but fairly continuous output of alluvial tin.

It was the prospecting of the secondary tin ores which first called attention to the Heemskirk tinfield about 40 years ago. The work carried out since that time by individuals and small working parties has been somewhat erratic: a patch of alluvial tin ore would be discovered, a small party formed to work it, and when this patch was worked out, fresh prospecting for a new patch would be initiated.

The secondary tin ores are widely distributed throughout the district in small quantities, but no important deposits have been located. The distribution of the tin is not a difficult matter to explain, when the topography of the district is kept in mind. The Heemskirk Range, which mainly determines the drainage system, is of stanniferous granite, and the degradational forces which have been for long periods wearing down the exposed areas of granite, have freed the contained tin oxide, which has naturally accumulated in the watercourses draining the area.

Nearly all the streams heading in the granite country, and some of those in the slate, carry more or less alluvial tin. In their upper reaches, the grade is usually too steep to allow of any accumulation of the heavy mineral, but when the grade becomes flatter, which usually happens when the stream traverses the old peneplaned surface, conditions are more likely to be favourable for an accumulation of tin ore, and this is actually what has happened. Most of the deposits of secondary tin ores which have been worked have been found to occur in the creeks cutting through the old peneplain. As these streams are young, however, in relation to the present land surface, and are still actively engaged in grading their beds, it could scarcely be expected that any extensive alluvial deposits would occur in the creeks, and it is found to be so in practice: the deposits are usually of small depth and extent, and consist rather of detrital than of true alluvial material.

One of the most extensive deposits of secondary tin ore in the district is that at the foot of the southern slopes of Mt. Agnew, in the vicinity of the Agnew Creek. The average depth appears to be about 4 feet, and the deposit consists essentially of well-rounded boulders of quartz-tourmaline veinstone of various sizes, undoubtedly derived from veins in the granite on the hills above. The flat is fairly extensive, but has been well prospected, and apparently most of the payable patches have been worked out.

The occurrence of secondary tin ore in the upper course of Pyke's Creek, at Sweeney's Mine, where it has collected in the spaces between immense boulders of granite, has been described elsewhere. This cassiterite is detrital, freed by the weathering of the granite.

On the Cumberland Dam plateau several small patches have been profitably worked, and where conditions have been suitable for the lodgment of the heavier material brought down from the dissected granite by the streams, deposits of secondary tin ores have been discovered in most of the consequent streams flowing westward into the ocean. It has been remarked that two classes of material occur in some of the deposits which have been worked in the beds of the creeks cutting through the coastal peneplain, some of it being sub-angular, other well-rounded. In the case of the tin won from these patches, the same feature is noticeable. In some localities well-rounded quartz and quartz-tourmaline gravel, sometimes associated with deposits of tin ore which have been profitably treated by ground-sluicing, have been noticed on the ridges separating adjacent creeks belonging to the present drainage system. These several facts are to be explained by the past geological history of the district. It has already been explained that at the close of a long cycle of denudation, during which the granite itself was dissected, a considerable area of the district was worn down almost to base-level, forming an extensive plain; at this stage the grade of the streams was so flat that the streams were unable to carry to the sea their loads of detrital material derived from the denuded land surface. This material was consequently deposited. A subsequent uplift of this level surface rejuvenated the streams, which once more commenced to actively erode their beds, and as the grade increased much of the material which had previously been deposited was carried seawards, but in places patches were left at a higher level, and remnants are found at the present time on some of the ridges. The thoroughly well-rounded pebbles in the more recently accu-

mulated deposits have been derived in part at least from these old accumulations, which have been cut through and intermingled with the more recent rock waste. Some of the more-rounded nuggets of cassiterite and of tin ore have also been derived from these older alluvial deposits.

With reference to the nature of the tin in these secondary ore-deposits, and its source, it is not surprising to find that in all the deposits worked the tin ore is present partly in single crystals and crystal aggregates of cassiterite free from gangue, and partly in specimen pieces with quartz, tourmaline, or both of these minerals. Although portion of the tin may be derived from scattered crystals disseminated through the granite, freed in the course of denudation of the igneous rock, there can be little doubt that much of the valuable mineral is derived from veins and lode formations, both in the granite itself and in the adjacent sedimentary rocks. It must be borne in mind that the present deposits of alluvial tin represent the concentrates from vast amounts of rock material which have been carried out to sea under the long-continued action of weathering and transportation agencies.

As a rule the impurities occurring with the tin ore are not such as to cause any serious trouble in obtaining a clean marketable product. Tourmaline is always present, but gives the experienced tin-dresser no trouble. Pyrite is sometimes present in small quantities. A little monazite is sometimes noticed. Where the deposits have been derived partly or wholly from the contact sedimentaries, or where the basic igneous rocks have contributed to the drainage of the streams which have been responsible for the formation of the alluvial deposits, magnetite, chromite, and ilmenite may be present in variable quantities. This, however, is rather the exception in the district.

It remains to refer to another class of secondary tin ore which has proved of some importance in the past, and which has distinct possibilities in certain parts of the district, for profitable exploitation in the near future. This is the detrital deposit: the deposits dealt with above have been essentially alluvial depoists. In certain cases no very hard and fast line can be drawn between the two classes, but in others a distinction is justified in the opinion of the writer.

In the case of Mayne's Tin Mine, on Pyke's Creek, a deposit of detrital tin ore was accidentally discovered which was very profitably worked. The tin ore in this instance occurred in the form of angular pieces up to several pounds

in weight, of pure cassiterite and of rich specimen pieces. These occurred with rock *debris* on a hill slope and in the creek below, forming a deposit varying in depth from a few inches to several feet. The surface was stripped and sluiced and disclosed the source of the tin, viz., lode-formations in the country-rock below. The deposits were derived from these lodes in the process of weathering and denudation, some of the lighter rock material being carried to the creek below, the heavier tin oxide forming to some extent a natural concentrate, although the process of concentration had not been carried very far.

On the Federation Mine, again, detrital deposits occur which are likely to pay for working. Some quartz-tourmaline outcrops on the highest part of the property carry good tin values, and the material freed from these outcrops in the course of weathering has accumulated on the hillslopes, gradually finding its way down towards the creeks. This movement, however, and also the natural concentration of the material, are hindered by the growth of button-grass which protects the deposit. A fair proportion of the detrital material is stanniferous, and a good deal of cassiterite has been set free during the gradual decomposition of the lode material. It is probable that some of these deposits will be worked.

B.—WOLFRAM ORES.

Secondary wolfram ores are not, on the whole, of commercial importance in the district. At one locality (on the Federation Mine near the old inclined tramway), a deposit of alluvial of limited extent was worked, and several bags of wolfram ore won. The deposit was of detrital rather than of true alluvial material, and the wolframite won occurred in angular and sub-angular form, up to several pounds in weight. It was associated with a certain amount of tin ore. Although not definitely traced to its source, there can be no doubt that it is derived from a lode-formation in the immediate vicinity. Wolframite has been shown to be a constituent of certain of the vein-types of tin ore, and it is not improbable that shoots of ore may occur in certain of the veins in which wolframite will locally increase in amount until it becomes the predominant, and cassiterite the subordinate mineral of economic importance. In the course of weathering, the wolframite from such an ore shoot would accumulate in the creek beds and gradually find its way seawards.

Wolframite in small quantities may be expected with the secondary tin ores of the district, being derived from the primary tin ores as above, but the writer was not able to hear of any secondary deposits of wolfram ores other than that described above.

C.—NICKEL ORES.

Little need be said under this heading, as the secondary nickel ores of the district have not so far been shown to be of any importance. The presence of primary pentlandite in the serpentine at Trial Harbour has been discussed, and reference made to the presence of garnierite. This mineral, a hydrous silicate of nickel and magnesium, is undoubtedly secondary, and its presence gives some of the ore obtained the impress of a secondary nickel ore.

The serpentine is stained green in places with garnierite, which, however, is not sufficiently abundant to be regarded as an ore of nickel. The mineral occurs as encrusting green masses in places on the weathered surface of serpentine, giving a valuable clue to the presence of primary ore below, as well as in green stainings in the partially oxidised ore.

Sulphides occur in the serpentine almost to the surface, and hence no description of the ore other than that already given under the heading of "Primary Ores" is called for.

About a mile east of the Trial Harbour Nickel Mine, near the eastern extremity of the serpentine, the latter is silicified in places, and intersected by veins of chalcedony. Garnierite was noticed here, and owing to its close resemblance to some speciments of zaratite from the Heazlewood district, careful tests were made by the writer to determine its nature.

The mineral occurs encrusting opaline serpentine, which is honeycombed and cut through by chalcedonic veins. It is amorphous, and the encrusting masses are of no great thickness. The colour varies from pale to bright apple-green. The lustre is resinous, hardness 3, and streak pale-green. Insufficient pure material could be isolated for specific gravity determinations. The mineral is friable, and translucent in thin fragments. It is infusible, but decrepitates and blackens on heating, becoming magnetic. Heated in a closed tube it blackens and yields water. Borax beads are violet hot, and brownish-violet

cold in the oxidising flame, and semi-opaque grey in the reducing flame. Microcosmic salt beads are reddish-violet hot and yellow cold in the oxidising flame, and reddish-violet hot and semi-opaque greyish-yellow in the reducing flame; in the microcosmic salt beads is an undissolved residue of silica. It is partly soluble in nitric and hydrochloric acids. It does not dissolve readily in hydrochloric acid even when heated, but is decomposed, leaving a siliceous residue, which, however, is not gelatinous. It is unctuous to the taste.

The mineral is garnierite, a hydrous silicate of nickel and magnesium. It differs from zaratite in its behaviour with hydrochloric acid, and its silica content. Garnierite has not previously been recorded from Tasmania, so far as the writer is aware.

D.—IRON ORES.

As noted elsewhere in this report when describing the basic igneous rocks of the district, the weathering of iron-bearing minerals sets free iron compounds, which are frequently deposited as a crust of limonite on the surface. In this way secondary deposits of iron ores have been formed, which are deserving of mention, since work has been done on them in several localities.

On the flat crossed by the Trial Harbour Road to the south of Mt. Agnew, and just on the Zeehan side of the Agnew Creek huts, is a fairly extensive superficial deposit of iron ore. This deposit has evidently been regarded as a gossan capping a lode-formation, for at several points shallow shafts were noticed, now partly filled in. The depth of the deposit is not exposed, but where the road crosses, it appears to be about 4 or 5 feet. It consists essentially of limonite, which has usually a nodular structure. Included in the limonite are fairly abundant grains of magnetite. The underlying rock, as shown by occasional outcrops, is gabbro-amphibolite. The limonite has been derived essentially from the ferro-magnesian minerals of this rock, as they have decomposed under the attacks of weathering agencies. The primary magnetite of the rock-mass would be set free, and become mechanically entangled in the limonite. Although no analysis was made, it will probably be found that the content of titanium and chromium will be appreciable, and that the phos-

phorus content will not be negligible, since the composition of the residual iron ore will be partly determined by the composition of the igneous rock from which it has been derived. The presence of ilmenite, chromite, and apatite in the basic igneous rocks would be expected to contribute the impurities mentioned.

Quite similar iron ore to that described above occurs on the surface of the serpentine area lying to the east of Trial Harbour. It is present sometimes in small fragments, forming a regular ironstone gravel, sometimes in nodular masses of irregular shape, and sometimes in cemented masses. The mode of origin is quite similar to that of the material occurring with the gabbro-amphibolite, being derived from the iron compounds set free in the weathering of the serpentine, and including residual magnetite from the same rock, some of which is probably itself secondary, having been set free from the olivine of the peridotite in its conversion to serpentine. On one of the northern hill-slopes about ½-mile east of Trial Harbour, the iron ore is very abundant, and several shafts have been sunk. This work appears to have been carried out many years ago, and the shafts are mostly in a state of disrepair; in this case, also, the limonite seems to have been mistaken for the gossan capping a lode-formation. There appear to be five or six shafts at this locality, at varying distances apart, sunk in a line on this hill-slope. The deepest appears to be over 30 feet, and is in limonite with magnetite, most of the way. The shaft is inaccessible. Fragments of serpentine on the dump-heap indicate that this rock was encountered in sinking, and it is probable that the shaft bottomed on this rock, which forms bottom at varying depths below the present surface. If the limonite cover at this point is as much as 30 feet, the thickness is probably exceptional, as the serpentine rock itself outcrops at intervals through the limonite cover.

A sample of the limonite (which carries entangled magnetite) from the collar of the deepest shaft, was submitted to Mr. W. D. Reid, Government Assayer, who reported—

Iron ..... 52·07 per cent.

The grade of ore is certainly satisfactory if quantities are available, but this fact remains to be proved. The thickness is likely to be variable. While placing on record the occurrence of this secondary iron ore, the writer is of opinion that it can scarcely be regarded as of commercial importance under existing conditions, although it should

be worth further investigation if a local demand for iron ore arises.

It should be borne in mind that it is not a gossan forming a lode-capping.

(8)—Summary of the Genesis of the Ore-deposits.

As explained in the chapter on General Geology, at the close of the Silurian era the area under review was occupied by sedimentary rocks. These rocks belonged to two distinct periods. The older series (formed, probably, in Cambrian or Ordovician time) having been intensely crushed and altered by earth movements, were again partly or wholly submerged beneath the Silurian ocean, and formed the bedrock on which further sediments accumulated. The succeeding period of uplift exposed the sedimentary rocks once more at the surface.

Up to this time, no ore-deposits had been formed.

The comparative calm of the Silurian era was succeeded by a period of intense igneous activity in Devonian time, when all the primary ore-deposits of the district were introduced.

Owing probably to some decrease of pressure, a huge mass of molten rock-material was introduced into the deeper portions of the earth's crust. As this mass commenced to cool, the processes of magmatic differentiation became operative, causing a partial separation of the originally more or less homogeneous mass, into two submagmas, one containing the more basic constituents, and the other the bulk of the water and more acid constituents. After a time, owing to some further variation in conditions of pressure, this basic mass was forced up towards the surface, rising to very different heights at different points. With this basic material was introduced the nickel, the magnetite contained in the basic rocks, and the iron compounds now forming the secondary iron ores covering the basic rocks. As this molten mass of basic material gradually cooled there was a tendency for the more basic material to still further segregate and accumulate near the margin of the mass. With this more basic material the nickel became more concentrated, this concentration becoming more marked as cooling proceeded. With the nickel were associated iron and sulphur compounds, and when such a condition of temperature and pressure was reached that they could no

longer remain in solution, certain of these elements entered into combination and crystallised out as pentlandite and pyrrhotite, just as other of the elements present combined to form other rock-forming minerals (for example, as iron, magnesium, and silica combined to form olivine). Thus, the writer believes the nickel ores to have been the earliest-formed, and is of opinion that the pentlandite is to be regarded as having become concentrated under the action of magmatic differentiation processes, and to have crystallised out as the magma cooled, with the true rock-forming minerals.

The intrusion of this mass of basic igneous rock must have had a considerable effect in weakening the crust and causing fissures in the overlying rocks. It is doubtful whether the basic rock itself reached the surface at all, though it may have done so in the form of dykes at isolated points: the bulk of the rock consolidated at a considerable depth.

Closely following upon the consolidation of the basic rock the great mass of more acid material was forced up into the crustal region, and with it were introduced the metals which enter into the composition of all the ore-deposits of the district, other than those mentioned above. The acid magma was introduced at an extremely high temperature, and the overlying and adjacent rocks were tilted and subjected to great pressure. As the magma gradually cooled, magmatic differentiation caused a partial concentration of certain of the constituents in particular localities. At some points the magma became particularly rich in metallic constituents such as iron, zinc, and sulphur, and solutions rich in such elements forced up under considerable pressure through the overlying rocks which had been previously fissured, resulted in the formation of the contact metamorphic deposits. It would seem that in some cases at least the solutions traversed fissures in the earlier formed basic rocks, deriving from them some of the material which entered into the composition of the minerals of the ore-deposits. These deposits appear to have been formed prior to the consolidation of the granite. As cooling proceeded the rock-mass tended to form sub-magmas of slightly different composition, as explained in detail elsewhere, the metallic constituents from the molten mass tending to accumulate at different points. The outer crust of the mass eventually solidified, and as cooling proceeded, the solid crust grew thicker. In the meantime the still molten central portion of the magma was becoming progressively more acid. Contractional stresses induced by cooling caused

strains in the solidified outer crust of granite, which eventually resulted in the formation of fissures. These fissures in some cases allowed the escape of some of the still molten rock material to form dykes of granite porphyry and aplite, and as is of far greater importance from the economic standpoint, they connected with some of the reservoirs in the heart of the molten mass, in which metallic compounds had become partially concentrated with other constituents of the magma which were soluble in water at the high temperature, for these reservoirs appear to have contained much water. Mineralisers (compounds of boron, fluorine, &c.) were present, and played a very important part in the formation of the ore-deposits. Portions of these concentrated solutions may have been expelled before the magma completely solidified, but it would seem that solutions became most active and most of the veins were formed *after* the granite had solidified. It must be borne in mind that the "solutions" at this stage were at such high temperatures and pressures that they must have existed as gases, and not as liquids. These volatile compounds (such as borates, fluorides, tungstates, sulphides, &c., of the metals) were set free on the final consolidation of the magma, and being under extremely high pressure and at very high temperatures, were very active chemically. Rising through fissures which had been formed in the cooling crust, these gases attacked the walls, and minerals which had consolidated from the silicate magma were altered and replaced. As the solutions reached the upper zones, the temperature and pressure eventually were lowered to such an extent that certain of the metals could no longer be retained in solution and were consequently deposited on the walls of the fissures and in the adjacent rock which was penetrated by the solutions. Clearly, the substances which were most insoluble would be deposited first in the deeper zones, while the relatively soluble ones would be retained longer and deposited only in the cooler upper zones. Thus we should expect to find cassiterite typically deposited in the deeper (higher temperature) zones, galena in the shallower (lower temperature) zones, the gangue minerals being characteristic. It is obvious that no hard and fast lines can be drawn between the two zones, and there will be considerable overlapping, minerals characteristic of both zones being found at certain horizons. Another factor which must be taken into account is the progressive cooling of the solidified rock-mass during this period of mineralising. Thus a par-

ticular horizon which was at one period at such a high temperature that typically high-temperature minerals were deposited, might later be the repository of a different set of minerals if the same fissure were again traversed by mineral-bearing solutions. Still another factor worthy of note in passing is the variation in the composition of these metallic reservoirs at different points, which would result in variations in the mineralogical composition of deposits formed at approximately the same horizon.

The processes indicated above have operated in the granite in forming the various mineral deposits, and in view of what has been said it is not difficult to understand the variations in composition which are known to occur.

But at the time these mineral deposits were formed the granite was covered by a thick layer of sedimentary rocks, which had been disturbed and fissured in various directions. These rocks had been raised to a high temperature by the intrusion of the molten magma, and the mineralising solutions on reaching the outer crust of the granite mass, in many cases continued outwards into these sedimentary rocks, the fissures in the rocks giving the solutions the opportunity to escape. In these rocks they continued their work of altering the wall-rocks and of depositing their metallic burden. Thus ore-bodies were formed in the sedimentary rocks as well as in the underlying igneous rocks, their structure depending partly on the nature of the rocks themselves, and partly on the fissures which had been developed in them. As the solutions migrated further and further from the magmatic reservoir into regions of lower temperatures and pressures, the general characteristics of the mineral deposits which were formed changed from those of the deposits formed in the heart of the igneous rock, and typical low-temperature deposits were formed.

In the concentration of the metallic constituents of the magma by differentiation into particular " reservoirs," it is certain that such concentration was not complete, and that small quantities of cassiterite crystallised out from the silicate magma and were included therein upon its consolidation to form the granite rock. This became important at a later stage.

With the close of this period of igneous activity, the introduction of ore material into the district ceased. The igneous activity was succeeded by a long-continued period of quiescence during which degradational forces were active in wearing down the land surface. The operation of these forces had an important effect on the district from the

economic standpoint, for a great thickness of overlying rocks was removed and the ore-deposits were exposed at the surface. As the rocks were more deeply dissected the upper portions of some of the ore-deposits were removed, and as a large portion of the area was worn down to a general base-level, and a river system developed which differed somewhat from that of the present day, the material from the higher ground gradually accumulated as the grade of the streams became too flat to allow of its being carried to the sea. With this material was a good deal of cassiterite derived from the ore-deposits which had been degraded, and a certain amount from individual crystals set free in the disintegration of the granite itself. Upon a subsequent uplift of this base-levelled area, the rivers were rejuvenated, and started cutting down their beds again. This process has continued up to the present time, and the older deposits of alluvial material have been dissected and the heavier constituents reconcentrated to form the secondary tin-ore deposits of the district.

The secondary iron ores have been formed in recent times by the action of weathering agencies.

(9)—Building and Ornamental Stones.

Although in the past nothing has been done in the way of utilising any of the rocks of the district for building or ornamental purposes, the possibility of such being done is worthy of brief mention. In this connection mention may for convenience be made to the available rocks under separate headings.

Granite.—The granite of the district is the only rock which is likely to be used for building or ornamental purposes, although nothing has been done with it in the past. The varieties of granite in the district have been described in detail elsewhere, and it has been pointed out that all are closely related, being derived from the same intrusive mass. The pink granite, which is of medium to coarse grainsize, the relative grainsize being even, is a handsome rock which would make an excellent building stone if more favourably situated. It has been shown to take a good polish, and is a hard rock, its handsome appearance giving it a possible value as an ornamental as well as a building stone. An excellent illustration of a polished slab of this granite, collected by the writer, has been recently repro-

duced in natural colours in " The Building and Ornamental Stones of Australia," by Richard T. Baker, F.L.S.,(193) page 32. The rock compares very favourably with other " red " granites of Australia illustrated in the work named.

Varieties of this rock are typically grey in colour, but the quantities available are smaller; the rock is handsome, pale flesh-pink orthoclase felspars showing a tendency to develop porphyritic crystals.

More abundant than this grey rock, and second only to the " pink " granite, is the " white " granite of the district (also known as the tin granite). It is a handsome fine to medium-grained rock of even grainsize, and would probably take a good polish. The distribution is wide, but the variety is not quite so accessible as the coarser-grained pink variety, although if an industry were ever established, it would almost certainly claim a share of attention.

Although there exist here rocks which would be prized if they occurred under more favourable conditions, it must be admitted that at present they can scarcely be regarded as of economic value. They are far removed from a centre of settlement, and working costs would be high. Although the facilities for working are good, the coastal cliffs, rising to over 300 feet, presenting faces which could be exploited, the cost of transport would be considerable at the present time, the unreliability of Trial Harbour (the only port available) having been explained elsewhere.

The rocks undoubtedly have many distinctly favourable features. The colours are certainly pleasing and are comparatively regular over considerable areas. Tourmaline is present in small aggregates and sometimes filling minute fissures in the pink granite, but in this rock its presence would not detract from the handsome appearance of the fresh rock. Where exposed, the granite appears to be fairly free from cracks, and as the rock is usually little altered even within a few inches of the surface in the case of exposed outcrops, there would be a minimum of waste in working. This freshness almost to the surface indicates that the rock would be durable.

There is reason to believe, therefore, that in the future, when the local demand for such material increases, the Heemskirk granite may be exploited as a building and ornamental stone.

(193) Published as Technical Education Series No. 19 by the Department of Public Instruction, New South Wales, 1915.

Serpentine.—This rock is scarcely likely to prove of value as a building or ornamental stone, judging by its appearance on surface outcrops and in the only mine workings available (Nickel Reward Mine). It is usually a dull-bluish colour, sometimes bluish-green, and does not show the bright tints and variegated effects which render some serpentines valuable. There appeared to be little variety in the exposures available for inspection at different points.

Slate.—Mention has been made in the course of this report of the large development of slates of Pre-Silurian age. At no point visited, however, did these rocks give any promise of being of value for flagging or roofing. They are usually indurated, but are not fissile, and cannot be regarded as being of any economic value.

(10)—Possibilities of Pyrite Crystals in Wireless Telegraphy.

The occurrence of abundant crystals of pyrite in the soft pipe material which has been profitably worked for its cassiterite content on the Federation Mine, has been noted elsewhere. Perfect crystals varying in size from $\frac{1}{32}$ inch to over 1 inch across are common. The forms represented are the cube and the pyritohedron, and combinations of these forms. The cubes are usually perfectly regular: they sometimes show striated faces, but not always so. Groups of crystals intergrown are frequently found, also pyrite intergrown with cassiterite, tourmaline, or quartz, or with more than one of these minerals. In many cases, however, the mineral is pure and fresh and faces regular.

Owing to the reported value of such crystals for use as detectors in connection with wireless telegraphy, the writer selected crystals of various sizes and showing various combinations, as well as samples showing only cubical and pyritohedral faces, and despatched one parcel to the Wireless Telegraph Station, Melbourne, and another to the Wireless Telegraph Station, Flinders Island, with the request that the officers in charge might test them and express an opinion as to their value in wireless work.

The officer in charge at Flinders Island wrote:—

" I have forwarded some of your specimens away to be specially treated: result you will be advised. They are in the present state sensitive, but below the standard; but

may be improved with treatment. I find galena of a particular kind gives the best results."

No further advice was received, although it is possible that the crystals were forwarded to Melbourne, and that the results were included in the following reply received from the officer in charge, Wireless Telegraph Station, Melbourne:—

"I am in receipt of your crystals of iron pyrite. I have tried a couple of dozen specimens as detectors for wireless receiving, and they are all more or less sensitive. However, I did not get such good results as with the iron pyrites crystal that we have been using for some months. I think the crystal we use comes from Java, and it appears not to have so much iron in it. I do not think that there would be any commercial value for our work, as the demand is so limited, and a crystal practically lasts for ever with care and cleanliness. X([194]) gets 7s. 6d. per crystal for the Java stuff, but the only demand since the war are ship operators."

From the above it would appear that the crystals have at present no value for wireless work. Although suitable crystals bring good prices, it seems that it would scarcely pay under present circumstances to have numbers tested in the hope of finding an occasional sensitive one.

([194]) Name suppressed.—L.L.V.

VI.—THE HISTORY OF MINING ON THE FIELD.

The early history of mining in the Heemskirk district makes interesting reading, and the writer proposes to record the main incidents, so far as they can be ascertained.

Reviewed broadly, several chapters in this history stand out prominently, indicating the phases through which mining in the district has passed. These may be called the periods of (*a*) prospecting, (*b*) boom, (*c*) collapse, (*d*) neglect, (*e*) recovery.

(*a*) *Prospecting*.—This chapter provides a story of pioneering work, of courage and hardihood, of indomitable pluck and endurance in struggling against and overcoming difficulties, which compels the warmest admiration. What these difficulties were can only be appreciated by one familiar with the West Coast of Tasmania. The inaccessibility of the district was one of the greatest drawbacks. The nearest settlement in the early prospecting days was at Mt. Bischoff, some 35 miles distant. But mere distances convey little idea of the difficulties which confronted the pioneers, for nature seemed to have opposed obstacles at every turn. The nature of the country is forbidding, mountain ranges rising to 3000 feet, intersected by deep gorges carrying streams liable to flooding at short notice, and occasional strips of open plain country liable to be converted into marshes in the wet season. The mountain and hill slopes were usually heavily timbered and almost impenetrable scrub, in which horizontal, bauera, and cutting-grass were prominent, covered large areas: the barriers offered by these shrubs are well known to those familiar with the West Coast. The climate increased the prospector's difficulties, as rain was almost incessant, and falls of snow on the higher ground, dense fogs, and gales of wind were frequently encountered. Added to these natural obstacles, was the scarcity of food in these solitudes. An occasional kangaroo on the plains, and wombats which usually avoided capture, made welcome if infrequent additions to the prospector's larder. The necessity for carrying all supplies on his back obviously hampered the operations of the hardy pioneer enormously.

On account of the difficulties of the overland routes to the district, some of the parties travelled by boat, landing

at Macquarie Harbour or the mouth of the Pieman River, and working from either of these places as a depot: this method of travelling was expensive and to some extent uncertain.

Tin was discovered in the district by the late Mr. C. P. Sprent, surveyor in charge of the West Coast district (and afterwards Surveyor-General) in April, 1876. Acting upon instructions received, Mr. Sprent proceeded from Table Cape to Waratah, and there formed a party consisting of Messrs. David Jones, John Bourke, and Frank Long, setting out to examine and report on the country between Mt. Bischoff and the West Coast. They travelled *via* Mt. Ramsay and the Yellow Band Plain, over the Parson's Hood Mountain to the Pieman River near its junction with the Meredith River. Returning for provisions they were joined by Mr. Frank Lempriere, and, taking a more southerly course from the Parson's Hood Mountain, the party eventually crossed the Pieman River not far from its junction with the Heemskirk River from the south, reached Mt. Heemskirk, and after spending a little time prospecting and taking general observations as to the nature of the country, were compelled by bad weather to return to Waratah. Tin ore was discovered on this trip, apparently on the west side of Mt. Heemskirk, gold, platinum (probably osmiridium), and copper being reported from other localities as a result of the same trip. This appears to have been the first authentic discovery of tin in the Heemskirk district, and Mr. Sprent's report of the results of this trip resulted in the commencement of prospecting operations in earnest.

In 1876 or 1877 three prospecting parties visited the Heemskirk district, on behalf of various prospecting syndicates. Messrs. Owen and George Meredith appear to have prospected on the Pieman and in the country between that river and the Heemskirk Range, eventually pegging out four sections, each of 80 acres, for tin at North Heemskirk. These sections appear to have been the first taken up in the district. About the same time a party of three men, led by Mr. Charles Donnelly, travelled per ketch "Coral" from Hobart to the Pieman River and thence to Heemskirk, and another party, led by Mr. T. B. Moore, travelled through to Heemskirk from New Norfolk *via* Lake St. Clair and the Eldon Ranges, packing provisions on their backs. Donnelly's party returned by this route. Each of these parties appears to have taken up ground for their respective syndicates.

In a recent letter to the writer, Mr. David Jones (now district surveyor at Waratah) states: "When we went to Heemskirk again in 1877 we had a lot of surveys to effect. Other sections [besides those of the Meredith Brothers.—L.L.W.] were marked off by Gam. Webster, Con. Curtain, McCaviston, and further south at Mt. Agnew, Charles Donnelly, Frank Long, Joseph Harman, and Alex. Tengdahl." Mr. Jones continues: "The first tin ore from Mt. Agnew was obtained by C. P. Sprent and Frank Long and taken into Waratah by John Bourke and myself. I obtained a horse from Mr. Kayser, manager of the Mt. Bischoff T.M. Co., rode to Burnie, and forwarded the tin ore from there to Dr. Butler, of Hobart."

With regard to some of the earliest alluvial work on the field, Mr. A. S. R. Osborne (now of Ascot, Queensland), writes:—

"I call to mind that the first syndicate to prospect for a payable tinfield that way [*i.e.*, Heemskirk] was formed in Hobart, that the directors were of that city . . that about six men were despatched by ketch to Macquarie Harbour, thence by land to Heemskirk, with a complete supply of alluvial mining tools, stores, &c., for six months, that work was commenced on a creek fed by the mount, and strongly recommended by the late Mr. Surveyor Sprent as being rich in tin. A sluicebox was made and placed in position, and sluicing commenced—taking the whole width of creek washdirt, perhaps 15 feet wide—and after one month's work some six bags (600 lbs.) of tin were recovered. The owners would not credit the result as reliable, and operations were continued until the creek (gully, really) was scooped out up to the bare rock slope of the mount without further recovery: about this time one of the original prospectors put in an appearance to indicate to the manager where good payable tin was situated, but to that gentleman's chagrin he was reluctantly compelled to acknowledge that he and his mate were in grievous error, and hence that part of the locality was abandoned and the men's services transferred to a point about 5 miles beyond the mount proper towards the Pieman River, to test another gully for tin recommended by Mr. Sprent and the prospectors, Frank Long and another, but little tin was found, and this also was abandoned."

About the same time Mr. C. Donnelly went to Heemskirk with a party of 12 men and two horses, on behalf of the Great Western Prospecting Association, and some alluvial work was done; the Meredith Brothers also took a party

of men by ketch to the Pieman, and started work on behalf of the Emu Bay and Pieman River Prospecting Association. In neither case, however, did the ground prove payable.

"Somewhere([195]) about this time Frank Long was sent with Joseph Harman to prospect at Heemskirk for a Hobart syndicate, and their experience illustrates the hardships which many of the pioneers had to endure. They travelled overland from Waratah, the arrangement being that stores of provisions should be sent by sea to Macquarie. The vessel, however, did not put in an appearance until two months after her due date, and for five weeks the ill-starred travellers had to exist on a very meagre supply of badgers and wallabies, often being near starvation. Breaking along the coast to Macquarie, in the hope of seeing the looked-for vessel with "tucker," they were fortunate enough to meet with a member of Donnelly's party, who at this time were cutting a track from Macquarie Harbour through Heemskirk to ground Donnelly had there taken up. Accompanying Donnelly was George Bell, who had also been sent out by the Great Western Company to continue prospecting while the former started working the sections already secured. . . . On being made acquainted with the troubles of Long and his mate, Donnelly supplied the two hungry men with a month's provisions, and generously packed the stores for them to the Big Henty. Long and Harman then prospected near Mt. Agnew, discovered alluvial tin, and selected ground, Harman staying to prospect further while his companion crossed over Mt. Agnew, proceeding along the Heemskirk Range to what is known as the Gap. Sprent and party were surveying ground taken up by the Emu Bay Company, and after pegging out sections in the same vicinity, Long started for Macquaire laden with specimens. He had the misfortune to sprain his ankle *en route*, but managed to reach his mate near Trial Harbour, and they proceeded to Macquarie."

([196]) On December 25, 1877, Mr. Mark Ireland arrived at Macquarie Harbour with a party from Hobart in the ketch "Priscilla." They proceeded *via* Heemskirk to the Pieman River, returning to North Heemskirk and prospecting the Tasman River flats, which it was decided were not payable. Returning to the Pieman, they prospected unsuccessfully and then worked back, prospecting between Granville and Heemskirk. They then packed provisions from Macquaire Harbour, and took a prospecting trip round the Heemskirk Range, working from the south end, along the eastern edge of the range and back round the north end, the trip lasting three weeks. Members of this party were Messrs. Mark Ireland, George Bell, and John O'Donnell. Prospecting was unsuccessful, and the party returned to Macquarie Harbour short of food. Fortunately the ketch "Starling" arrived, having on board Mr. Osborne and a party of men to work ground discovered by Long and Harman. The ketch took Mr. Ireland and several members of the party back to Hobart *via* the north coast. It is stated that at this time some tons of supposed tin were sent to Hobart, but on arrival the mineral proved to be mainly titaniferous iron ore, and consequently worthless.

([195]) Extract from "The Wild West of Tasmania," by Wilberton Tilley, p. 9.

([196]) This information culled from articles published by "The Examiner," Launceston, July 5, 7, 10, and 12, 1913—"West Coast Pioneering," by Mark Ireland.

The field may now be said to have entered on the second period of its history.

Although dealing with a locality beyond the boundary of the Heemskirk field, it is interesting to note that as one result of the prospecting activity at this period, a discovery was made which had very far-reaching effects, viz., the discovery of argentiferous galena at what is now Zeehan. This discovery was made by Mr. Frank Long on 8th December, 1882, when prospecting with Mr. John Healey, Messrs. William Johnston and William Monks being also prospecting in the neighbourhood. Although some temporary excitement was caused when the result of this discovery became known, its full significance was not realised for some years, and serious mining does not appear to have been attempted until 1890.

As everything for the Zeehan field was in its earlier history landed at Trial Harbour, and carted inland, it will be seen that the discovery had an influence on the operations being carried out on the Heemskirk field.

(*b*) *Boom Period*.—This was essentially the period when the lode tin mines were being opened up and to some extent prospected. Exaggerated reports of their richness were furnished by some of the prospectors; the field, as already mentioned, was inaccessible, and the reports received caused great excitement. After examining the mode of occurrence of the tin ore on the field, the writer is prepared to believe that many of the reports furnished in these early days were not wilfully misleading, but that the prospectors

concerned really believed that their discoveries were of the utmost importance. The tin oxide does occur (as explained elsewhere) in rich shoots, and doubtless some of these were located, and after seeing the rich detrital ore shed by outcrops at particular points, the finders assumed, without adequately testing the truth of their theories, that enormous bodies of rich ore existed. There can be little doubt that in some cases the estimate formed of the actual tin content of some of the stone was also exaggerated, the wish being in reality father to the thought. Doubtless the knowledge that the Mt. Bischoff Mine had about this time an output of about 250 tons of tin oxide per month, also led to exaggerated ideas being formed of the value of the Heemskirk lodes.

There can be no question of the integrity of most of the directors of these properties, who honestly believed their mines were as rich as they were represented to be.

The facts are that excitement prevailed, money was forthcoming in abundance for the new field, and as a consequence, speculation was rife. Undoubtedly many sections were pegged (and actually floated in some cases) which had no prospects whatever. An idea of the state of affairs may be gained by a glance at the mineral charts of the district, accompanying this report. The extremes to which this pegging-out of ground was carried is shown by the fact that eight or nine of the mineral sections extend varying distances out to sea: in some cases more than two-thirds of the area of the sections extend out to sea. It is certain that in some of the sections for which money was forthcoming, a pick had never been put into the ground. There could eventually be but one result of such wild speculation.

In the case of the properties which had genuine prospects, however, the period was essentially one of spending money on surface opeartions—on plant, roads, tramways, &c.—without due regard to the development of the mining properties, which should of course have been attended to first. There appears to have been quite a stampede to erect batteries, without waiting to determine whether the properties warranted such a procedure. Clearly, this state of affairs must end disastrously, in some cases at least.

The Montagu Mine was worked in 1879,([197]) and tin ore won therefrom, and about the same time the Montagu

([197]) Communication to the writer by David Jones, Esq., District Surveyor, Waratah.

Extended, Cumberland, West Cumberland, Orient, Mt. Agnew, Empress Victoria, Cornwall, Cliff, and Peripatetic Mines started operations. In 1880 lode tin-mining certainly attracted attention, and in June, 1881, Mr. G. Thureau, then Government Geologist, reported on the field: this report was not available to the writer.

It is interesting to note that 10 batteries were erected about this time, and the following list shows the more important mines, with names of their managers and brief headings of the plant installed:—

Cumberland Mine.—Manager, A. B. Gallagher: turbine, 10-head battery, jigs, and buddles.
West Cumberland Mine.—Manager, G. Lightly: waterwheel, 5-head battery, buddles.
Montagu Mine.—Manager, A. R. Ingleton: turbine, 15-head battery, jigs, and buddles.
Orient Mine.—Manager, T. S. Williams: boiler and steam-engine, waterwheel, 10-head battery, buddles, and hydraulic concentrator.
Cornwall Mine.—Manager, M. Gardiner: waterwheel, stonebreaker, 10-head battery, Frue vanner, and buddles.
Cliff Mine.—Manager, E. Perrow: waterwheel, 5-head battery, buddles.
Peripatetic Mine.—Manager, C. H. Curtain: waterwheel, 10-head battery, buddles.
Carn Brae Mine.—Manager, J. T. Rabling: waterwheel, 10-head battery, buddles.
Wakefield Mine.—Manager, ——: portable steam-engine, 5-head battery.
Empress Victoria.—Manager, — Gardiner: First steam hoisting plant on West Coast, but no treatment plant.

Batteries were afterwards erected at the New West Cumberland, at Sweeney's, Healey and McIvor's, Kelvin, and R. Clarke's (old Prince George) Mines.

Early alluvial tin-mining companies were the Mt. Heemskirk Company, Great Western Company, Emu Bay and Pieman River Company, Star of the West Company, Glenora Tin Mining Company, and others.

The Orient Company's battery was the first to start crushing on the field, early in 1884, although other mines had started to erect their batteries some months before Some very interesting particulars concerning this and other mines on the field about this time have been kindly sup-

plied to the writer by Mr. Luke Williams (now manager of the Balfour Reward Copper Mine), who visited the field in 1882. It is interesting to note that the time taken by the s.s. " Amy " (35 tons register), by which Mr. Williams travelled, was 19 days from Hobart to Trial Harbour.

The expense of bringing batteries and plant to the field and then erecting them, at this period of its history, was very considerable, and undoubtedly several of the companies concerned spent a considerable amount of their available capital on machinery in the excitement of the boom time which should have been available for prospecting and developing their mines. It is fair to add that in many cases, and probably most cases, the mining managers were not to blame, as they did not recommend the erection of machinery, but were instructed by the directors to erect crushing and dressing plant purchased on account of the influence brought to bear by shareholders, who apparently would not be convinced that prospecting was needed. This policy was carried out in the case of several properties with really good prospects, as well as with those which genuine prospecting would have shown to be too unpromising to warrant any expenditure at all on plant.

At this time there were probably about 200 men employed in the district, for Mr. Thureau stated in his report of 1884 that in 1881 over 150 miners were employed in mining proper and in prospecting.[198] There was about this time at the Montagu Mine, a general store and post-office for the field.[199] At Trial Harbour (the port of Heemskirk) the township of Remine was being formed. Some idea of conditions on the field is given by noting that[199] wages were eight shillings per shift, freights per steamer £5 per ton from Hobart, price of chaff calculated at double rates: still living does not appear to have been expensive, averaging from ten shillings to twelve shillings and sixpence per man per week, when " batching."

As indicated above, the " boom " stage was for several reasons destined to be short-lived. Closely following upon the erection and commencement of work of the various plants, came the third period in the history of the district.

(*c*) *Collapse.*—About the year 1884 came that unfortunate event the " bursting of the Heemskirk bubble." The writer has indicated in the preceding section that this event

[198] *Op. cit.*, p. 12.
[199] Information kindly supplied by Mr. Luke Williams.

was almost inevitable. The tin ore occurs throughout the district usually in comparatively short but frequently rich shoots. When batteries were erected, and treatment plants in position, in most cases available capital was exhausted, and sanguine shareholders looked to battery returns from the first few crushings to recoup them for their outlay, and provide funds for future operations as well as dividends. In a few instances, if these anticipations had not been fulfilled, the mines might at least have paid their way, had sufficient developmental work been carried out previously, to open up sufficient ore of a suitable grade, to keep the batteries working, but this was not done. In some instances shoots of ore which had been located were worked out, but little was done to locate fresh ones. The concentrating plants on the whole would appear to have been efficient, but the operation was usually tedious and costly. High freights on the tin produced (which in some cases at least was of the usual battery grade, 68 to 70 per cent. metallic, as good tin-dressers were employed), combined with a low market price for the product,[200] also militated against success.

Pyritic ore appears to have been encountered in one or two instances at this stage, and this gave trouble and discouraged the companies concerned, owing to the difficulty of cleaning the ore (roasting was not practised) and of finding a market for a pyritic concentrate.

Again, in one or two instances black tourmaline (extremely abundant throughout the district) appears to have been mistaken for cassiterite, with anything but satisfaction to the shareholders interested.

The net result of this state of affairs was a loss of confidence on the part of investors in the Heemskirk field, which meant the collapse, temporarily, of the mining industry of the district.

The field at this time got a bad reputation, not justly, which it has never quite outgrown.

(*d*) *Neglect.*—It is not surprising to find that the collapse of most of the mining companies was followed by a period of neglect, during which the field was abandoned to a few prospectors. This state of affairs appears to have continued for some years. A few spasmodic attempts were made to resume work, but nothing of any consequence was done, as capital was not forthcoming. In 1893 Messrs. Fowler and Dunn were profitably working the West Cum-

[200] *Vide* table, p. 300.

berland property, and about the same time a little work appears to have been done on the Cumberland Mine. A company was formed to take over the old West Cumberland property a little later, but unfortunately most of the available capital was spent in bringing water from the Cumberland Dam, and in erecting a battery and treatment plant. Provision does not appear to have been made for a continuous supply of ore to the battery, and although some stone was crushed, the quantity appears to have been small before the mine was once more shut down, and eventually fell into the hands of the present owners, who hold the properties of the West Cumberland, Cumberland, and East Cumberland companies.

It is uncertain whether this period has not continued more or less to the present time, but the writer prefers to regard the present stage as one of recovery.

(*e*) *Recovery.*—Of recent years there has, in the writer's opinion, been a tendency for the recovery of the Heemskirk field from the condition of neglect into which it had fallen. Although unfortunately little activity is actually being displayed at the present time, there are indications that at no distant date there will be many more men employed, and that several of the mines will be working profitably. After such a collapse as that which followed the unwarranted boom of the earlier days, the process of recovery was necessarily slow. " Prejudice dies hard," and public confidence in the field was so completely shaken that for some years the name " Heemskirk " was almost sufficient to condemn a property: unhesitatingly the writer states that such feeling is unwarranted, and if the lessons of the past are taken to heart, that the Heemskirk tinfield will rise, not to the dazzling though insecure heights of the boom period, but to the position of stability and productivity it is entitled to occupy.

A discovery which caused some excitement of comparatively recent years, and which for a time put new life into the field, was the finding of rich tin on Mr. John Mayne's farm, 2½ miles south of Mt. Agnew. In the earlier history of the field, this ground formed part of the West Orient Company's section, and adjoined the Orient lease. The rich detrital deposits of tin ore were but 8 chains distant from the battery of the old Orient Company, and yet their presence was not suspected. This may have been due partly to the fact that prospecting was confined mainly to the granite, instead of being extended to the adjacent slates as well.

Long after the Orient Company ceased operations, Mr. John Mayne established a farm whose boundaries included the tin deposits, and lived for some years within 5 or 6 chains of the spot where a small fortune lay waiting for him to claim it.

Referring to the discovery of this rich ore, Mr. Donald Clark[201] says: " His [Mr. John Mayne's] boys wanted a holiday, so he gave a provisional promise that if they could show him a claim yielding a pound of tin to the dish they should have it, as well as a cash bonus. The boys never went more than 300 yards from the house in which they had lived for years, got a prospect from the base of an uprooted tree, and earned their reward. The father and sons started to work, pegging out a comparatively small area, for they then thought that in such a patchy place they would soon work it out. As time went on discoveries were made which caused the fortunate owner to form a different opinion. A small pot-hole on the side of the hill, only a short distance from his back door, gave nearly £1000 worth of metal. A couple of men could have easily taken all the stuff out in a day. Lode after lode was opened, giving pounds weight of oxide to the dish, and without having done as much sinking as a wombat would have gone through in the time, upwards of 30 tons of oxide were extracted by the most primitive means."

This version varies slightly from that given to the writer while on the field, by one who was in the district, which was to the effect that one day a piece of stone was picked up on the hillside as a suitable missile to alter the course of a straying cow belonging to the farm: the " stone " was found to be very heavy, and its weight led to enquiries being made in the locality as to its nature, apparently unsuccessfully for some weeks owing to its unusual colour and form. Its subsequent identification as tin oxide led to the discovery of the detrital ore. The writer cannot verify either story, but it seems clear that the discovery was not due to systematic prospecting, and that its importance was not realised at first. The discovery appears to have been made about the end of 1901. The first official record is that of the Secretary for Mines in his report on the " Progress of the Mineral Industry of Tasmania for the quarter ending 31st March, 1902."

This discovery led to a decided revival of interest in the Heemskirk field. The property was sold early in 1903, and

[201] " Australian Mining and Metallurgy," by Donald Clark (Critchley Parker, Publishers), First Edition, 1904, p. 225.

a bright future was anticipated for it. Rich tin certainly was won and dividends were paid for a time.

Unfortunately the mine was shut down after a comparatively short life; the careful prospecting of the locality which might have resulted in the discovery of other orebodies along the line of contact, does not seem to have been carried out.

The adjoining property has been working profitably for some time, though in a small way only.

The successful operation of several of the smaller properties on the field, although working under adverse conditions, will assist in this process of recovery, and the operations of the Heemskirk Tin Syndicate at the north end of the field([202]) should have an influence in restoring confidence.

The presence of pyrite in some of the tin ore treated in the past has been considered an almost insuperable difficulty, but the successful treatment of densely-pyritic tin ores elsewhere, by roasting, regrinding, and concentrating the pyritic concentrates, shows that this difficulty can be overcome: this fact seems to be realised now, and the difficulty is after all a minor one, if the tonnages of ore, and sufficiently high tin content of that ore, are available, more particularly as the ore is not, as a rule, densely pyritic.

The writer has derived some of the information contained in this chapter from written communications received from Messrs. A. S. R. Osborne, Luke Williams, Mark Ireland, and David Jones, to each of whom he would tender sincere thanks: he has also consulted " The Wild West of Tasmania," by Wilberton Tilley.

([202]) *Vide* Geol Surv. Tas. Report 6, 1915.

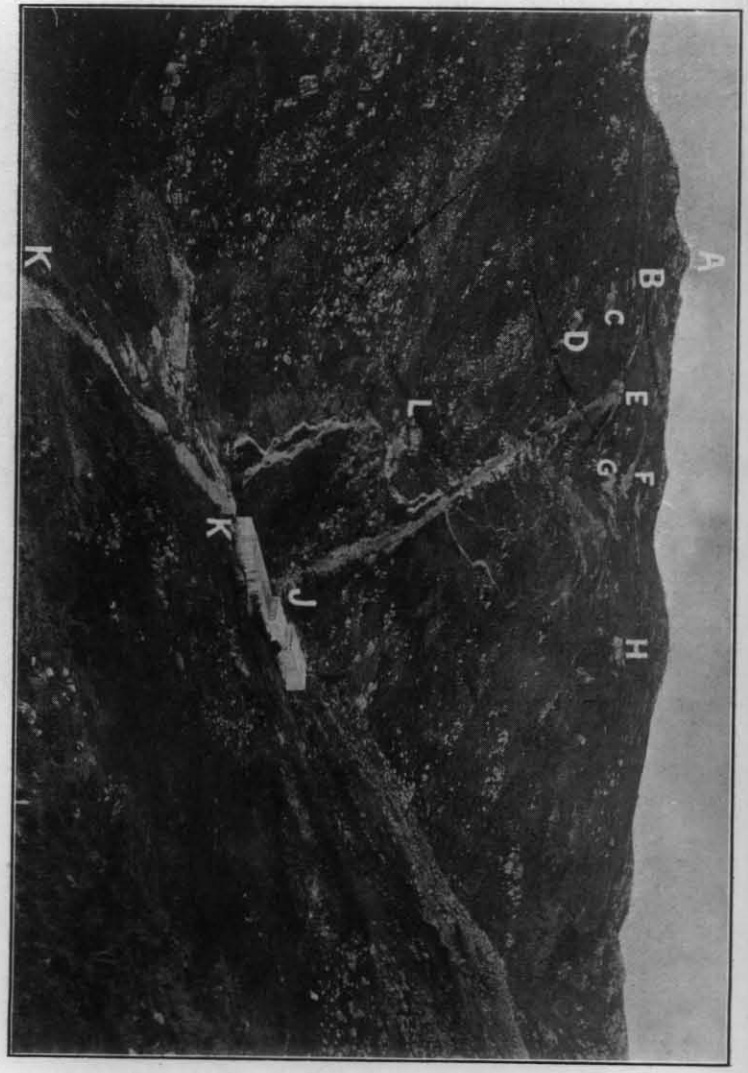


PHOTO. 18.—FEDERATION TIN MINE, SHOWING HAULAGE, BATTERY, AND WESTERN WORKINGS.

[L. Lawry Waterhouse, Photo.

VII.—THE MINING PROPERTIES.

(1)—*Consolidated Lease* 3917M *and Section* 5765M, *J. H. S. Munro. (The Federation Tin Mine.)*[203]

Location.—The Federation Mine is situated near the southern end of the Heemskirk Range, on the western slopes of the range. It is distant about 7 miles from Zeehan by air-line, in a south-westerly direction. It is only about 2 miles from the coast, Trial Harbour being 3 miles to the south, and connected by road with the mine.

Access.—Access is given by the Zeehan-Trial Harbour-Corinna road, which approaches within about half a mile of the property; a branch road connects with the mine. By this route the distance is 14 miles from Zeehan. Unfortunately the road is in a bad state at many points, rendering carting difficult and costly. There is a route shorter by about 3½ miles, available for pack-horses only, branching off from the main-road about 2 miles beyond the Comstock, and climbing over a high saddle of Mt. Agnew. This track is steeply graded in places, but is in fair condition, with the exception of a few culverts which need renewing.

Although necessaries are at the present time carted by road from Zeehan, there is a steel tramline of 2-feet gauge, constructed to Comstock between 6 and 7 miles, which could be utilised if necessary.

On the whole the grade of the road is good, yet several deviations would be advisable if there was a prospect of much heavy carting. When repairs are being effected on the road, attention should be given to the carrying away of rain water, for neglect of this precaution in a district of very heavy rainfall has been largely responsible for the present bad condition of the road.

Area of Leases.—The area held at the time of the writer's examination was 308 acres, comprised in a consolidated lease, 3917M, of 268 acres, with an adjoining lease on the south, 5765M, of 40 acres, both charted in the name of J. S. Munro. There is also a water-right, 784W, of 15 sluice-heads, on the Cumberland Dam, also held by J. S. Munro.

[203] This report was prepared prior to the writing of the remainder of the bulletin, as an advance report: it has since been slightly modified in a few places, but has not been rewritten, hence there is a slight duplication in some particulars of what has been written.

The adjoining sections were all vacant at the time of examination.

Comprised in the present Federation lease are properties which were previously owned and worked by separate companies: the West Cumberland, Cumberland, and East Cumberland properties are all included, also the New Cumberland, which was formed to incorporate both the Cumberland and West Cumberland properties. Tin was discovered in 1875, and work has been carried on very intermittently since that date.

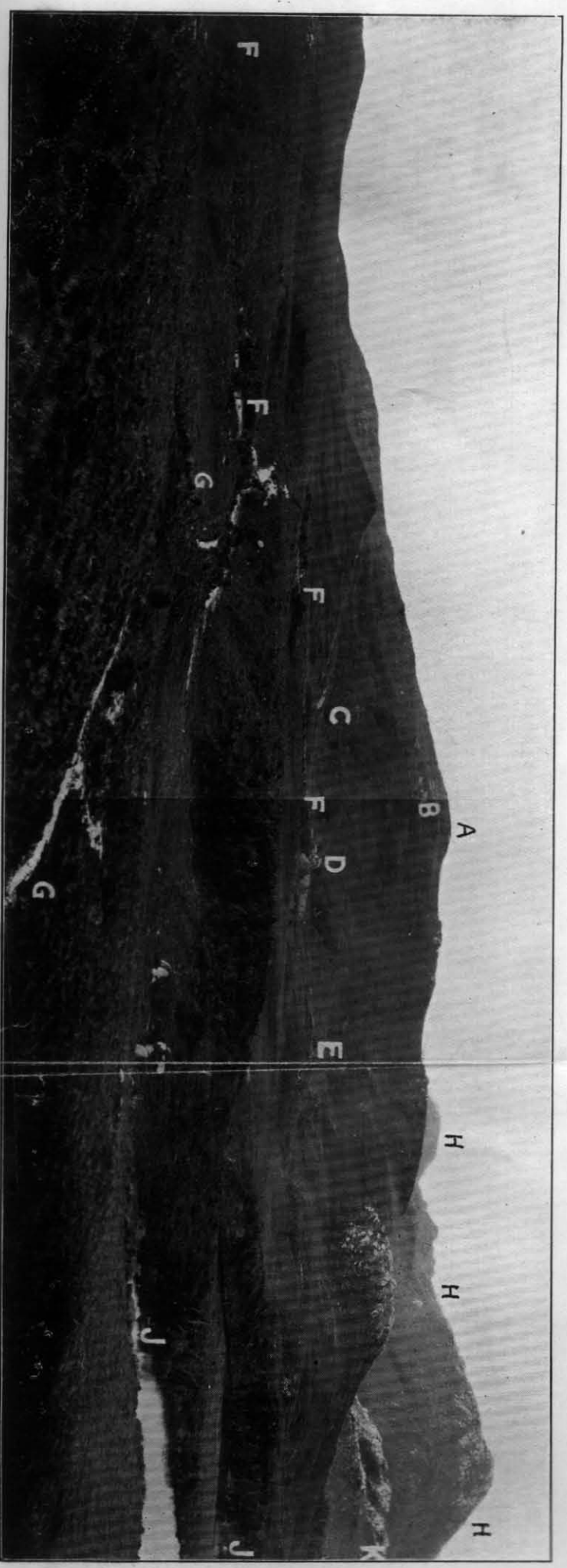
Since Mr. G. A. Waller, Assistant Government Geologist, reported on the property in 1902, very little work has been done excepting at what are known as the tributers' workings, on the western slope of the hill, where some rich tin was won, so that this report must necessarily be to some extent a repetition of what has appeared in Mr. Waller's report, more particularly in the descriptive section.

Topography and Water-supply.—Topographically the mine is very favourably situated, with respect to prospecting, exploitation, and mining: the topography, too, offers exceptional advantages in allowing of the storage of water at a high elevation, and its utilisation for power purposes. The mine is situated on the western slopes of Mt. Agnew, about 2 miles from the main peak. Mt. Agnew slopes steeply to the west for about 1400 feet to the level of the Cumberland Creek, where there is a basin rising again towards the west, and then falling away steeply again to the coastal peneplain, about 600 feet above sea-level. West of the Cumberland Creek in the vicinity of the Federation Mine, there is practically no timber, the hill slopes being covered with button-grass, with bold granite outcrops forming precipitous cliffs in places. The upper slopes of Mt. Agnew, however, are thickly wooded with splendid timber, which extends down to the level of the Cumberland Creek: a large area here has been reserved by the Government from leasing.

The basin at the foot of the steep western slope of Mt. Agnew, which really forms a hanging valley, with the Cumberland Creek flowing through it, has been turned into an artificial lake by means of a short embankment across the rocky defile which forms the natural outlet of the creek. This body of water, now known as the Cumberland Dam, is reserved from leasing. It was previously known as the New Cumberland Dam.

Something of the value of this magnificent body of water will be realised when it is said that the water is dammed

PHOTO. 19.—PART OF CUMBERLAND DAM, PLATEAU AND FEDERATION MINE, HEEMSKIRK RANGE IN BACKGROUND.



[L. Lawry Waterhouse, Photo.

back over a mile, and its volume is stated to be about 100,000,000 gallons. The capacity could readily be increased many times over, by raising the embankment and by-wash. The embankment is only 1 chain in length; it is very substantially built and faced with granite, and on the present embankment as a base, the higher wall may confidently be erected. The catchment area is certainly limited, but the rainfall is generally so abundant that by increasing the storage capacity any dry spell can be safely negotiated.

Such a body of water stored at an elevation of 500 feet above the machinery site presents obvious advantages. At the Federation Mine, 450 feet of pressure can be obtained at the present battery site, by means of a race 94 chains in length, and pipe column of little over 1000 feet.

Further reference is made to the Cumberland Dam in another part of this report.([204])

The old West Cumberland Company brought water from Packer's Creek to work their battery by means of a water-wheel, which, however, was situated at a lower level than the present battery. This at once suggests that for dressing water, a race might be constructed from Packer's Creek, at a higher elevation than the old one, to the present battery site—a perfectly feasible plan.

So that with regard to water-supply the Federation Mine is highly favoured.

The topography of the locality has played an important part in the prospecting of the property, and is destined to be of great assistance in its future development. During the long period of degradation to which the region has been exposed, the streams have cut deeply down into the granite mass, dissecting and exposing the lode-formations. The immense advantage of this state of affairs will be recognised when it is remembered that towards the centre of the property the elevation is nearly 1800 feet above sea-level, while in the creek bed on the western boundary it is only about 700 feet. This means that the outcrops of the lodes are exposed in some instances, at points deep below the original surface, where they may be attacked and exploited at a minimum cost by means of adit levels and crosscuts. So in this respect nature has done much to assist man to win some of her hidden treasure, which would otherwise have been inaccessible without deep mining.

([204]) *Vide supra*, pp. 7, 24–26.

Geology.—The geology of the locality is comparatively simple. During Devonian times there occurred a period of intense igneous activity in different parts of the island. In the district under review there was developed at this time a series of sedimentary rocks, now removed by denudation. Into the rocks, deep below the existing surface, huge masses of molten material were forced, and cooled and consolidated gradually, under conditions of high pressure. As the outer crust of the granite cooled, it also contracted, and fissures were formed in the solid material, which offered a ready means of escape to the superheated and chemically active vapours and solutions which had gradually become concentarted in the heart of the still molten mass, owing to a process known as magmatic differentiation. These vapours and solutions carried the metals in solution, and deposited them with the non-metallic contents, under conditions of reduced temperature and pressure, nearer the surface, since the solvent action of the vapours was lessened under such conditions. These fissures were in many cases minute originally, but the rock-walls were attacked, some of the material taken into solution, and other deposited. So in the actual lodes occurring, we frequently find a central vein, bounded on either side by altered granite which merges gradually into normal country-rock. It generally happens that the central vein carries tin oxide, but that the vein material fringing this central vein, also carries disseminated cassiterite.

The mineralogical composition of the ore is comparatively simple. It frequently consists of quartz, black and green tourmaline, and cassiterite: pyrite is sometimes present. In most cases where absent, it is probably only as a result of weathering, and it will be found in nearly all instances in the true primary lode-matter. The presence of pyrite has in some cases been a serious hindrance in the successful working of the ore-body, and in fact in the earlier history of the property good shoots of tin ore were regarded as valueless when accompanied by pyrite, as a market could not be found for a pyritic concentrate.

Exceptionally a little fluorite is present. Native bismuth and bismuthinite have been reported from the property: these minerals do sometimes occur in the vein-type.

Mispickel is apparently present in small amount in one or two localities.

Wolframite may be found in places: none is known to occur *in situ* on the property, although it has been found in the alluvial. It does occur, however, associated with

cassiterite on an adjoining section. Blende also occurs on an adjoining section, but has not been located on this property. Tourmaline is always abundantly represented, both black and green varieties being present: the latter is usually the more favourable for tin, but in some cases it is absent, and yet rich tin occurs, as, for instance, in Gray's lode.

The cassiterite varies considerably from point to point, in grainsize and colour. In places it is crystalline, in jet-black crystals, or again the crystals may be brown and translucent. It also occurs extremely finely divided, of a light-brown colour, and apparently without crystalline form. Various occurrences will be dealt with in more detail below.

With reference to the actual distribution of the tin in the lodes, the work already carried out gives certain definite information as to (*a*) the longitudinal, (*b*) the vertical distribution of the tin values.

It is evident that the richer tin occurs in definite shoots in the lodes, different shoots being connected by lode material which generally carries disseminated cassiterite, although sometimes not in payable quantities. The longitudinal distribution of the tin in shoots should be always kept well in mind when carrying out future prospecting and mining operations. The lode channels are generally distinct and easily recognisable, and should a lode be cut at a point where the tin values are low or absent, it does not necessarily follow that the lode is of no value: prospecting along the length of the lode is to be strongly recommended, to try and pick up a shoot of rich ore. The topography of the property has been described, and mention made of the fact that the granite, with included ore-bodies, has been deeply dissected by various creeks. One result of this dissection is that a vertical section of nearly 700 feet at a maximum has been exposed of some of the lodes. This is a fact of considerable importance, not only scientifically, but because of its practical bearing. Not only does it mean that the lodes may be worked economically, but definite information is yielded with regard to the continuity of tin values to a considerable depth. At the deepest point at which the lode has been cut, the tin values do not appear to have suffered any deterioration. This feature is certainly encouraging, as there is no evidence to suggest that faulting may have accounted for the difference in level. In cases where tin lodes are exposed in granite country, mining has in a few cases proved that denudation has been active for such a long period, and the heart of the granite mass

has been cut into so deeply since the formation of the lodes, that only the stumps of the tin deposits remain, and the payable ore has cut out at comparatively shallow depths from the surface existing at the time of their discovery. It is distinctly encouraging to find that such is certainly not likely to be true in this case. Apart from the evidence already noted, it appears from field evidence that there has not been an excessive amount of denudation, and that in this locality, although the overlying sedimentary rocks which probably existed at the time of the formation of the ore-bodies have been removed, and the granite itself dissected, it is likely that the tin lodes will be found to continue from the present surface to depths beyond the reach of economic mining.

Apart from the lodes already dealt with, there is at least one (and possibly more than one) example of a pipe in the granite. This is approximately oval in cross-section, and follows a very irregular course, dipping sometimes vertically, then pitching suddenly at different angles, in very different directions. It was followed down for some distance and was found to carry rich tin in the form of coarse crystals of cassiterite, associated with crystals of pyrite, in a soft micaceous groundmass, sometimes thoroughly kaolinised.

The cassiterite crystals are frequently twinned, and the pyrite occurs in perfect crystals, the forms developed being the cube and pyritohedron, or various combinations of these two forms: they are sometimes intergrown with cassiterite, tourmaline, or quartz.

The walls of the pipe are much altered, and carry tin, but merge gradually into normal non-stanniferous granite.

Further work should certainly be carried out, as the pinching of the pipe at the spot where work ceased is probably local, and there is no reason to doubt the continuance of the pipe with good tin values to a depth.

The Lodes.—A little may be said here with regard to the character of the lodes; they will be dealt with more in detail when the various workings are being described. There are so many outcrops showing on the property that a considerable variation is to be noted in the nature of the lode material. With the comparatively small amount of work carried out up to the present, these outcrops cannot all be correlated with each other, and doubtless in some cases a certain amount of faulting may have occurred. The outcrops frequently stand out distinctly above the peaty button-grass covering the granite, and may be traced continuously for considerable distances. When the mineralogical composition of the outcrops is taken into consideration, the reason for their standing out in relief is obvious. The bulk of the material is quartz in several instances, although this is frequently accompanied by tourmaline. Both these minerals strongly resist weathering agencies; in the case of the granite, the felspar and mica are prone to decomposition, and consequently the disintegration of the country-rock is rapid. From their nature, the lode outcrops tend to break off in pieces rather than to disintegrate bodily, and one result of this action is that the hillsides are strewn with these fragments of quartz-tourmaline, and all the creek beds likewise carry them in abundance. Much of this detrital material on the hillsides carries good tin values, which will pay for extraction, according to values obtained by systematically sampling. Naturally the creeks received their quota of the heavy metal, but most of the alluvial patches have been worked out.

Although the quartzose and quartz-tourmaline varieties of lode material form the bulk of the outcrops, white mica is sometimes present, forming the variety known as greisen.

Workings and Details of the Lodes.

For descriptive purposes, the workings on the property may conveniently be divided into three groups, (*a*) Western, (*b*) Central, and (*c*) Eastern Workings.

(*a*) *Western Workings.*—These workings are mainly the result of operations carried out by the old West Cumberland Company and Messrs. Fowler and Dunn. They are situated in the western portion of the consolidated lease, and on the western slope of the range. They consist mainly of adits driven into the hillside, either on the course of the lodes or through country-rock to intercept them, with drives and stopes therefrom, some open-cut work, and several shallow shafts, in addition to surface trenching.

What are known as the Whip Shaft Workings comprise an adit called the 570-feet level, another higher up the hill, the 500 feet, and a shaft known as the Whip Shaft, still higher up, but connecting with the two lower tunnels.

In the nomenclature in vogue on the mine, levels are calculated according to their vertical distance below the collar of Munro's shaft, a shaft sunk on the top of a hill about the centre of the property, and which is about the highest point on the mine. To avoid confusion, this nomenclature

will be adhered to as far as possible during the course of this report.

No. 4 Adit, or 570-feet Level.—This level is driven on the course of a quartz-tourmaline vein which has a general strike of about N. 50° E. Much of the lode is very quartzose, though it frequently shows a central seam of green tourmaline with a border of quartz-tourmaline, merging into ore characterised by quartz, tourmaline, and mica, which in turn seems to merge into granite. The width varies from point to point from 6 inches to 6 feet.

On the outcrop the lode shows abundant black tourmaline, often in radiating masses, and does not look very promising for tin values, which usually accompany green tourmaline in this district.

The total length of the drive is 418 feet. No crosscutting whatever has been carried out. At 237 feet from the entrance a rise connects with the 500-feet level 70 feet higher up the hill, and thence to the surface, the upper portion being known as "The Whip Shaft." This is inaccessible at the present time.

A short length of tramway connects this adit with the main inclined self-acting tram leading to the battery.

The course of the adit varies, although the reason for some at least of the bends is not very obvious. On a bearing of N. 48° E. the drive extends for 82 feet; it then bends 6° further to the north for 38 feet. It takes then a course of N. 60° E. for 74 feet before bending 13° further north again for 42 feet. Then on a bearing of N. 64° E. it extends for 136 feet, when it bends sharply round to the east, leaves the lode, and on a bearing S. 74° E. has been driven for 46 feet through granite.

At the entrance the lode is comparatively narrow, but is well defined. At 48 feet in is a well-marked vertical fissure filled with kaolin junctioning with the main vein without cutting across it from the southern wall. At 88 feet the vein widened, and a shoot of good tin ore was cut. This was stoped to the surface for a length of 27 feet. This stope was inaccessible, but the width is reported to be 20 to 24 inches in the back of the stope near the surface. There is said to be good tin continuing underfoot here, the width being about 3 feet. At the end of the stoped ground, in the back of the drive, there is a narrow central soft seam of tourmaline, carrying some cassiterite, bordered on either side with quartz-tourmaline vein-stone, which again merges into a variety in which white mica is developed. From this stope some rich ore is said to have been won.

At points about 30 and 50 feet respectively beyond this stope cross-veins with lode material join the main vein from the southern wall, about 15 and 36 inches wide respectively, but no crosscutting has been done to prove either of these formations.

About 100 feet from the entrance a vertical fissure comes in from the southern wall, and the main vein splits, about 3 feet of lode material crossing into the opposite wall.

At about 140 feet in there is promising looking lode material showing in the northern wall for 12 feet. It is soft and rubbly in nature, carrying much kaolin.

Approaching the rise there is on the south wall 10 feet of similar soft kaolinised lode material. In both these cases it is uncertain whether it is a local widening in the vein which has been followed, or whether it is a distinct lode junctioning with the main one. No attempt has been made to decide the question by prospecting.

The rise is now filled up, but the writer was informed by the manager that a vein of good tin in quartzose pyritic matter occurs about half way between this level and the next above (500-feet level) in the western corner of the rise.

At 372 feet in the drive makes a sudden deviation, for no apparent reason, and extends for 46 feet in a direction S. 74° E. through very hard fresh light-coloured biotite granite, medium to coarse in grainsize. This granite is a good deal fissured, and is cut through at various angles by narrow quartz-tourmaline veins. A fact worthy of note is that solutions leaching from the present face of the drive are depositing a good deal of limonite. This limonite is probably derived from a pyritic formation, possibly tin-bearing, at no great distance ahead. This drive is worth continuing for a few feet further. The face is about 11 feet east of the lode cut in the 400-feet level, driven from Fowler and Dunn's open-cut, which is 170 feet vertically above this drive. The dip of this lode appears to be about vertical near the surface.

At the point in the 570-feet level where this deviation is made, 372 feet from the entrance, the lode is left in the face. It is not even cut across, but remains exposed in the north wall, a width of 6 feet being here opened. The dip is vertical. The lode material consists of soft rubble, with harder bands of quartz with black tourmaline. The softer material is much decomposed and iron-stained, much kaolin being present. It carries vughs of pyrite, and also of tourmaline. The average assay value is said to be 1 per cent. metallic tin.

For nearly the whole length of the drive lode material has been left on the northern wall, but at no point has any crosscutting been done. In most instances the true width of the lode has not been exposed.

Samples taken by the manager along the length of the lode indicate that the average value is over 1 per cent. tin.

As has been remarked, the granite country-rock away from the lode is fresh, and very hard and tough. Along the course of the lode, however, it is soft and decomposed, owing to alteration by the vein-forming processes, and carries a little tin in places.

This adit was driven by the old West Cumberland Company, and, although it seems that all the stone from the drive and rise was crushed, there is no record of the battery-returns.

It is surprising to find that no steps were taken to prospect the lode thus opened up by cutting across it. Such a course is certainly to be recommended. At a point about 130 feet from the entrance a cut should certainly be put across the lode to expose the width and value of the stone. At several other points, too, a little more work could advantageously be carried out.

500-*feet Level (No. 3 Adit).*—At a point 70 feet above the No. 4 Adit previously described, and 500 feet below the collar of Munro's shaft, the No. 3 Adit was driven by the old West Cumberland Company a total distance of 170 feet. It seems to have been driven to intersect a vein cut on the surface by trenching.

The level is connected with the main inclined haulage line by a short branch tramway round the face of the hill, connecting with a plat on the main line. This branch line was constructed to enable the full-sized trucks to be brought in, loaded, and sent down the incline to the battery without the necessity of rehandling the ore broken.

The adit is driven 49 feet on a bearing of N. 57° E., then 62 feet N. 53° E. The course then bends round 12° further east for 59 feet. The adit intersects a number of narrow quartz-tourmaline veins which cut through the granite in various directions. One of these veins has been followed for some distance, but does not appear very promising. Although passing within a few inches of it, as originally driven the adit does not seem to have exposed the pyritic lode which was afterwards opened up by tributers, who came into the old level and commenced to break through to connect with the Whip Shaft overhead. The ore as exposed has been slightly opened up. The lode appears to strike

about N. 30° E., although it is difficult to judge exactly from the small exposure made.

The length of stope is 16 feet, from 104 feet in. The lode material is pyritic at this point. It is kaolinised, and carries a good deal of tourmaline, with much soft gossan. Throughout are geodes of quartz and irregular masses of pyrite, generally with a little quartz, from about 1 inch to 12 inches in diameter. These are frequently completely surrounded by gossan or kaolin, and there are no apparent veins connecting them in the ore-body. This habit enabled the more highly pyritic material to be hand-picked when work was going on; much of this was picked out, and as the shaft connecting the 500 and 570 feet levels was open, this was used by the tributers as a convenient dumping-ground.

When this portion of the mine was being worked by tributers the pyrite met with caused the party a considerable amount of worry and anxiety, and eventually led to the abandonment of the tribute. The stone was crushed in the battery, but the tin could not be dressed clean, and when a parcel of pyritic tin concentrates was despatched to the Bischoff smelting works, it was rejected, as no roasting furnaces had been installed at the time. Some time afterwards the parcel was sold at a remunerative price to a Sydney firm. This particular parcel is said to have assayed 63·5 per cent. tin.

The pyrite carries tin, but under modern methods of treatment would not present difficulties such as were involved in the earlier history of the mine. A good deal of the tin present in the ore is free. It must be borne in mind that the ore at this level is not truly primary ore. Near the surface the ore was free milling, owing to the oxidation of the pyrite.

The length of the shoot of ore is still unknown, as no work has been done to prove its extent. A width of 6 feet is exposed in the stope, but the full width is probably greater than this. The average value as exposed has been shown by battery returns to be 1 per cent. tin. The writer was informed that over 300 tons of ore were crushed from these workings, and that the figure quoted represents the average return from battery treatment of this quantity of ore.

The opening up of the lode at this level was due to surface prospects. After working for some time from the Whip Shaft, by underhand stoping and hauling, it was decided to break through to this level, and save hauling charges. As to the extension of the ore-shoot at a greater depth,

nothing is known. It seems unlikely that the ore cut in the lower (570-feet) level is the same lode, and the desirabilty of cross-cutting from this level has already been noted. There is no reason to doubt the continuation of tin values to a considerable depth.

The level is driven mainly through granite, which shows fissures in different places, generally filled with kaolin, and sometimes showing slickensides, indicating that some movement has taken place in some instances.

The face of the 500-feet level is in rather coarse-grained granite showing abundant pink orthoclase felspar, with some lode material showing.

There appear to be two lodes, one not very promising, being a hard quartz and black tourmaline vein, but the other, divided by a narrow strip of granite, is, in general respects, similar to that in the rise and stope. It carries a good deal of gossan and green tourmaline, and looks very favourable for tin values. The width is not exposed, though a short crosscut is certainly justified here. The lode cannot certainly be correlated with any other exposure, but may possibly prove to be continuous with one of the lodes exposed in the lower level.

Whip Shaft.—The Whip Shaft has already been referred to in describing the two previous levels. It connects the 570 and 500 feet levels with the surface, although not accessible throughout at the present time. A few feet below the collar of the shaft a very shallow adit was driven, and the material overhead has now been removed, leaving the excavation as a narrow open-cut, the shaft being filled up. From fragments of ore left lying about it is seen that there are abundant masses of crystalline quartz, evidently the filling of geodes. Prismatic crystals showing terminal pyramidal faces, and frequently perfectly clear and transparent, rest on a quartzose base, included in which is frequently noticed extremely finely divided brown and black cassiterite. The quartz crystals often show signs of secondary growth, a film of red oxide of iron coating the primary crystal, and showing clearly through the transparent silica forming the secondary crystal.

A little tourmaline is present in some instances.

One specimen showed interlacing prisms of quartz one half inch in length and one-eighth inch diameter, the interstitial spaces being filled with granular and finely crystallised cassiterite.

At the end of this open-cut is a small cavern worked out, about 12 feet by 15 feet by 20 feet high. There is about 9

feet of ore showing in the face, said to assay 1 per cent. The full width of the ore-body is not exposed. In the face is hard quartz-tourmaline in a softer clayey gossan, probably representing weathered micaceous material. Pyrite has been present in the primary ore, but has been removed by oxidising agencies. Some portions of the ore consist of hard masses of haematite with radiating black tourmaline, said to carry from 2 to 4 per cent. tin. This occurrence of primary haematite, which is distinctly magnetic, is interesting, and has been referred to elsewhere.([205])

The relation of this ore-body to others exposed is not certain, but it seems likely that it may junction with a body exposed, but not yet opened up, on the western side of Fowler and Dunn's open-cut, about 1½ chain to the south-east. Prospecting between these points is warranted.

A few chains to the south-east of the workings described is another group, including the 530-feet level (No. 2 Adit), 400-feet level (No. 1 Adit), Fowler and Dunn's open-cut, and the old West Cumberland Adit, now known as Yates' Level. From these workings some good tin has been won.

No. 2 Adit.—This adit is also known as the 530-feet level, from its vertical distance below the collar of Munro's shaft. A long approach (65 feet) was cut, and from the entrance the adit extends for 37 feet 6 inches on a bearing of N. 8½° E.: it then bends to N. 4° W. for 28 feet, and finally continues 47 feet 6 inches on a bearing N. 34° E. Thus the length of the adit, without considering the approach, is 113 feet. It was driven by the old West Cumberland Company, on a lode which outcrops for some chains on the hillside, and which is about 3 feet wide in the approach. For some distance the back of the level is close-lathed, but stone can be seen in places. At 29 feet in, stone seems to be going into the west wall, but the drive is continued on a vein 4 to 5 feet in width, with granite on either wall of the drive. At 32 feet there is a pass, and here granite seems to come in underfoot. This pass, although now collapsed, connected with the surface, 80 feet, and when the No. 1 Adit was being driven, and surface work going on here, stone was sent down this pass, and trucked from the No. 2 Adit to the inclined tram, and thence to the battery. The drive now continues on the course of the lode, which has hard granite walls, much fissured. At 37 feet from the entrance is a short crosscut, perhaps 15 to 20 feet, but now collapsed, driven

([205]) *Vide supra*, p. 155.

on a bearing N. 44° E., in granite. At this point the drive intersects a lode about 3 feet 6 inches in width, composed of soft decomposing lode-stuff with some hard quartz-tourmaline. The strike is N. 41½° W. at this point, and the dip appears to be south-west, but a heap of mullock at the entrance to the crosscut partially conceals it. Unfortunately, the lagging and filling on the north-west wall make it impossible to examine the intersection of this lode with the main one on which the adit has been driven: the latter certainly widens here, and is at least 6 feet, perhaps more. The drive continues with veinstone on the eastern wall and in the back, and granite on the west wall. At 41 feet from the entrance a cross-vein was cut, striking N. 60° W.: this is about 15 inches wide in the granite on the western wall. About 2 feet further in there is a local development of granite for about 18 inches on the eastern wall, then a mass of soft, thoroughly kaolinised material with abundant tourmaline in radiating masses, harder quartz-tourmaline sometimes making its appearance: this material is exposed for 13 feet on the eastern wall of the drive, but the back is covered in this vicinity. At 56 feet in another cross-vein was cut, apparently striking about N. 60° W.: the relation of this to the main formation is hidden by the lagging. Beyond this point, no further stone appears in the level which is driven through hard granite, much fissured in all directions. At 71 feet is a well-defined fissure which appears to be a fault plane: the felspars seem crushed, suggesting that some movement has taken place. This fissure strikes approximately N. 54° W. At 100 feet from the entrance is an old rise. At this point a fissure cut across the drive, differing in no respect from many others already intersected in driving: it carried a mere thread of black tourmaline. For some reason now unknown, it was decided by the old company to rise on this fissure, through the hard biotite granite. After rising 30 feet, rich stone was met, and between 60 and 70 tons of tin were taken out. Unfortunately these old workings could not be examined, as they have long since collapsed. It is probable that this rich shoot of ore occurred at the intersection of two fissures. The excavation from which this tin was taken was about 25 feet high, 20 feet wide, and 30 to 40 feet long: it is reported that the ore seemed to cut right out above and below, a flat fissure forming the roof. Some time after this ore was worked out, the property was taken over by Messrs. Fowler and Dunn, and an accidental fall from the roof disclosed the fact that more ore existed

higher up. The old workings were in such a precarious state it was unsafe to work there, and the party came to the surface, started to sink to locate this ore, struck rich tin, and worked out what is now known as Fowler and Dunn's Open-cut, taking out about 60 tons of tin oxide. Seeing that two masses of rich ore were discovered in such close proximity to each other, it is a matter of great surprise that so little work has been done to try and locate further shoots of ore. From the old pass, which connected these workings, the No. 2 Adit has been driven about 13 feet in granite which shows in the face.

Further prospecting work is certainly recommended here: the adit might well be continued to the north, and as faulting appears to have been responsible for the sudden cutting out of the shoot of tin, crosscuts should certainly be driven east and west.

Fowler and Dunn's Workings.—When Messrs. Fowler and Dunn took up the property which had been forfeited by the old West Cumberland Company they intended searching for more tin in the neighbourhood of that taken out by the company, but were ordered out of the excavation referred to, by the inspector of mines, who considered it unsafe. Tools were left in the workings, but on returning for these it was found that a fall of the roof had taken place: this material was found to be rich in tin. It was decided to try and locate this from the surface, and two holes were sunk, both happening to disclose rich tin. The shoot of ore was then opened up and worked out by open-cut methods; the material was crushed in the old battery and concentrated by means of buddles, for a return of 6 per cent. tin, altogether about 60 tons of tin oxide being won. The excavation at present is about 100 feet long, and about 30 feet broad, narrowing towards the bottom to 8 feet: the face is 47 feet 6 inches high, the cut running out to nothing. It appears that a certain amount of underhand stoping has been done, and the old workings filled in.

There is not a great deal to see at the present time. The country-rock is medium to coarse-grained granite, much fissured, and intersected by veins of quartz-tourmaline, some of them mere threads in width: these are hard and resistant to weathering, and stand out in the softer partially-weathered granite: they are generally tin-bearing. The granite shows irregular seams of brown to reddish limonite, sometimes inclined to be nodular.

Quartz crystals were noticed in places, sometimes fringed with soft decomposing micaceous material: one specimen

broken showed cubical cavities which still contained a little pyritic material, surrounded by a crust of limonite. On the sides of the cut there is seen to be a floor of limonite on the under-side of quartz-tourmaline veins which are lying very flat. The same class of material appears to have been worked out, and to have carried good tin. The best ore is said to have been always iron-stained, and where the limonite was absent the tin values were always poor. Obviously the ore in its primary state has been pyritic, pyrite and cassiterite having probably been introduced simultaneously: the oxidation of the pyrite under the action of weathering agencies has given rise to the limonite encountered. In the case of some of the nearly horizontal quartz-tourmaline veins, the iron oxide leached out in solution has been deposited on the lower side of the vein.

The face of the open-cut is interesting. It is 47 feet 6 inches high, 36 feet wide at the top, and about 8 feet at the bottom. Into this face an adit has been driven, which will be referred to later. In the granite is a very irregular vein of quartz-tourmaline, about 4 feet 6 inches in width at the top of the adit, widening to 9 or 10 feet in places: sometimes it pinches, and in other places it appears to split and reunite. Near the surface there are several comparatively narrow veins branching out from the main quartz-tourmaline vein. Several of these are exposed on the sides of the cut, where they appear as veins of quartz-tourmaline lying very flat: these carry tin. There are noticeable fissures in places, cutting through both the granite and quartz-tourmaline veins. In the quartz-tourmaline itself, veinlets of black tourmaline stand out distinctly.

At about 20 feet back from the face a winze has been sunk on the eastern wall on a quartz-tourmaline vein, and the lode material underhand-stoped. This winze connects with the adit below.

On the western side of the cut, about 45 feet from the face, a small crosscut was driven for 15 feet west, and a very promising body of ore exposed. The lode material consists of soft yellow-brown kaolin carrying mica, with harder quartz-tourmaline, some of it much iron-stained: the lode is said to carry rich tin. It is about 5 feet in width where exposed, but appears to be widening. This lode material is said to be very similar to that worked out by Messrs. Fowler and Dunn from the open-cut.

Nothing has been done to prove the extent of this lode, or its value, beyond this one point. The discovery is important, and should be followed up. Two masses of rich ore have been taken out in close proximity, and it is reasonable to expect that others may be found. Although the No. 1 Adit has been driven, practically no crosscutting has been done. It is possible that the ore exposed on the western side of the open-cut may junction with that exposed by the Whip Shaft workings. Prospecting is certainly to be recommended to test this ore-body and try and locate others: conditions are favourable for the existence of other bodies.

No. 1 Adit.—The No.1 Adit, or 400-feet level, was driven by the New West Cumberland Company, who took over the property from Messrs. Fowler and Dunn. From the face of the open-cut, it extends 48 feet on a bearing N. 15° E., then bending a little further east, bears N. 29° E. for 40 feet. At this point short crosscuts extend 7 feet east and 12 feet west. On a bearing of N. 4° E., the level has been driven for 29 feet. Finally, on a bearing N. 15° E., it extends for 27 feet to the point where a winze was sunk, and a further 55 feet to the face; thus the length of the drive is 199 feet.

A few feet from the face, a short drive has been put in for about 15 feet to the west on lode material, and a rise, now collapsed, is said to be up for 30 feet on ore. A body of ore has been cut here which is said to assay over 0·5 per cent. tin oxide. It strikes N. 63° W., and appears to dip at rather a high angle to the south-west. The width varies a good deal: it is 5 feet 3 inches at the collar of the drive, widening in a few feet to 7 feet, while in the face it is 8 feet 6 inches. The lode material appears to be fissured in all directions: it contains a good deal of gossan and iron-stained kaolin: also a variety of ore consisting essentially of hæmatite and black tourmaline.([206]) On either wall is soft, thoroughly-kaolinised granite. This lode probably corresponds with one outcropping at the surface, and also with that exposed in the adit to the west, now known as Yates' Level.

There is a short drive (about 9 feet) to the east, now filled with material from the collapsed rise overhead, said to be 30 feet.

The winze referred to, at 144 feet from the entrance, is full of water and consequently inaccessible. Mr. A. Yates, mine manager, has kindly supplied the following information concerning it.

([206]) *Vide supra*, p. 155.

It was cleaned out to 50 feet, but the depth may have been greater. Although an old report stated that tin and bismuth crystals occurred in the bottom at one stage, the depth was not stated, and a certain amount of doubt now seems to attach to the report. Samples from the ends of the winze showed bismuth but no tin at all. The bismuth is reported to occur both as sulphide and carbonate, and to be associated with quartz and tourmaline. The sides and ends of the winze are in clean granite, with no sign of a lens of ore, although at 48 feet, on the south end, some limonite had been left from the old workings: the granite at this point appeared normal: the width of this gossan was 2 feet. At about 25 feet down, a vertical fissure was noticed in the granite for a few feet, cut off by a horizontal fissure above.

The winze is 7 feet 6 inches by 4 feet.

Overhead is a filled-in rise, about 20 feet above the floor of the level, and some stoping has been done. All the ore won was crushed, and the bismuth concentrates sent to England. Mr. Montgomery reported that 15 cwt. of concentrates, assaying 39 per cent. of bismuth, were won.

Further work on this shoot of bismuth ore is advisable.

The lode in which this shoot of bismuth occurred, and on the course of which the adit has been driven, appears to be quite distinct from that cut towards the end of the drive, the latter being a cross lode: it is a matter for regret that the main level has not been continued beyond the intersection: this work is worth carrying out.

The lode driven on in the No. 1 Adit does not look very promising towards the entrance. There is a fairly well-defined fissure with altered granite on either side, and sometimes quartz-tourmaline veins. At about 88 feet the width increased to about 16 feet, only to pinch again. It is said to carry tin at this point: short crosscuts have been driven east and west, a total distance of about 18 feet.

A noticeable feature in this adit is the fissuring of the granite. During the first 100 feet many fissures were noticed cutting through the granite in different directions.

Above the winze the main fissure crosses the level, and then forms one wall (the western) of the adit. It strikes N. 15° E., and is almost vertical, sometimes dipping east at a high angle. The fissure shows slickensides in places and generally about 3 inches of soft kaolin, forming a clay "dig." At 176 feet from the entrance another fissure appears on the eastern wall, standing vertically.

At 182 feet a cross-fissure was noted, with a strike of N. 65° E., and dip south at 60 degrees. This appears to end at the main fissure, being probably earlier and slightly faulted by it.

The main fissure appears to cut through the cross-lode exposed in the end of the drive in a somewhat irregular fashion, but without displacing it.

From the present face of the level, the backs available would probably amount to about 100 feet.

Yates' Level.—About 60 feet to the east of the No. 1 Adit, and a few feet lower down the hill, is an adit known as Yates' Level, driven by the old West Cumberland Company, probably with the object of cutting a cross-lode outcropping on the surface. The entrance to the adit is about 100 feet south of the face of Fowler and Dunn's open-cut and the entrance to No. 1 Adit.

The level is 283 feet in length, driven on a bearing of N. 22° E., and consequently running nearly parallel with No. 1 Adit.

The level has been driven through biotite granite, generally hard and fresh, but adjacent to lode-formation it is much softened and decomposed. The granite carries abundant nodules of quartz and tourmaline, and the level exposes many fissures, running at all angles, sometimes almost horizontal, and forming the roof of the level for some distance.

At 70 feet from the entrance, a rise was put through to the surface for air, but is now inaccessible: from this wooden pipes were carried along the drive.

At about 200 feet a fissure appears, which is evidently a true fault plane. It has a strike of about N. 20° E., and the adit has been driven part of the way along the course of this fault plane.

Lode material was cut at 235 feet: it has well-defined walls in the granite, and has a width of 5 feet 3 inches in the main drive. The strike here is N. 74° W., and dip vertical. The lode appears to be displaced by the fault referred to, to the extent of about 3 feet, the fissure being traced to the present face, where it still shows slickensides, and deposits of limonite: in the face itself, harder tourmaline granite is exposed, which does not look unpromising for tin. The main fissure here dips east at 81 degrees, this figure representing the average of a number of observations.

The lode material seems to be a good deal shattered, as exposed in the level, but consists essen-

tially of banded quartz-tourmaline, and abundant black tourmaline in radiating nests, with some green tourmaline and quartz. Some bands are very hard and quartzose, showing a little black tourmaline. The weight of some of the masses of black tourmaline is striking, and further examination than has been given is necessary. Prisms of quartz are sometimes present, and some minute yellow crystals were noted under the magnifying glass, which have not yet been determined. This material is said to carry a little pyrite, although none was seen in the stone broken.

The lode is very wet, and as a result of the soakage water, a good deal of the lode material is soft and decomposed.

At 237 feet from the entrance, a crosscut has been driven for 75 feet east. Fifteen feet further on is a drive to the west. Here a winze was sunk on the lode, and underlies to the west. The depth is unknown. Some underhand and overhand stoping have been done here, but the extent of this work, and the extent of the driving carried out on the lode, are unknown. The lode here is said to carry bismuth, and it is reported that assays have shown as much as 8 per cent. over the old winze.

A sample broken over a width of 3 feet from the eastern side of the drive, and consisting of soft kaolinised material with some tourmaline, was submitted for analysis to Mr. W. D. Reid, Government Assayer, who reported:—

	Per cent.
Tin	0·46
Bismuth	3·76

Although the tin value is low, the bismuth value must be considered as very satisfactory, and certainly such as to justify further work on the shoot of ore. The assayer reports that the bismuth is present in the ore as bismuthinite (bismuth sulphide).

In the northern drive the strike of the lode, as exposed, appears to be N. 57° W.

It is very probable that this lode is the same as that cut in the No. 1 Adit, and which outcrops boldly on the surface. As will be readily seen from the above description, little real prospecting has been done from this adit. The crosscutting done is insignificant, and even when a well-defined lode has been cut, no driving has been carried out along its course to prove whether shoots of payable ore do exist within reasonable distance of the main adit.

Such work is certainly desirable.

Surface Workings on Cross Lode.—The lode, which has been called the cross lode, and which has been cut in No. 1 Adit, and also in Yates' Level, apparently outcrops on the surface, where it has been slightly opened up at one or two points. It must be borne in mind, however, that with so many quartz-tourmaline outcrops as exist on the Federation property, it is not always possible to correlate with certainty a particular surface outcrop with a lode cut in the underground workings. It is important in tracing such surface outcrops and attempting to correlate them, to consider the dip of the lode, for on a steeply-sloping hillside such as this, the dip will determine the course taken on the surface by the actual outcrop. In most cases, too little work has been done to enable this to be determined with any accuracy, and it is frequently a matter of conjecture. Few of the lodes outcrop quite continuously for any great length, the peaty button-grass cover generally encroaching at various points. In some instances this does not cause any ambiguity, but frequently one is left in doubt as to whether faulting has occurred or whether the lode has simply pinched, and the narrow vein failed to stand out above the granite surface. This is very likely to have happened, and, in fact, is certain to have occurred in some instances.

Caution, then, must be exercised in attempting to trace out any particular lode.

One or two old trenches have been cut across the lode outcrop of what appears to be the cross lode, on the rising ground north and north-east of Fowler and Dunn's opencut. The lode material looks promising, and is said to be tin-bearing. At one point there is a bold outcrop of radiating black tourmaline in a groundmass essentially of hæmatite.([207]) The ore is very dense, and carries a little tin. It is very similar to that cut in the No. 1 Adit, and is probably the same lode. The width is about 5 feet. Just above this is a shaft about 25 feet in depth, inaccessible. This shaft would appear to be almost over the old rise referred to, in the No. 1 Adit, but there is no connection broken through.

On the brow of a spur, and forming a bold outcrop, there is a junction of a north and south lode with the

([207]) *Vide supra*, p. 155.

one under consideration. Neither seems to be dislocated. The outcrop consists mainly of white quartzose stone, with a little black tourmaline, and although such an intersection is undoubtedly an extremely favourable place for the deposition of tin values to have taken place, it must be admitted that on the surface the stone does not look very promising. It is probable, from its general course, that Yates' Level was driven with the object of cutting this intersection.

About 250 feet further west, on a spur above the horse tram, is a trench exposing an interesting section, known as the "White Trench." It is not certain that the lode exposed is really the cross lode, and the writer is rather inclined to think it is not, although it is nearly on the line of strike.

The trench is 24 feet long, and has been cut to a depth of about 9 feet. It is seen that there are two distinct bodies of stone, lying nearly horizontal, perhaps dipping at a low angle north-east. These are about parallel, and are separated by 4 feet of decomposed granite. The true width of stone available is not exposed. In the face of the trench the upper body is 3 feet thick, but this is not the full width, for it forms a broad outcrop covered with detrital material, indicating that portion of the lode has suffered disintegration. The lower body of stone is only cut into for about 12 inches in the face of the trench, but continues underfoot. On account of a slight north-easterly dip at this point, the thickness exposed is greater at the toe of the trench, where it is at least 5 feet. So the width of stone available is probably at least 10 feet. It is said to carry ½ per cent. of tin in a very finely divided state. The stone consists essentially of white quartz, which, on a close examination, is seen to be of two generations. Disseminated through it are irregular aggregates of black tourmaline. It is also cut through by minute veins and threads of tourmaline, representing fissures which have been filled under the action of highly-heated vapours. No tin is visible in the stone. Even on the surface the lode is pyritic, carrying roughly spherical segregations of pyrite, which occurs in perfect crystals. On the lower side of the upper body of stone, and forming the boundary between the white lode material and the granite band included between upper and lower bodies, is a narrow quartz-tourmaline vein, carrying a good deal of green, as well as black, tourmaline. The thickness is about 1 inch. Bounding the upper edge of the lower

body of stone is a similar occurrence, but consisting of two continuous parallel veins 5 inches apart. Similar quartz-tourmaline veins sometimes cut across the intervening granite band, connecting the upper and lower bodies of stone. It is rather to be expected that this band of granite will carry disseminated tin, but it is said that tests made have given negative results.

Nearly horizontal quartz-tourmaline veins were noticed on the sides of Fowler and Dunn's open-cut, where a body of rich tin ore occurred. In the end of the cut a vertical vein was noticed, and the enrichment seems to have occurred at the intersection. Such an intersection is acknowledged to be a most favourable locality for the deposition of tin.

In the case of the White Trench, described above, we have nearly horizontal veins carrying tin values, and the intersection of these with more nearly vertical fissures would certainly be a favourable spot to prospect for another rich shoot of ore. As already remarked, the relation of this lode-formation to the cross lode is not established, this trench being the only work done in the immediate vicinity to prove or disprove the theory.

From a point a little west of the old horse tram, the strike of the cross lode is seen to be N. 63° W. This corresponds with the observed strike in the No. 1 Adit, and differs little from that in Yates' Level, though it must be remembered that the latter was taken on a very short exposure, and that consequently too much reliance cannot be placed on it.

About 650 feet west-north-west of the entrance to No. 1 Adit, on a spur at a considerably lower level a shaft has been sunk on what appears to be the cross lode. The depth is 30 feet, but the shaft was not accessible. The lode-material here consists of banded quartz-tourmaline. Both black and green tourmaline are present, and the stone looks very promising for tin values. Some bands carry pure black tourmaline. The quartz in the ore is generally white and saccharoidal in the groundmass, but also occurs in clear, glassy crystals lining geodes.

The full width of the ore-body is not exposed. A trench shows that the width is considerable, and that a large quantity of ore is available. It has been proved to be tin-bearing, assays showing from 0·5 to 0·75 per cent. tin. Some good lumps of cassiterite were found on the surface a little lower down, and had probably been shed from this formation. It is not unlikely that rich veins will be

found to occur through the big formation, but the important question is the bulk value of the ore. The situation is favourable for economic mining.

Although the samples taken seem to indicate that the ore-body is low-grade, it must be borne in mind that with a large body of ore, and facilities for cheap mining, a low percentage of tin may pay to work.

The cross lode does not outcrop on the low ground towards Packer's Creek, nor is it exposed in the bed of the creek.

About 800 feet west-north-west from the prospecting shaft just described, and about 3 chains inside the northern boundary of the lease is an old tunnel, driven apparently to prospect this lode.

The tunnel is now in a state of collapse, and could not be examined. It is reported to extend for a total length of about 160 feet. It was driven for about 110 feet through granite country, and then intersected a quartz-tourmaline vein 18 to 20 inches in width, carrying traces of tin. The bearing of the tunnel is about S. 66° E.

About 7 chains east of this tunnel a second one was driven for a short distance in a southerly direction, apparently with the object of cutting the cross-lode, but it does not seem to have been continued far enough to be of any value. This tunnel has also collapsed, and was too unsafe to inspect. No lode formation at all seems to have been intersected.

About 8 chains further east still a trench has been cut across a very promising lode outcrop, about 30 feet above the level of Packer's Creek. The country to the south and south-east rises fairly steeply. This trench has been called the "Green Trench," on account of the colour of the variety of tourmaline abundantly represented. The northern boundary of the lease is between 3 and 4 chains distant. The width of the formation has not been fully exposed, but it is quite considerable at this point. The strike is N. 11° W. for 2 chains north of the boundary, when it appears to bend round to N. 5° E., and outcrops to the summit of the spur. This bend in the surface outcrop may be due to the dip, which is not exposed in the green trench at all clearly. At one point some of the quartz-tourmaline veinstone is banded, and appears to be lying almost horizontally. It may be that the main lode is here joined by one or more flat veins, but the true structure is not apparent from the small amount of work done. The class of stone is extremely favourable, and, in fact, some of the stone lying on the heap shows fine brown tin oxide abundantly distributed

throughout. Geodes of quartz crystals occur, and sometimes of green tourmaline as well, with a quartzose groundmass which often carries tin. The general class of ore carries abundant green tourmaline and some black, with glassy quartz. A hole, now filled with water, was sunk 9 or 10 feet on good tin ore, but this, with the trench, represents the extent of the work done. Indications are very encouraging, and further prospecting of this line of lode is to be recommended.

A few chains up the spur this lode, if continuous, will junction with the cross-lode, and the vicinity should be prospected. Where two such tin-bearing veins intersect, conditions are favourable for a body of rich ore.

Tributers' Workings.—Returning to the Western Workings, there remains to be described a group of workings now known as the Tributers' Workings, on a body of ore of comparatively recent discovery. The workings comprise an open-cut, shaft, and adit, the shaft being sunk from the floor of the open-cut, and connected by means of rather tortuous workings and an intermediate drive with the level below.

From the top of the inclined haulage, near the mouth of Yates' Level, the Tributers' Level is 271 feet in an easterly direction. The tributers' open-cut is above this and a few feet further east.

It seems that the discovery of this pipe of rich lode-stuff was made by Mr. Yates in prospecting at the calculated intersection of the cross lode with another meeting it at an angle. There was no lode outcrop, and nothing on the surface to indicate the presence of rich tin below. Some good tin seems to have been found in the creek below. A prospecting hole was sunk through the button-grass cover and underlying detrital material without success. Neither this nor the underlying granite carried appreciable tin. After cutting through 18 inches of partially decomposed and altered fine-grained granite, a mass of soft white clay was met with, which was found to carry from 7 to 10 lb. of tin oxide to the dish. This clay was fairly coherent, and could be readily moulded in the hand, but carried harder lumps through the mass. A second hole was sunk a short distance away, with a similar result. This portion of the property was then let on tribute to a party of four men, who subsequently carried out the work described below.

The country-rock is normal. Above the workings are bold granite outcrops on the hillside which consist of rather coarse-grained granite carrying abundant pink orthoclase

felspar. This carried a little disseminated black tourmaline The granite cut through in the tunnel driven by the tributers is rather finer in grain, and carries abundant quartz-tourmaline nodules. In a few instances a little fluorite was noticed in the heart of these nodules. In the immediate vicinity of the lode the granite is decomposed, being white and fine-grained, carrying nodules and also narrow veins and fissures filled with black tourmaline.

The lode-material is of two distinct classes: (*a*) The quartz-tourmaline veins; (*b*) the pipe material.

(*a*) Exposed in the open-cut is a quartz-tourmaline vein varying considerably in width from 6 inches to 5 feet. It strikes N. 27° E., and the dip is about vertical. There is a well-defined central seam of tourmaline fringed by quartz, muscovite mica, and tourmaline. It has no very well-defined walls, merging more or less gradually into altered granite, and this in turn into more normal granite. The winze seems to have been sunk on this vein. It is rather significant that the main vein is intersected by another greisen vein about 9 inches wide, which lies at a very flat angle, and is noticed to split in places. The main greisen vein is tin-bearing, and said to be worth about 1 per cent. tin.

In the Tributers' Tunnel, about 104 feet from the entrance, a quartz-tourmaline vein was cut which does not appear on the surface. It is of a very promising character, and carries tin. The width is about 4 feet. It strikes N. 6° W., and dips east at 70°. A crosscut was driven about 10 feet north, and then a rise put up 30 feet on it to connect with a winze from the open-cut on the surface. This ore-body is worth prospecting, and crosscuts north and south are to be recommended. The possible connection of this lode with an offshoot from the main pipe will be referred to later.

(*b*) The pipe material was the source of practically all the tin won from these workings. It is quite different to the lode-matter occurring on any other part of the property, with one possible exception (in the vicinity of the Cumberland Dam). Although white in colour at the surface, it is typically of a greenish-grey colour. It is soft, has a greasy feel, and waxy lustre, being translucent in fine scales. It occurs in aggregates of minute scales and flakes, and seems to be intimately associated with kaolin. The material seems to be pinite, a mineral which belongs to the mica group, and is an alteration product of felspar and mica. Crystals of quartz of small size occur disseminated throughout the

lode material. The lode-matter is only semi-coherent, and in the pipe proper was extracted by means of mattocks and shovels. If not amenable to this method of extraction, it was considered by the tributers to be too hard to pay them for extraction and treatment by their crude methods. Through this soft material crystals of cassiterite are abundantly scattered in single crystals or groups and aggregates of crystals. The cassiterite is in tetragonal prisms, with dominant pyramidal faces (both first and second order pyramids). Frequently prism faces are wanting, the crystals being doubly terminated pyramids. Twinning is common. The colour is usually brownish-black; the size varies from half-inch to less than 1/32-inch. Associated with the tin are abundant crystals of pyrite, crystals being of all sizes, from one thirty-second to over 1 inch across, the forms represented being the cube and pyritohedron, and combinations of these two. Crystals are sometimes intergrown. Many examples were noticed also of crystals of pyrite and cassiterite intergrown, sometimes also with tourmaline and quartz.

The pipe proper appears to have had quite well-defined walls throughout its course, so far as traced. The wall material, however, also carries rich tin values, and is therefore economically important. It is a good deal harder than the true pipe material, although the mineral constitution seems similar. The pinite is in rather larger scales, and is much more compact. Quartz is more abundant, and kaolin seems absent. It appears to gradually merge into granite, of which it represents an alteration product. The tin content decreases with increasing distance from the pipe, as is to be expected.

Although the two classes of lode material described are so widely different in their general characteristics, the two are evidently related to each other, and connected with the introduction of the tin. In the western offshoot of the main pipe, described below, in the face the true pipe material which is very soft and very rich in tin is bordered by an arched quartz-tourmaline vein 1 to 3 inches in thickness. Veins of quartz-tourmaline, generally narrow, appear in the walls at different places, and the manager states that wherever these occurred rich tin was encountered. The fact is significant.

The main pipe has been followed for a total distance of about 115 feet, and a branch from the main one for another 30 feet. Throughout the whole length so far worked the pipe has carried remarkably rich tin values. Its course has,

up to the present, been so very irregular and tortuous that the workings have also necessarily been very irregular. After working out as much as possible by open-cut methods, it was decided to follow the pipe, and as it was continuing down vertically, a shaft was sunk. At about 30 feet it was found to bend sharply, and making an angle of 9° with the horizontal, it dipped in a direction N. 58½° W. for 17 feet 6 inches. At this point a branch or offshoot was discovered, and worked horizontally for 30 feet in a direction N. 47° E., the main pipe bearing N. 79° W., and dipping at 19° for 31 feet. Here there is a pass connecting with the intermediate drive. The pipe then dips at about 11° for 36 feet 6 inches on a bearing N. 16° W. It has not been followed further, but continues into the face of the intermediate drive.

After following the pipe down on its course for some distance, an adit was driven in at about 60 feet below the collar of the shaft. At 104 feet in a crosscut was driven about 10 feet north, and a rise put up 30 feet to connect with the shaft from the surface. Owing to a miscalculation, however, a drive of about 15 feet south from the rise was necessary to connect. The adit has been driven 61 feet on a bearing N. 49° E., and then for 98 feet in a direction N. 65° 15' E. The quartz-tourmaline vein cut in driving has already been referred to. The adit is driven through white nodular tourmaline granite. At 159 feet a rise was put up for 16 feet 6 inches, and an intermediate drive extended for a total length of 69 feet. For 25 feet it bears N. 14° W., when it bends to N. 36½° W. for 17 feet, and finally for 27 feet the bearing is N. 9½° W. From the rise the intermediate drive follows an almost horizontal fissure in the granite, which forms the roof for 34 feet. This fissure dips east at angles varying from 5° to 12°. At 34 feet a rise of 5 feet was put through to the pipe. This was used as a pass from which the lode material was trucked through the intermediate drive. The intermediate drive has been continued for 35 feet beyond the pass to the present face. At the end of the drive the pipe has been cut through, and dips into the face at the "toe" of the drive. The nature of the harder pinite forming the walls of the true pipe has already been described. In the work done up to the present only the very soft true pipe material has been worked out, and there remains a good deal of payable ore along the course of the pipe. In the face this is also true. Here a winze has been commenced, 8 feet long by 5 feet wide, and has been sunk for 6 feet in rich lode material. Sinking was not continued on account of the water encountered. Rich lode material continues under foot. From the fines of the stone taken out from this winze 1 ton of free tin oxide was won by sluicing, the forkings not being crushed, but stacked for future treatment. A glance at this material shows that there is much tin in this heap. Forming the eastern wall of the winze is a well-defined fissure, which has the appearance of being a true wall. That it is not really so is shown by the fact that where it has been broken there has been disclosed behind it similar lode material to that already taken out. This fissure dips vertically so far as exposed, and has a strike N. 13° E. In the face granite appears; several intersecting fissures are noticeable here, too, in one case forming approximately the boundary between hard pinite lode material and granite, although this is not universally true, one usually merging into the other. At the end of the intermediate drive there is exposed 16 feet of the harder pinite lode material along the length of the drive, carrying good tin. This is on the lower side of the pipe. In one place a quartz-tourmaline vein is visible, but it is not sufficiently exposed to enable its strike or dip to be determined.

Similar harder pinite lode material carrying good tin occurs along the whole length of the pipe as worked, and also along the offshoot to the south-west previously referred to, which has been worked for 30 feet. In the face the true pipe material is associated with a firm brown iron-stained clay, representing probably kaolin cemented with iron oxide derived from the decomposition of iron pyrite. The section here is interesting. The true pipe is oval, 18 inches by 12 inches, being very soft and carrying rich tin. This is surrounded by a vein of quartz-tourmaline 1 to 3 inches thick; then comes a zone of soft kaolin and pinite, with firm clay gossan, which carries tin freely, surrounded by a band of 12 to 15 inches of harder pinite lode material with quartz, merging into nodular tourmaline granite. Throughout its course the pipe material in this offshoot is described as having been very soft, containing much kaolin, as well as pinite, and abundant crystals of cassiterite and pyrite, and as having had well defined boundaries. It was oval in shape, varying in size from about 5 feet by 1 foot to 5 feet by 2½ feet. The course as far as explored has been approximately horizontal, but in the face it appears to be dipping west. At 18 feet 6 inches from the main pipe, on the south wall of the offshoot, is another mass of soft white kaolin with very rich tin, about 2 feet across, depth not exposed. It tapers out on either side, and is surrounded by harder

quartz-pinite lode material. This is evidently another branch pipe, and should be followed up. The main pipe varied considerably in size throughout its course, but after bending from the vertical it appears to have shown definite "wings," *i.e.*, it was not truly elliptical in section, but while approximately so, it tapered out on either side along the direction of the greatest diameter, apparently along a fissure. In the face of the intermediate drive the pipe is about 5 feet long by 1 foot broad. Here the apparent dip is 29°. As cut by the level it was 4 by 2 feet; for 30 to 40 feet back it was about 4 by 4 feet, widening gradually to 5 feet by 5 feet, and further on to 12 by 7 feet. In the vertical portion it was 6 by 4 feet, and is described as having spread out and become "funnel-shaped" near the surface, measuring as much as 25 by 15 feet. This portion has all been worked out, and the measurement could not be verified. It is probable that the measurement included some of the harder pinite wall material. The open-cut is about 25 feet by 30 feet by 15 feet high in the face.

It remains to refer to the method of working. This, it will be seen, was very crude, and the actual tin recovery only represents a fraction of the original tin content of the lode as mined. The pipe material was taken out with shovels, sometimes with the aid of mattocks, but no attempt was made to crush it. The rough handling it received was expected to disintegrate it sufficiently. It was trucked from the workings into a hopper, run out with water on to hopper-plates with 1 inch holes at the top, and then half-inch, and all the oversize forked off on to the hopper heaps. The undersize was box-sluiced in the usual way. The loss in sluicing must have been excessive, for it must be remembered that no classification was attempted, although the tin crystals and aggregates of crystals varied so much in size, and the "puggy" nature of the lode material played its part in increasing the percentage loss of tin. Even a glance at the heap of forkings in the vicinity of the old sluice-boxes is sufficient to convince one that a considerable proportion of the available tin is still waiting extraction by the crushing of this oversize material. Likewise, the dam in which portion of the tailings is stored, pending further treatment, tells its own story of a large amount of tin not recovered in the sluice-boxes.

With the concentrate from the sluice-boxes was a large amount of iron pyrite in crystal form. A clean separation was effected by sieving and jigging. An attempt was made to roast some of this concentrate in a crude way, but without much success.

From the description given of the method of treatment adopted for the lode material won, it will readily be understood that no attempt could be made to treat any of the harder material (it must be borne in mind that the word "harder" is used simply in a relative sense, to denote material more compact than the soft kaolinised pipe material, most of which could be extracted with a shovel). Consequently, in and about the Tributers' Workings there is stacked a large tonnage of stanniferous lode material awaiting battery treatment. The manager estimates the tonnage mined and awaiting treatment at 800 tons, worth about 2 per cent. of tin.

To try and obtain some idea of values of the various grades of pipe material, samples were taken and vanned by the manager in the presence of the writer, who afterwards submitted concentrates, &c., to the Government Assayer for weighing and calculation of values. The pyritic material was weighed, roasted, reground, and revanned.

The Government Assayer estimated that in the samples of pipe material submitted there was about 10 per cent. pyrite.

A sample of the true pipe material from the face of the intermediate drive returned 14 per cent. tin oxide.

From the face of the branch pipe west, 30 feet from the main pipe, true pipe material returned 23 per cent. tin oxide.

From the small offshoot south from this branch, 18½ feet from the main pipe line, true pipe material returned 5·6 per cent. tin oxide.

Another sample of the soft white pipe material from the main pipe was assayed by the Government Assayer by the usual methods and returned 5·3 per cent. tin (or 6·75 per cent. tin oxide).

Similarly, for a sample of the harder pinite forming the walls of the main pipe, the Government Assayer returned 5·3 per cent. tin (or 6·75 per cent. tin oxide).

These results can only be regarded as extremely satisfactory.

From the lode material treated from these workings, 20 tons of free tin oxide were taken, of an average assay value of 70 per cent. metallic tin.

Enquiries have been made concerning the value of crystals of pyrite for use in connection with wireless telegraphy, and the results recorded elsewhere.[208]

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[208] *Vide supra*, pp. 223–224.

Water for sluicing was brought round the hillside in a short race from a small dam of a temporary nature erected in a break forming the head of a creek just on the western fall of the range. The capacity is small, but the nature of the work was intermittent, and it seems to have suited the purpose for which it was constructed.

On the brow of the hill above the Tributers' Workings is a trench on a lode-formation of very promising nature. It consists essentially of quartz and green tourmaline, with a small amount of black tourmaline as well. Cutting through it are veins of a soft micaceous mineral, probably pinite. There are irregular geodes of crystallised quartz. The width exposed is 12 feet, although the true lode is wider than this. This lode is worth testing.

Gray's Lode.—Belonging to the group of workings known as the Western Workings, there remains to be described one lode, distinct in several respects from any other on the property. This is Gray's lode. It is situated within about a chain and a half of the southern boundary of the consolidated lease 3917M, but actually on section 5765M, which is also held by Mr. J. S. Munro. It is on the western slope of the range, but near the summit of the spur which forms the divide between Cumberland and Packer's Creeks. It was discovered by tracing up the spur tinstone which was first found in the creek below. The amount of work done on the lode is very small, consisting of two trenches a few feet apart, one slightly lower than the other. The lower cuts only partly across the formation, the upper one, a few feet south, continuing the section. The lower trench bears N. 88° W., has a length of 20 feet, and width of 4 feet, the lower end, owing to the slope of the hill, showing stone underfoot, the upper a face of 9 feet of stone. The upper trench, 6 feet south, is parallel; it is 30 feet long, and 9 feet deep in the face.

No other work has been done on the lode, although rich tin has been disclosed in these trenches.

The strike of the lode appears to be N. 10° E., and dip east at a steep angle.

The formation disclosed is an interesting one, and different to other lodes on the property. The tin is associated with quartz and black tourmaline in the complete absence of the green variety. The lode consists of a series of quartz-tourmaline veins, many of them approximately parallel, and impregnations of the granite from these veins. Although the main fissures appear to be parallel, there are others crossing them at all angles. Some rich stone has

been exposed, several bags of picked stone sent away returning over 60 per cent. tin. The best ore is a laminated quartz-tourmaline: there is a black tourmaline groundmass, with abundant veinlets cutting through, some filled with quartz, many of them carrying fine cassiterite, light-brown in colour, and not noticeable excepting under the magnifying glass. Crossing these veinlets are minute, needle-like prismatic crystals of tourmaline, while between them doubly terminated prisms of quartz were noticed in some cases. Sometimes the masses of quartz-tourmaline lie almost horizontally, and are lens-shaped.

The sections exposed by these trenches are fully described elsewhere, and it is seen that there is a crustified structure, masses of black tourmaline being edged with white quartz (usually showing a crystalline structure), and this in turn by a quartz-tourmaline stone which apparently merges gradually into granite. Blocks of granite are included. It is shown that the structure is rather unusual in the district, but that the formation as a whole is really a variation of a quartz-tourmaline-cassiterite vein, forming a lode rather than a simple vein.

Complete assays of the various classes of material are desirable to show what the distribution of the tin really is. Although so very little work has been done on it, the lode has several very encouraging features, and is certainly worth further prospecting on the surface. Trenches should be cut east and west of the present ones to get some information with regard to the extent of the shoot of ore. If the *bulk* value of the formation warrants such work being carried out, an adit could be driven to expose it at depth from lower down the hillside, but surface prospecting and sampling must first be undertaken.

The group of workings known as the Western Workings has been described, and a description given of the lodes and the work done upon them. Reference should be made to the means employed for transporting the ore won from the workings to the battery. The general situation of the workings high up on the spur has been described; the battery is on a branch of Packer's Creek, about 450 feet below Yates' Level. Originally an aerial tramway was used for the conveyance of ore from workings to battery, but this gradually fell into disrepair, and eventually a self-acting tramway was constructed. From the station at the mouth of Yates' Level the full trucks were lowered under the control of a strap-brake bearing on the end of the drum, and by means of a tail-rope, pulled the empties up from the

battery. The various workings described were connected with this tramway.

The inclined tramway is at the present time in a state of disrepair.

Central Workings.—North-east from the Western Workings, the hill rises steeply for about 450 feet vertically, and on the highest portion of the lease, a distance of about 30 chains north-east of Yates' Level and the top of the haulage, are the Central Workings. Here the work done has been by means of open-cuts, adits, and shafts. It is safe to say that the developments on this portion of the property are of such importance as to practically constitute a mine of themselves. More work is necessary, as will be seen when the present workings are described, but the surface prospects are really good, and there is every reason to believe that further exploitation will confirm surface prospects.

There is a very large outcrop on the hill, which appears to have been formed at the intersection of several distinct lodes. The stone is very dark in colour, appearing quite black when viewed from a short distance away, owing to the large amount of dark-green tourmaline present. From this fact the open-cut, which exposes a face of this dark-green quartz-tourmaline stone, has been rather aptly termed the "Black Face."

For descriptive purposes it seems best to consider first the most northern of these workings, taking the others in order from north to south.

220-*feet Level.*—This level was commenced at a point 220 feet below the collar of Munro's shaft on the summit of the hill. From this point a horse-tram was constructed, winding round the northern and western slopes of the hill, and connecting with the main inclined tram to the battery, at Yates' Level. The ore mined from the Black Face workings was lowered by an inclined tramway about 6 chains in length to the horse-tram, trucked round the hillside, and lowered to the battery.

The 220-feet level appears to have been driven with the object of intercepting the Black Face lode, and for 200 feet bears S. 5° W.: if continued on this bearing, it would in another 200 feet be directly below Munro's shaft. Up to this point it is driven through light-coloured medium-grained biotite granite. Here, however, a cross-vein was struck, making an angle of 16 degrees with the course of the drive, from which the granite is mineralised on either side. The drive then bends for no apparent reason, and bears about S. 30° E. for the rest of its course (14

feet) through much-fissured granite which is hard and fine-grained, and carries pyrite in places.

About 100 feet higher up the hill a tunnel has been driven for about 45 feet on a bearing S. 52° W. It appears to be on the wall of the lode, for quartz-tourmaline stone is showing all along the south-eastern wall, while on the other wall is fine-grained granite, of an aplitic nature. The wall exposed stands vertically.

From the mouth of this tunnel along the hillside to the Eastern Workings (bearing N. 69° E.) the lode outcrop seems continuous: it is covered here and there by button-grass.

86-*feet Level or Cross Drive.*—This is driven through lode material for about 40 feet: this is somewhat soft and decomposed in the earlier portion of the tunnel. For 27 feet assays have shown the average value to be ½ per cent. tin. Crosscuts have been driven north-east and south-west for about 20 and 40 feet respectively. In the north-eastern crosscut is lode material to the face, consisting of hard quartz-tourmaline with some gossan in places. The south-western crosscut discloses at 25 feet a mass of quartz-tourmaline going into the south wall: the true wall does not appear to have been cut. In the end of this crosscut is a seam of about 3 inches of what appears to be fairly pure kaolin, which is white in colour, and quite free from grit when crumbled between the fingers. It is striking, occurring in a very dark-coloured stone with quartz and abundant tourmaline. This seam does not appear to carry tin. In the main drive at 10 feet from the face, is a cross-vein of very hard quartz-tourmaline, the tourmaline being of the favourable green variety. Tin is present in the stone, and it is stated that assays show the value to be ½ per cent. Granite is showing in the face of the main drive, and here, as in the crosscuts where exposed in the vicinity of the lode, it is much fissured and carries a good deal of tourmaline.

For some distance to the east of this level there is rich tinstone showing on the surface. In nearly every piece examined in this vicinity cassiterite was present. Most of this was detrital, but some was *in situ*. The brown tin oxide occurs in crystals disseminated through the stone, and in small geodes with quartz.

Above the 86-feet level is a small cut driven for about 15 feet into lode material. The stone carries abundant green tourmaline here as usual, and good tin values are present. There are included masses of crystalline quartz

showing abundant cassiterite crystals, and frequently fissures are filled with the same mineral, and if specimens be broken along the fissure, very showy specimens are obtained.

No. 2 Bench.—About 20 feet west of the small drive previously described some of this lode material has been worked by an open-cut known as the No. 2 Bench: this is about 30 feet below the Black Face. The dimensions of the cut are—length 38 feet, width 21 feet at the entrance and 17 feet 6 inches at the face, height of face about 20 feet. The cut exposes a mass of ore of a general dark-green colour owing to the abundance of tourmaline of that colour present. The strike of the formation at this point appears to be N. 30° E. The ore taken out was crushed with that quarried from the Black Face. On the western side of the cut is exposed granite intersected by numerous fissures parallel with the strike, and cut through by a second series about at right angles. At the edge of the granite are masses of soft green tourmaline, with little accompanying quartz, although the latter is generally present throughout the ore. In the face is an exposure of 15 feet of banded quartz-tourmaline, apparently impregnations from a series of parallel fissures, and showing cross-fissures filled with limonite, sometimes botryoidal; limonite also occurs in nodular form. On the eastern wall, in the south-eastern corner, is a belt of hard gossan with tourmaline. On this side of the cut, too, is a band of very soft lode material, apparently consisting largely of chlorite with kaolin: the strike is about east and west, and dip north at 45 degrees. The width is variable, the seam opening out in places into vughs of considerable size. Rich tin values are present in this soft lode material, the cassiterite being in a very finely-divided form. On the same wall, a few feet further north, is another mass of similar lode material, also carrying very rich tin. The tin oxide is in the form of slime, and resembles a light-coloured reddish-brown mud: it is of very pure quality.

From this cut, values have been traced for at least 30 feet east.

A sample of the green tourmaline from this formation was roughly crushed and vanned by the manager in the writer's presence, and the concentrate weighed: the result of this sample was 5 per cent. tin oxide

Black Face.—The excavation known as the "Black Face" is an open cut, from which a good deal of lode-material was extracted by the present owners of the property, and crushed for a satisfactory battery return. From this cut, and the lower one known as the No. 2 Bench (previously described), 720 tons of ore were crushed, and yielded 12 tons 18 cwt. 22 lb. of tin oxide, assaying from 68·7 to 69·4 per cent. metallic tin. Assuming an average of the two values given for the grade of tin produced, the actual battery return is equivalent to 1·24 per cent. metallic tin in the ore treated. Numerous samples have been assayed from this cut, which have generally indicated a higher value than that mentioned, but it must be borne in mind that the concentrating plant available was not capable of effecting a high recovery of values, particularly when dealing with very fine cassiterite, such as is present in the lode-material from this point, and the discrepancy is to be accounted for—in part, at any rate—by actual battery losses. That this is true is shown by the fact that the tailings were retreated recently at a profit.

There are two classes of lode-material present—(*a*) soft, dark-green tourmaline; (*b*) hard, lighter-coloured quartz-tourmaline veinstone, containing green tourmaline. The former material generally carries the better tin. It is characterised by the presence of limonite in nodules, irregular veinlets, and compact masses, frequently carrying tin. The limonite is a result of the oxidation of pyrite contained in the primary ore. It is said to assay about 2 per cent. tin. This softer material is cut through by the harder quartz-tourmaline veinstone which occurs in veins, and in irregular masses enclosed in the dark-green tourmaline. These masses are encrusted with crystals of quartz projecting outwards, and with fine needle-like prisms of tourmaline. These faces are sometimes covered with crystals of cassiterite, which also occurs in vughs through the mass of the stone. The general dip of these quartz-tourmaline bands is east at about 70 degrees. Occasionally bands of very soft material are noticed lying at a very flat angle, or forming vughs several feet across, with narrow connecting veins, filled with very soft, dark-green amorphous material, apparently chlorite and kaolin. These bands and masses carry rich tin values, the cassiterite occurring in the form of light-brown masses of very finely-divided material, and never showing any crystal form. Some rich assay results have been obtained from this soft lode-material.

The writer did not systematically sample the lode-material exposed here, but submitted a single sample of

the massive green tourmaline, slightly stained with limonite from the face of the cut, to the Government Assayer, Mr. W. D. Reid, who reported—

Tin ... ... 1·8 per cent.

The face was sampled by Mr. Waller in 1902, who reported.(209)

"I took a bulk sample across 12 feet of the soft lode-matter at this point, which yielded 2¼ per cent. metallic tin. Another sample from the hard bands, totalling 5 feet 8 inches in thickness, yielded 0·35 per cent. This gives an average of 1·64 per cent. metallic tin for a width of 17 feet 8 inches."

The actual battery return quoted above for the crushing of 720 tons, indicates that Mr. Waller's figure would be very close to the average value of the ore.

In addition to the work described, a winze was sunk from the bottom of this cut for 9 feet, and a bore-hole put down 9 feet 6 inches from the bottom, and this work disclosed the same class of lode-material, carrying similar values to that already taken out.

A few feet higher up the hill than the Black Face, and a short distance to the south-west, a short adit has been driven for about 10 feet on the course of a black vein 5 feet 6 inches wide, carrying good tin. The central 3 feet consists of dense dark-green tourmaline, with regular lines of cavities caused by the removal of some mineral, probably pyrite, flanked on either side by very honeycombed dark-green tourmaline with limonite. This, again, is flanked by quartz-tourmaline stone of fairly even grainsize and medium texture, the tourmaline being the green variety.

Above this cuddy is some hard gossan exposed, with green tourmaline, similar to some of that met in the drive.

Munro's Shaft.—This is a vertical shaft sunk on the lode to a depth of 51 feet. It was sunk in the early history of the property. At the time of the writer's visit it was inaccessible, and for information concerning the work done he is indebted to Mr. Yates. The shaft is sunk on lode-material all the way, and from the bottom a drive was extended eastwards for 16 feet before meeting granite. The dip appears to be east at 87°. A large sample broken from 16 feet in this drive by Mr. Yates yielded 1 per cent. tin. On the west side of the shaft is a vein of

(209) Report on Tin Ore Deposits of Mt. Heemskirk, p. 27.

richer tinstone about 1 foot in width, assaying between 5 and 6 per cent. tin. On the surface, over a width of 13 feet, assays have returned over 2 per cent. tin.

The stone here is a rather hard quartz-tourmaline, of fairly even grainsize, green tourmaline being common. There is, however, a distinct central seam, consisting mainly of green tourmaline, with cavities lined with crystals of quartz and cassiterite. The cassiterite occurs in radiating needles on a base which generally shows a concentric structure. It is also disseminated through the stone, and is of a light-brown colour. The body of the stone carries finely disseminated pyrite. Cross-fractures were noticed, bearing N. 75° E., cutting through the lode in the vicinity of the shaft.

The shaft is sunk on the highest portion of the property, and most of the adits are named from their vertical distance below the collar of the shaft. The width of outcrop at this point is 43 feet.

A little to the west of the main line is a bold outcrop for about 2 chains of very quartzose lode-material, with a little green tourmaline in veins through it, but said to be poor in tin. The surface outcrop ends abruptly, but what is probably a faulted portion of the same formation appears lower down the hill, about 5 chains to the west, for a short distance. There is also an outcrop on the northern side of Packer's Creek for a few chains, which appears further to the west again.

Underlay Shaft.—About a chain south of Munro's shaft another shaft was sunk by the old Cumberland Company, and is now known as the underlay shaft. A trench on the surface exposes the lode, which is 36 feet wide. It is quartz-tourmaline, showing pseudomorphs of tourmaline after felspar, and also some dense green tourmaline bands.

The shaft is inaccessible, having no ladders, and being partly full of water. It was sunk on the underlay on the eastern (hangingwall) side of the lode through granite, until the main body of stone was intersected. The shaft was then sunk vertically in this lode-material for 25 feet. The total depth of the shaft is said to be 60 feet. The stone on the dump-heap at the collar of the shaft does not look very promising for good tin values. It consists mostly of quartz, with some veins of tourmaline, and carries finely-disseminated pyrite. It is said to carry low tin values.

On the summit of the hill, a few feet west of this shaft, are scattered on the surface, masses of quartz-tourmaline

and dense green tourmaline, partly cemented by limonite. Fragments are sometimes well rounded. This appears to be on a line of lode on which a little work has been done, and which strikes N. 13° E. A little further south the outcrop is well defined. A vein filled with black tourmaline and a little quartz is seen cutting through the main vein, and bearing N. 63° E. Another similar vein was noticed still further south, with a strike of N. 74° E., but in this case the main vein is obviously the later, since it cuts through the smaller cross-vein, although no displacement is noticeable. There is here a well-defined vein carrying crystals of cassiterite, flanked by veinstone of quartz and green tourmaline, the latter being pseudomorphous after felspar. In places the green tourmaline is fairly massive, but is cut through by irregular veins filled with chalcedonic silica, and geodes lined with crystals of quartz. Cassiterite is to be seen disseminated through the stone.

A trench across this lode a few feet south from this point, but still near the top of the hill, exposes an interesting section. The full width is not exposed. There is a central vein with rich tin, flanked by a banded stone, generally of fairly dense quartz-tourmaline, but carrying also bands of white quartz, and of very quartzose material with a little scattered tourmaline. This stone without the central vein assays about 2 per cent. tin. The central vein would probably return 10 to 12 per cent. tin. It varies in width from 2 to 5 inches, and has been traced for a length of 20 feet. It contains crystals of quartz and cassiterite, and shows distinct crustification, *i.e.*, the minerals have been deposited on the sides of a fissure at different times, each deposit forming the base on which the succeeding deposit rests. This vein has been described elsewhere,([210]) and the significance of its occurrence noted.

A few chains further south, and lower down the hill, the same line of lode is exposed for a width of 29 feet by a trench. The 5 feet in the centre of the trench is granite, but the trench is shallow, and it is not by any means certain that this is really *in situ*. It may be a loose block of granite which has been embedded in the loose detrital matter, which is abundant here. However, it may be a band of country-rock which divides the lode at this point into two bodies of ore, which unite again north and

([210]) *Vide supra*, pp. 156-157, 160.

south. On the eastern side the stone is essentially white quartz, which appears to be of two generations, but contains a little tourmaline, partly in disseminated aggregates, also as a filling of fissures, and in nodules through the mass. The material has a banded structure, some bands being of quartz and tourmaline in nearly equal amounts. Vughs of crystalline quartz with tourmaline occur throughout the mass. The western section (10 feet) of the trench exposes dark-green tourmaline, with vughs containing crystals of quartz, and a band of dark-coloured very hard quartz-tourmaline stone about 2 feet in width, on the western edge, this stone also showing miarolitic cavities.

This trench continues on for about 2 chains, but exposes no further lode. It is of value, however, in that it opens up a quantity of detrital matter, which shows abundant specimens of good tinstone, and which will probably prove payable.

About 4 chains further down the hill is another outcrop of a lode bearing N. 7° E., which, however, appears to end abruptly as though faulted. No work has been done to prove its continuation or otherwise to the south. The same lode appears to have been exposed in a trench on the brow of a spur about 3 chains to the north, and about 3 chains in a direction S. 77° W. from the 60-feet shaft. There is a promising lode exposed here, of quartz and green tourmaline with vughs of crystalline quartz, the width being 23 feet. The dip appears to be slightly east.

60-*feet Shaft*.—This shaft is about 4 chains in a direction a little east of south from the Underlay Shaft previously described. It is an old shaft sunk on an outcrop not fully exposed, but apparently about 30 feet wide. This is only about 1 chain west of the Air Shaft line of lode (to be described). The lode strikes N. 8° E. The shaft is sunk in the eastern wall, and has a slight underlay to the south. Its depth is said to be 60 feet, but the shaft was inaccessible at the time of my visit. Near the surface there is a vein very dark in colour, and consisting of dark-green tourmaline and quartz in about equal amounts, with vughs of crystallised quartz and tourmaline. It is said to carry good tin. The width as far as the vein is visible appears to be fairly regular, and from 6 to 9 inches, excepting near the surface, where it widens to 18 inches. On the western side of this vein is white quartzose stone, very similar in appearance to that exposed in a trench on the Air Shaft line of lode, but with irregu-

lar veins and lenses of quartz-tourmaline. It carries good tin in nests and pockets with crystallised quartz, and also in cross-fissures. On the eastern side the main vein merges into decomposing greisenised granite which carries veins and nodules of quartz and tourmaline.

The outcrop on which the 60-feet shaft has been sunk is visible for only about 50 feet on the surface. On the south, a shallow adit extends beyond the point at which it should have been cut had the lode been continuous, without disclosing any sign of the formation. There is no sign of any outcrop to the north.

Air Shaft Line of Lode.—This line of lode is one of the earliest prospected on the property, and one on which further work is destined to be done in the future. The work done up to the present consists of surface trenching, a shallow adit, and a shaft connecting with an adit driven from the low ground near the Cumberland Dam, known as the Long Tunnel.

About 130 feet south-east of the old 60-feet shaft, and on the southern slope of the hill, is a trench across the lode, exposing a width of 30 feet. The stone is essentially a white quartzose material, with crystals of glassy quartz in a very fine quartzose groundmass. It weathers very white. There is a small amount of tourmaline present, especially near the edges, where nodules with black tourmaline appear. It carries a little fine tin right through the stone; also in vughs sporadically distributed, where the cassiterite is in crystals associated with crystals of quartz, and in occasional soft seams of kaolin through the ore. The average value of the stone here is said to be barely 0·5 per cent. tin.

Below this trench is a shallow adit driven north-west for 141 feet. It is difficult to understand why this adit was driven, for it does not cut the Black Face line of lode. To do this it would have to be driven another 120 feet, and then the amount of backs obtained would be too small to justify the work. The air shaft lode is cut through at the approach, almost below the trench just described, and giving only about 12 feet of backs. The width here is 29 feet 10 inches. The stone is quite similar to that exposed in the trench above, and carries a little tin right through, occurring as described in the trench. The main body of stone is free from tourmaline, although a little occurs in nodules near the edges of the lode-formation.

Air Shaft.—About 20 feet to the east of this adit is the shaft known as the "Air Shaft." The shaft is at present quite inaccessible, but the writer is indebted to Mr. Yates, who has examined it, for information. The shaft was sunk partly vertically, partly on the underlay. At 100 feet from the collar there is a crosscut into the lode (the shaft being apparently sunk in country-rock) for 14 feet, but not exposing the full width at this point. Assays from here varied from 0·4 to 0·9 per cent. tin. A rise was put up from the Long Tunnel, but did not connect by 15 feet. The work done from this lower adit on the lode is unknown. The stone taken out seems to have been crushed by the old Cumberland Company, and some rich tin ore is said to have been won. The collar of the Air Shaft is 270 feet vertically above the Long Tunnel, that amount of backs being, therefore, available.

About 2 chains to the south is another trench. The formation has been cut, but the information to be obtained from the trench is indefinite. The lode outcrops again further to the south, forming a bold ridge for a short distance. Again, it disappears under the peaty button-grass cover, and outcropping again appears to dip below the tributers' dam. The strike here is N. 14° E. The dip appears to be slightly south. North from the Air Shaft there is a well-defined outcrop bearing N. 14° E. for about 3 chains, when it appears to bend round to about N. 74° E. About 6 chains on a small cut exposes about 5 feet of stone, although this is not the full width. The stone is similar in general appearance to that at the air shaft, but carries a little more green tourmaline; it is tin-bearing where exposed. Between these points any outcrop is completely concealed by button-grass, but there is a distinct ridge falling away steeply to the south-east, which probably marks the line of outcrop.

Still further to the east is a small cut on a quartz-tourmaline formation, which may represent a continuation of the same line. The width exposed is about 4 feet. The strike is apparently N. 30° E., and dip vertical. The stone resembles that exposed in the Eastern Workings. It is partly an open green tourmaline rock, with white quartz, and there is also exposed a hard, dense variety, with quartz and green tourmaline in about equal quantities, and cut through by tourmaline-filled fissures. No black tourmaline is noticeable in the stone. It is tin-bearing, the cassiterite being very fine and reddish in colour.

This formation did not outcrop at the surface, and was only exposed on sinking through the detrital material, which is abundant at this point. No attempt has been made to trace it further, although it should junction with the line of lode connecting the Black Face and Eastern Workings, which is distant only about 1 chain to the north-west. Prospecting at this point is unhesitatingly recommended, for the prospects of locating some good ore at the intersection of the two lines of lode, both known to be tin-bearing, are good.

The Long Tunnel.—From the southern boundary of the consolidated lease, at a point on the low-lying ground not far above the level of the Cumberland Dam, a tunnel was driven by the old Cumberland Company, apparently with the object of cutting the Black Face line of lode at a depth: the tunnel is about 320 feet below the outcrops on the hill. Its total length is 997 feet, and it thus proves a valuable asset for the future prospecting and development of the mine. The tunnel was connected by a tramway of about 1 mile in length with the Cumberland Battery, where the stone won from the stopes was crushed. The battery is now dismantled, although remnants of the old plant remain, while the rails have been removed from the tramway, and the embankment has suffered considerably from the long-continued exposure to weathering agencies.

The tunnel is driven for 766 feet on a bearing N. 48° W.; then for 97 feet it bears N. 41° 30′ W., and for 134 feet to the face the bearing is N. 35° 30′ W. Records of the old work done are scanty and rather indefinite. The Air Shaft lode seems to have been cut, and some stoping done: it seems that the width here was 20 feet, and that a rise was put up to connect with the Air Shaft sunk from the surface, but that the two did not connect by 15 feet. This lode was cut about 700 feet from the entrance. The extent of work done on the lode is not known: for 24 feet there is filling overhead.

A cross-lode cut in the tunnel, which may perhaps be the same as that upon which the 60-feet shaft has been sunk from the surface, strikes N. 16° E., and dips slightly east: the width is 12 feet. There is a central vein of black and green tourmaline, varying in width from 3 to 12 inches, and carrying good tin. This merges into hard quartz-tourmaline stone, in which a little fluorite was noticed, but which is said to carry only very low tin values. There is a short drive east about 12 feet: this was about 800 feet in.

At 893 feet from the entrance another lode was cut, on which a little more work was done by the Cumberland Company. Crosscuts were driven east and west on the course of the lode, as rich tinstone was met in the main drive. The western crosscut extends for 40 feet in lode material (worth about ½ per cent. in the face), and here a winze was sunk. It is said that some driving was done, but the winze is now full of water, and has not been examined by the present owners, although a pump and 4½-horsepower Coulson oil engine have been installed. It is reported that good tin exists in the bottom of the winze, which has been sunk for 80 feet, and would therefore be about 400 feet below the surface. At the plat some underhand as well as overhand stoping were carried out. The eastern crosscut bears N. 70° E. for 66 feet 6 inches, where a cross-vein was intersected, then N. 88½° E. for 49 feet 6 inches. Bending round after cutting through the main lode, for 10 feet the bearing is N. 40° E., while for the final 15½ feet to the face the course of the crosscut is N. 73° W. In the earlier part of its course the crosscut was driven on the lode, whose strike therefore is represented by the bearing of the drive, varying from N. 70° E. to N. 88½° E. For 33 feet from the main adit it has been stoped overhead for a height of 35 feet above the back of the level, and an average width of 6 feet. The value of the stone is said to be 2 per cent. here. The stone taken out was all crushed by the old company, although returns are not available. At 66 feet 6 inches from the main level, a cross-vein was cut through, of not unpromising appearance. This appears to cut through the main vein without displacement. The strike is N. 27° E., dip about vertical, and width 5 feet. This vein should be exposed by driving along its course north and south.

At 116 feet from the main level the crosscut appears to have cut through the lode which has been followed, on account of a variation in its strike. From this point to the face, the interpretation of the evidence is not very easy, as no cross-drives have been driven from the crosscut to expose the various bodies of ore cut through. The facts are that at the point noted, 116 feet from the Long Tunnel, granite appears on the southern wall, with lode material still showing on the northern side for a few feet, when granite appears here also. At 124 feet in, quartz-tourmaline stone appears again on both walls for a width of about 6 feet. Then the drive is through granite again, out in the face lode material appears again, being hard

quartz-tourmaline with visible pyrite. The country has evidently been somewhat disturbed here, but it appears that three distinct lode-formations have been cut. The main one, which the crosscut has been following, bends to the east, striking at this point N. 56° E.: this diversion may have been caused by a slight movement along a fault plane, now represented by the cross-vein encountered a few feet on, as ore-forming vapours and solutions would naturally find their way along any such plane of weakness. Whether the deviation of the main vein has really been caused in this way cannot at the present time be definitely determined, but the quartz-tourmaline cut through at 124 feet certainly appears to represent a cross-vein about 5 feet 6 inches in width, and striking about N. 15½° E. If each maintains its present course, the two veins should intersect a few feet in the north wall. Insufficient evidence is available to enable a prediction to be made as to what may be expected at the intersection, but no time should be lost in deciding the matter by a short crosscut, which could advantageously be driven along the course of either vein: it is rather likely that the cross-vein will be found to cut through the other, without displacing it appreciably. The granite between the two on the north wall is fine-grained, and appears to have suffered considerable alteration, much quartz being developed, apparently at the expense of the felspar and mica: this change is to be attributed to the ore-bearing vapours and solutions. It is difficult to understand why the crosscut was not continued a few feet to cut through the pyritic quartz-tourmaline formation showing in the face. It appears to be quite a distinct formation to either of the others exposed, but nothing definite can be said of its strike, dip, or width, although it appears to be about parallel to the cross-vein intersected.

The main vein on which these east and west crosscuts have been driven, generally shows a central seam filled with tourmaline and soft kaolin, with varying amounts of quartz, and frequently carries rich tin. The quartz-tourmaline stone fringing it on either side also carries good tin. In such a vein the richest ore is likely to occur in shoots of limited length, connected by poorer stone which may or may not pay to work. It will probably be found that if worked systematically and on a proper scale, rich tin shoots worked with the poorer intermediate stone will bring the average value to a payable figure: on the other hand, the intermediate stone may be almost or quite barren of metal

values, and the working policy must be based not on theory, but on actual assay values of a series of samples systematically taken along the length of the ore-body.

The length of the tin shoot worked by the old company here appears to have been about 150 feet. It was only by the merest chance that the Long Tunnel happened to intersect this vein at a point where a shoot of good tin occurred: had the tunnel maintained its original course, or swung round a little to the south instead of to the north, the vein would have been cut at a point where the values were low. This fact should be borne in mind, and should stimulate further prospecting of veins which have been cut but not driven on.

The correlation of this vein with any surface outcrop is difficult and uncertain. It does not appear to be the Black Face line of lode, which most likely lies in the virgin country ahead of the tunnel. It seems that no useful purpose can be served by a discussion of the point as to which surface outcrop is here represented, for the matter at present cannot be decided, and any opinion expressed would be merely a surmise.

From the crosscuts described, the Long Tunnel has been driven for 104 feet through hard medium to fine-grained white granite, fissured in places, but quite barren of any tin-bearing vein or lode-formation.

Assay samples were not taken from the Long Tunnel, but some of the lode material from the flat-sheet where the crosscuts were driven east and west, showed a nice prospect of tin on vanning, probably equivalent to over 1 per cent. free tin, without considering the coarse rejects. An examination of the heap of " seconds " stacked outside the tunnel by the old company shows that a fair proportion of the stone carries visible cassiterite. The *free* tin from a sample vanned from this heap, indicated over 1 per cent. tin, but this was not a bulk sample: this stone will probably prove payable.

Eastern Workings.—About 26 chains east-north-east of the Black Face workings on the summit of the hill, are some old workings on a promising lode-formation, generally known as the Eastern Workings. The work to be described was carried out in the early history of the property by the old East Cumberland Company, which is reported to have taken out 14 tons of tin oxide. The tin occurs in a well-defined green tourmaline lode-formation, and to a slight extent as an impregnation in the adjoining granite: a shaft

has been sunk from the top of a hill, and a shallow adit driven to connect with it, the stoping carried out being very limited in extent.

The lode material is quartz-tourmaline: the latter mineral is a pale-green colour, and is usually without visible crystal form, although aggregates are frequently more or less rectangular in shape and are probably pseudomorphs after the felspar of the original granite. The quartz is generally white and saccharoidal, filling the intermediate spaces. Cavities occur in the lode stuff, and occasionally green tourmaline of botryoidal habit is seen as a lining. Quartz crystals sometimes line these cavities, and may or may not be accompanied by cassiterite, which sometimes occurs as crystals; in one specimen prisms of quartz were noticed lining the cavity, covered with cassiterite, showing that the latter must have been introduced after the formation of the quartz crystals. The tin oxide is nearly always very finely divided, a good deal occurring as slime tin. It is generally light-brown or grey in colour, and occurs lining or filling cavities, also sometimes filling definite fissures. Its home seems to be in the green tourmaline lode material, although it occurs also in the altered granite. One specimen of lode material was obtained showing a minute vein of quartz cutting through crystals of both cassiterite and quartz. The country-rock here is a coarse-grained pink granite with abundant orthoclase felspar.

From a small creek flowing into the Cumberland Dam, and 50 feet below the outcrop on the hill, the adit has been driven for 90 feet on a bearing N. 75° W., the approach being 6 feet 6 inches in length. It is driven through soft decomposing whitish granite, with pyritic nodules at intervals. At 35 feet 6 inches from the entrance are short crosscuts, 7 feet north and 4 feet south. From the latter a winze has been sunk: its depth is unknown, although it is at least 10 feet. Here there are two approximately parallel fisures in the granite, forming natural walls. The face of the north crosscut is said to show a little tin on assay. At 42 feet 6 inches from the entrance is a quartz-tourmaline vein of 3 to 12 inches in width, and here the coarser-grained pink granite is noticed. This seems to merge, at 79 feet, into a pyritic lode-formation. At 84 feet 6 inches from the entrance is a connection with the surface, 50 feet up. This shaft was sunk on good tin-bearing lode stuff, the best tin being obtained near the surface, where the cassiterite occurs disseminated through green tourmaline lode stuff similar to that described above. The

shaft was not available for inspection. At the bottom, and above the level, on the north wall is granite, altered and carrying pyrite: lode material appears about 3 feet from the floor, although it does not seem to be continuing underfoot. The strike appears to be about north-east, and the dip about north-west at 30 degrees to 40 degrees. From the face, a short crosscut extends for 6 feet north, and another for 10 feet about south-west. In the face of the main drive are irregular lenses of hard quartz and black tourmaline with pyrite, connected by narrow, thread-like veinlets: these masses are sometimes several feet in diameter. The enclosing granite carries pyrite in places, and is said to show low tin values on assay. In the face of the north drive is pink granite, readily decomposing to a soft white granite on exposure. This crosscut should be continued, as it appears that the true lode has not yet been cut, but probably lies a little further in, ahead of the present drive. In the face of the south-west crosscut is a vein cutting through pink granite, with a central seam of kaolin, and altered felspathic material with hard quartz of a greenish tint, on either side: it appears to carry a little pyrite. The width is regular, about 4 inches. The strike is N. 9° E., and dip vertical. Limonite leaching from the face indicates pyritic material ahead of the present drive. The soft, partially-altered granite here is said to be worth 0·75 per cent. tin.

About 15 feet north of the entrance to this adit, and outcropping in the creek-bed, is a pyritic band, oxidised to a gossanous mass in places, evidently a continuation of the lode-formation cut in the drive. A few feet south of entrance to the adit, another pyritic formation is exposed in the creek-bed: a shallow prospecting hole has been sunk at one point, but no further work done on the formation: it may be the continuation of a well-defined outcrop on the hill above.

About the collar of the shaft on the hill is a strong outcrop of the favourable green tourmaline lode material, showing cassiterite in places. From the shaft a little stoping was done and the ore extracted sledged to the battery and crushed. It is said that in sinking this shaft, some slabs of massive cassiterite were obtained at about 20 feet from the surface. This indicates that some of the narrow fissures filled with tin oxide noted at the surface widen in places lower down.

About 1 chain south of the shaft is a bold outcrop of hard lode material consisting of quartz and black tourmaline,

with occasionally a little green tourmaline. It varies in texture, approaching that of granite in places, but sometimes very much finer. It has not been definitely traced further east, although the pyritic formation exposed in the creek below appears to be on the same line of strike, and may be connected with the same period of ore deposition. To the west the outcrop is continuous for a long distance; it is covered with button-grass in places, but appears to be continuous right through to the Black Face workings. The formation has been exposed at one or two intermediate points, but practically no work has been done on the line between these Eastern Workings and the Black Face. It is said to carry a little tin throughout. The strike near the Eastern Workings is N. 66° E., and dip appears to be slightly south, but cannot be definitely determined.

The connection of this formation with the one on which the work described above has been carried out, is not evident. Two short trenches have been cut in between the two, exposing granite with a few narrow veins which may connect the two.

The vein cut in the face of the drive strikes N. 9° E., and would therefore junction with this main line.

The deposit of ore is probably connected with the intersection of two fissures, although insufficient prospecting work has been carried out up to the present to enable the structure to be explained. Further work is certainly justified here: good tin occurs near the surface and certainly should continue to a depth: the extent of the lode is still unknown. The tin oxide is certainly very fine, but should be saved by an up-to-date plant.

In addition to the work described, a little surface prospecting has been carried out on various parts of the lease.

About 6 chains south of the Long Tunnel is an old shaft, now full of water, which is over 30 feet deep, sunk on a quartz-tourmaline vein 12 to 18 inches wide, which carried rich tin at the surface. It is stated that no driving has been done, and that one or two attempts to clean out the shaft have failed on account of the heavy water encountered.

About 15 feet inside the southern boundary of the consolidated lease, and due south of the Eastern Workings, is a very promising lode-formation, on which no work has been done beyond exposing the formation. There was no outcrop above the peaty button-grass, but the lode-formation was exposed in sinking for alluvial. From the little to be seen in the hole sunk for 2 or 3 feet, the lode-

material appears to consist of very soft, brownish kaolin, with a good deal of pinite, and abundant white quartz. A little black tourmaline is also present, but the green variety seems to be absent. Tin was present in a sample vanned. The width is not exposed, nor can strike or dip be ascertained. Further work is recommended here to open up and find out something of the size and structure of the ore-body. It may be another pipe, similar to that carrying such excellent tin in the western part of the property, and the good prospects obtained from the small exposure made of the lode should stimulate further prospecting. Two samples submitted to the Government Assayer returned a trace and 0·5 per cent. tin, respectively. The sample vanned on the property was richer. The deposit should certainly be exploited.

About 4½ chains north-east from this exposure is a trench across a pyritic lode-formation in the granite, with a second trench about 1½ chain further north. The latter is on low-lying swampy ground, and, consequently, water is troublesome. It was sunk to 7 feet. The width of the formation is about 8 feet, strike N. 8° E., and dip vertical, as nearly as can be judged. It consists of quartzose material, heavily charged with pyrite in well-formed crystals, in addition to crystals of quartz and of black tourmaline. The formation is said to carry no tin.

About 4 chains north is another trench with a hole 8 feet deep on a north and south lode-formation, said to carry 1 per cent. tin. Little information is obtainable concerning this lode.

At another point adjacent to the Federation Mine has a little work been done, which deserves mention. This is on the summit of the spur south of the battery, round whose southern and western slopes the old Cumberland race from the dam has been cut. There are several bold outcrops in this vicinity, usually of very hard quartzose formations, with a little black and green tourmaline in varying amounts, and not looking very promising, as a rule, for tin values. These cannot all be correlated with each other, or with other noticeable outcrops, but their occurrence is certainly suggestive of faulting in this locality.

On the summit of the spur a big trench has been cut across a favourable-looking quartz-tourmaline formation, which appears to be about 2 chains in width. The trench is cut about north-west and south-east. The formation is much iron-stained, and consists of a series of approxi-

mately parallel quartz-tourmaline veins, with intermediate bands of decomposed tourmaline granite. Some of the quartz-tourmaline stone evidently represents replaced granite, for the tourmaline aggregates are pseudomorphous after felspar, which has been metasomatically replaced. Towards the north-west end of the trench is a well-defined band of dense tourmaline.

The assay value of the lode-material exposed in this trench is said to be 0·5 per cent. tin over a width of 60 feet. A grab sample taken by the writer from the heap was reported by the Government Assayer to contain 0·23 per cent. tin.

The strike of the formation appears to be N. 25° E. here, but the outcrop is not definitely traceable for more than a few feet on either side of the trench. It may be that it represents a continuation of a line of lode which outcrops for a good many chains on the Federation lease, and on which the No. 2 Adit has been driven. If so, some faulting has taken place on the southern portion of the lode.

The formation is such a large one, and presents such splendid facilities for mining on an economical scale from deep-level adits, that a little further *surface* prospecting is justified, to enable a better idea to be formed of its extent and the distribution of values. No underground work is recommended at the present stage.

Unprospected Outcrops.—A description has been given of the work done on various portions of the property. It has been seen that several distinct lode-formations of different types have been prospected with varying success. Brief mention must be made in passing of several other bold outcrops, which have so far not been prospected. These are always very quartzose, but generally carry varying amounts of tourmaline, in addition. Consequently, they resist the attacks of weathering agencies much more strongly than the surrounding granite, and generally stand out above the general surface as bold outcrops. Some of these outcrops are of considerable width, and as many of the exposed portions are on the highest portion of the property, they present splendid facilities for economical mining by adits. Under these favourable circumstances, a low tin content may render some of these formations payable. The usual strike is a few degrees east of north and south, although in a few cases the strike is more nearly east and west. The latter, however, is quite exceptional.

It would appear that slight faulting has taken place in a few instances, the bold outcrops ending abruptly, and perhaps continuing about parallel a short distance east or west.

The outcrops are most abundant on the highest portion of the property, and on the western slopes; also on the western slope of the spur behind (south of) the battery.

It does not seem necessary to comment on the various outcrops in detail, although the positions of the more important ones are shown on the plan accompanying this report. It is highly desirable that in conjunction with more vigorous developmental work on the property, a scheme of surface prospecting of these outcrops should be drawn up and systematically carried out. It does not necessarily follow that a formation which is non-stanniferous at one point, is worthless throughout its whole length. The work already carried out on the property indicates that the tin occurs in the lodes in definite shoots of limited (although sometimes considerable) length. Hence it is recommended that systematic samples should be taken at regular intervals, and careful records kept of results for future guidance. As indicated above, this work might well be carried out while other work is going on.

The most favourable points for the occurrence of rich tin appear to be at the intersection with cross-fissures. These points may or may not be marked by well-defined cross lodes.

Alluvial Deposits.—Although small deposits of true alluvial material occurred in some of the creeks, these have been mostly worked out, but there remain on some of the hillsides fairly extensive deposits of what is really detrital material, which will probably pay to work. Reference has already been made in this report, when dealing with unprospected outcrops, to the typical manner in which these outcrops of hard quartz and quartz-tourmaline stand out above the general surface of the granite. Obviously they, too, are exposed to the same weathering agencies as the enclosing granite, although the effects in each case are very different. In the case of the granite certain minerals (felspar and mica) succumb to the attacks of wind and weather, and slowly decompose, causing the gradual disintegration of the rock-mass. Even fragments of rock, which may be separated from the main mass by breaking off along cracks in the granite, are subject to

the same forces, and disintegrate. In the case of the quartz and quartz-tourmaline outcrops, however, the behaviour is very different. The component minerals strongly resist decomposition, and the tendency is for pieces of the rock to split off along cracks which develop under the action of atmospheric agencies. These fragments naturally work their way by degrees down the hill-slopes, where, for reasons given above, they occur almost to the exclusion of the granite facies. Eventually, they reach the creek beds, and may be carried down to form alluvial deposits if conditions be favourable. During its downward journey, this detrital material naturally suffers a certain amount of disintegration, and some of the contained tin oxide is set free.

Bearing in mind these facts, it is not surprising to find that many of the hill-slopes are covered with detrital material shed from the lode outcrops higher up, in such quantity that it will probably pay to treat this material for contained tin values. From the explanation already given of their mode of origin, it is obvious that these are really " detrital," rather than " alluvial," deposits.

The most important deposit appears to be that on the northern slope of the hill, below the Black Face workings, and down towards Packer's Creek. This locality has been systematically sampled and this sampling by rows of prospect holes arranged alternately has shown that although the depth of material varies from point to point, it will average 2½ feet. For a width of 2½ chains, and a length of 10 chains, the manager estimates from his sampling that this detrital material will yield 2 lb. of free tin oxide per cubic yard, for the depth given. But in addition to the free tin, there is a good deal of specimen stone carrying visible tin, and it is probable that under favourable conditions the whole of this material could be crushed at a profit. A test sample of 35 lb. (dry) from a point where the depth of wash was 3½ feet, on being crushed and vanned by Mr. Yates, yielded 2¼ oz. of tin oxide, which is equivalent to about 0·4 per cent. tin oxide.

The size of the material is fine to medium, no very large boulders being noticed. An examination of the concentrates obtained from vanning some of this detrital, showed that the tin is mostly very finely divided. There is an appreciable amount, however, occurring in granular aggregates up to about ¼-inch in diameter. The cassiterite is usually brown in colour, although a little black and ruby

oxide were noticed. Associated is a very small amount of yellow sand, apparently monazite; a little pyrite is also present.

Some of the specimens of cassiterite show attached quartz, also tourmaline (both green and black).

No attempt has yet been made to work this detrital material, although it is a distinct asset.

Method of Working.—With reference to methods of working this ground, two methods suggest themselves. It must be borne in mind that we are dealing with a steeply-sloping hillside, and that some of the best material occurs nearest the lode outcrops, *i.e.*, high up towards the summit of the hill. The obvious method of treatment by sluicing is thus rendered difficult by the situation of the ground to be treated. Again, the fact that much of the stone carries good tin values raises the question as to whether it will not pay to treat this oversize, as well as to save the free tin. Obviously this involves the use of some crushing machinery to free the tin oxide and concentrating plant for saving the tin when freed. Consideration must then be given to two schemes:—

(1) Pumping of water to a height from which it may be utilised for sluicing in the ordinary way the material on the slopes below.

(2) Removing the whole of the material to a battery, crushing, and concentrating.

A third plan at once suggests itself, combining the features of the other two, viz., pumping water and sluicing finer material, stacking oversize, and treating this by crushing and concentrating.

(1) Water pumped from the Cumberland Dam would have to be raised about 300 feet to treat the detrital material near the Black Face. Much of the material is at a lower level. Probably about 3000 feet of pipe column would be required to convey the water to its work. A nozzle would be used to break down the ground and convey it to sluice-boxes, the coarse material being stacked for future treatment. The scheme has several marked advantages. The ground is quite free of timber, being merely covered with button-grass, and so no clearing will be necessary, and the overburden to be removed is negligible. Again, owing to the steep fall of the hill-side, there will be no difficulty in getting rid of the tailings; these might, in an unfavourable locality, need to be ele-

vated. If this sluicing work were carried out, the surface would be thoroughly prospected, and any lode formations which did not outcrop above the button-grass would be disclosed. Such have already been accidentally discovered at several points on the property. The value of the detrital worked, too, would give an indication as to the richest portions of the adjacent lode outcrops, for unlike a true alluvial formation, there has been no indiscriminate scattering of material derived from the surrounding outcrops. This finds its way slowly but surely downhill towards the creek beds without any great lateral distribution, and so rich detrital at any point will give a good indication as to the shoot whence it was derived. The facilities thus offered for prospecting should be taken full advantage of, if the work indicated is carried out.

There are certain disadvantages which are at once obvious. A pumping plant would necessarily have to be erected near the edge of the dam, and steam power provided. Fortunately, timber is abundant near the Cumberland Dam, and a short tramline into this would furnish an ample supply of firewood at a low cost. The question of water-supply, however, needs consideration. If the Cumberland Dam be called upon to supply water for generating power at the battery on the western side of the hill, as it undoubtedly will be when work is commenced on a proper scale, the available water will necessarily have to be conserved during the driest months. It will probably not be sufficient to maintain both classes of work. In the wet season, however, the water-supply would probably be sufficient to enable both classes of work to be carried on. Considering the present condition of the mine and plant, however, it is evident that a good deal of time must elapse after operations are commenced before the mine and plant are able to commence a regular output, and this time might be utilised in working the detrital deposits, should such a course be decided upon.

(2) The suggestion has been made that crushing and concentrating might be the best method of treatment for these deposits. It certainly presents the immense advantage over the last named, that a high percentage of the total tin contents would be recovered (the actual amount depending on the efficiency of the concentrating plant installed), whereas by sluicing, only the free tin could be recovered. One phase of the problem then resolves itself into the determination at different points, of the value of the detrital as a whole, coarse and fines.

If the idea of crushing be entertained, the position of the plant is an important point. Should the stone be crushed in the main battery on the western slope of the hill, or should a small plant be erected adjacent to the detrital deposit? In the former case, obviously the material could not be crushed while the preliminary work was being carried out, as could be done with a small plant on the spot. It would be necessary to either haul much of the material to the present tramline, send it round to the inclined tram on the west side of the hill, and lower to the battery, or construct a low-level line of considerable length, sending material down by some method, such as an aerial tramway, to hoppers, thence loading into large trucks, to be sent round the hill to the battery. Actual crushing costs would be smaller, and probably recovery would be higher on account of a more efficient concentrating plant than would be available in connection with a small battery installed to treat the material on the spot. A small plant might, however, be erected in Packer's Creek, directly below the detrital deposit. In such a case the head-waters of this creek would supply sufficient power, unless in very dry weather, when there would probably be a shortage. The detrital would be sent down by some style of self-acting tram, probably an aerial tramway, and tipped direct into battery hoppers. Thus, costs of handling and of crushing would be reduced to a minimum. A plant such as would be required for this work would be inexpensive, and a great advantage would be that work could be carried on, if thought desirable, while the main battery was being remodelled, and exploration work carried on in the mine. Should there be any overlapping in work here and at the main battery, work at the latter would not be in any way affected, since the water required for power in each case would be derived from a different source.

It seems scarcely necessary to comment in detail on the third scheme suggested for working the deposit, combining, as it does, some of the features of each of the other methods, for its applicability will at once be evident.

The foregoing remarks will serve to indicate possible methods of working this portion of the property to advantage. More figures relating to values, particularly of the detrital as a whole, as distinct from merely the free tin contained, are necessary before any final decision can be arrived at as to the best method to employ. This information is essential, because of the variation which is to be

expected from point to point, according as the detrital has been shed from a richer or poorer portion of the outcrop. One would expect, too, that the lighter material would work its way down the slope rather more quickly than the more highly stanniferous; consequently it is possible that the coarser material on the upper part of the slope, near the outcrops whence it has been derived, might pay well to crush, while that lower down might be too low grade. Discrimination should be used in working, for it will be found possible to leave or send to the dumps certain patches or strips of low-grade material which would not pay to handle. These points, however, can only be decided by careful sampling, as suggested above.

If the price of tin be satisfactory, this patch of ground should yield substantial profits over working expenses, and it has been indicated that an output of tin might be maintained from here while dead work was being carried out on other parts of the property in connection with the mine and plant.

In connection with any plan which may be considered for treating these detrital deposits, the question of overburden needs consideration. This is never heavy, but practically the whole of the surface is covered by button-grass which would necessarily have to be removed before the material were sent to the battery if it were proposed to crush it in the ordinary way, on account of the certainty of the grass roots clogging the battery screens. In this connection Mr. Luke Williams furnished the writer with some interesting notes in a recent letter. Mr. Williams says, "I saw a useful way of treating such stuff in Cornwall, where they used a rill of the fine-crushed material to bank up the water, and the crushed material could only pass away by floating *over* the rill. The fineness was regulated by the height of the rill or bank. Theoretically the efficiency of the stampers was affected by dropping in water, but the freedom from choking gratings more than made up the loss. In addition, there was the saving in the cost of buying gratings." This suggestion is worthy of consideration when arranging for the treatment of the surface material.

The preceding discussion has been confined to the detrital deposits on the northern slopes of the hill, below the Black Face. On the western slopes also, and, in fact, to a greater or less extent over the whole of the surface of the property, lode-material is to be seen. This is not surprising, in view of what has already been said with

regard to the number of quartz-tourmaline outcrops, and the hardness and resistance of this class of material to the attacks of weathering agencies. It is probable that at intervals will be found patches of detrital material carrying good tin values. In some instances these will be too small in extent to be profitably worked, but with the known tin-bearing outcrops in the Western Workings, it is likely that the deposits here may prove payable. Good tinstone is known to exist in places, but systematic prospecting to prove its extent and value has not yet been carried out.

The remarks already made with regard to the advantages of exposing the surface for prospecting apply here also. In other respects, too, conditions are similar. The surface is free of timber, and has a steep slope. Tin occurs both free and in specimen pieces of lode-stuff. Being high up on the hillside, it would be difficult to get water on. The remarks made with regard to the distribution of the detrital, and the relation of the best tinstone to the richest outcrops, also apply here. If this deposit were found on careful sampling to be rich enough (and there are good reasons for believing it will be), it will probably be conveyed to the main battery by the self-acting tram, and there crushed, either alone or in conjunction with ore won by mining operations.

On the southern slopes of the hill, too, are detrital deposits of considerable extent. In this locality a few patches have been worked at a profit, but it is likely that the whole will pay to strip. Either of the alternative schemes suggested for the northern deposit might be applied in this case, depending on tin values as disclosed by prospecting, but if the grade were high enough to warrant it, a tramline might be run round to connect with the main inclined haulage, and the detrital sent to the battery to be crushed.

Before leaving this question of the detrital deposits on the property, reference must be made to a little work done on the western slope of the hill, in a creek bed near the inclined tramway, and below the 570-feet level. Here some rich specimens of tinstone were found, usually occurring with quartz and tourmaline, and also some free tin. Although still high up on the hillside, much of this was rounded, owing to the pounding and grinding action of various boulders in the creek. Associated with the tin was some very fresh wolfram, and the creek bed was worked for nearly 2 chains, to trace the source of this

mineral. Water is scarce here, but as a result of the small amount of work done, one bag of high-grade wolfram was won, with five bags of tin oxide. The ground appears to have become too deep for the water available, and although wolfram still occurred as far as the work was continued, operations had necessarily to be suspended without locating the source whence the metal was derived.

The Whip Shaft Line of lode outcrops on a spur overlooking the creek at the point where work was stopped, and it may be that a shoot of wolfram occurs in this lode. Further prospecting is necessary to determine this point, but the work is justified.

Plant.—The plant installed at the mine will need complete reorganisation before it can be utilised. It is situated in the western portion of the property, on a branch of Packer's Creek, and at the foot of a high spur round which the old race from the Cumberland Dam was constructed.

The battery consists of 20 heads of stampers, all driven off one shaft. Fifteen stamps are said to be 800 lb. weight and five 700 lb., the latter having double discharge. Hand-feeding was employed. The battery is of an old type, the tappets being screwed to the shanks. The frame is of wood with steel guides. The main shafting is driven by a Pelton wheel, 2 feet 10 inches in diameter, with a $\frac{7}{8}$-inch jet, which operated under a head of 250 feet. This was not the total available head, water from the end of the race being led for about 200 feet (vertical height) down the hill in an open channel before entering the penstock, at the head of the column of 7-inch pipes. The drawbacks of such a method are obvious. The ore from the mine was tipped on to an inclined grizzly, bars being spaced $2\frac{1}{2}$ inches apart. The undersize went to the battery hoppers, the oversize to a jaw-crusher by B. Frey, Melbourne, driven by a belt from the cam shaft. Unfortunately this crusher was erected on a platform which was very unsubstantially supported, and, consequently, the vibration is said to have been excessive when the machine was working. The crushed ore fell into the battery hoppers. The crusher floor is 30 feet above the main concentrator floor. The ore was crushed very fine. The screens used appeared to be 30 or 40 meshes to the linear inch, and these screens were doubled in actual crushing, which would reduce the size of the product still further, and obviously reduce also the capacity of the battery. The pulp from the battery

ran to three spitzkastens. The overflow and slimes went to a slimes dam, thence to one Frue vanner. The sands were treated on five Frue vanners, 13 feet long, 4 feet wide, while two other vanners were used for dressing the tin. The vanners were all driven by a Pelton wheel 2 feet 4 inches in diameter, with a $\frac{3}{4}$-inch jet. The New West Cumberland Company also used a convex revolving buddle for treating their slimes. This buddle stood in the open, and was driven from an intermediate shaft, which itself was belt-driven from one of the vanner shafts. A canvas strake seems also to have been used.

Although latterly the ore was brought to the battery by an inclined tram from the Western Workings, previous to this an aerial rope was used for the purpose. When this was operating, the rope was wound for several turns round a horizontal grooved wheel, which operated a vertical shaft and spur-wheel. By bevel gearing this was connected with a horizontal shaft, and a belt connected a pulley on this shaft with one on the battery cam-shaft. This device was designed to enable the battery to assist the skips when they got towards the end of their journey, where, owing to the sag caused by its weight, the rope was very flat. Conversely, it was thought that when the full skips were descending the steeper portion of the stope, they would assist the battery.

The battery is housed in a galvanised iron shed in fair repair.

In addition to the plant described, there are several side and end tipping trucks on various parts of the property, together with various mining tools, and several hundred feet of pipe column.

Past History of the Property.—Before any attempt can be made to forecast for the future, it is a matter not only of considerable interest, but of great value, to look briefly at the past history of the property. Past successes and failures may prove valuable guides in planning future operations.

The consolidated lease of 268 acres now charted in the name of J. H. S. Munro, comprises leases formerly held and worked by the Cumberland Tin Mining Company, the West Cumberland Tin Mining Company, and the East Cumberland Tin Mining Company. The two former were among the first companies to operate in the district, and a good deal of the work done on the property was carried out by these companies, before 1885. The West Cumberland Company's property fell into the hands of Messrs.

Fowler and Dunn who carried out further work about 1893, and eventually sold their interest to the New West Cumberland Company, which exhausted most of its available capital in surface works. By this company the present battery was erected, although very little, if any, ore was crushed. Eventually the whole of the leases fell into the hands of the present owners, who have spent a good deal on the property.

Taking a general survey of the property and the work done on it, and in connection with it, one is struck by the fact that a considerable amount of money must have been spent at different times.

It may be well to mention some of the more striking features of the work carried out by various companies in the past. Among these are the road up the steep hillside overlooking the old Montagu Mine, which was cut to enable the Cumberland battery to be taken to the selected machinery site, the preparation of the machinery site, and erection of the plant upon it, the construction of the tramline connecting the Long Tunnel with the old battery, involving a good deal of cutting and filling, the construction of the Cumberland Dam and race to the old battery site, and later on, the race to the present site, with necessary pipe-columns, &c., the erection of the old West Cumberland battery on a branch of Packer's Creek, with race from another branch of the same creek; later on, the erection of the present battery and plant, with originally an aerial tram, and later an inclined tram, to connect with it, and the horse tram connecting Central and Western Workings.

In this connection it must be borne in mind that much of the work was carried out over 30 years ago, when costs of transit, &c., were very high. The actual mining work carried out has already been described in detail, and it is apparent that the expenditure involved in carrying out the various surface works is quite disproportionate to that spent on underground works. Here, it appears to the writer, is one reason why the mine is not being more actively worked at the present time. Too much of the available money has in the past been spent on surface works, and too little on mining development.

As a natural consequence of this course of action, no really systematic developmental policy has been followed in opening up the mine. A little work has been done, as we have seen, on different parts of the property, these workings and groups of workings being usually quite dis-

connected. It is, of course, quite unavoidable that where there are so many distinct lode-formations as exist on this property, the work in the prospecting stages should be very scattered, until some idea of the nature of the lodes, and the occurrence in them of the values, be obtained. But as soon as this information is available, it is advisable to concentrate the work as far as possible, instead of working from a number of disconnected centres. For example, if a deep-level adit be driven, as suggested elsewhere, and various workings in the vicinity be connected by intermediate levels and rises, the concentration thus effected must result in reduced working costs. Up to the present, the Long Tunnel is the only piece of work which has been started with such an object in view, and although this will be a valuable asset in planning future work, it has not up to the present been continued far enough to enable it to be advantageously connected up with the workings on the hill. Working costs in the past, then, have been increased through want of concentration of workings.

One of the greatest disadvantages which the companies had to contend with in the early history of the property was the inaccessibility of the mine. It must be remembered that the mine was being worked before the discovery of the Zeehan field, and the original plant and all necessaries had to be landed at Trial Harbour and carted thence to the property. This so-called "harbour" is merely an open roadstead, and exposed to the full force of weather from south to north-west. Trial Harbour has been described elsewhere, and the disadvantages accruing from such an uncertain harbour in the earlier stages, and later, from the costly carting of goods from Zeehan, have been referred to.([211]) These disadvantages were partly instrumental in hindering the development of the property.

In reviewing the past history of the mine, and noting that from time to time parcels of ore have been crushed, it is natural to enquire what class of concentrating machinery was employed. The earlier plant consisted essentially of buddles and tubs, which must have been exceedingly inefficient when viewed from the modern standpoint, although doubtless quite up-to-date when installed. Unquestionably, the loss of tin was excessive when treated under these conditions. Later on, Frue vanners were installed and used by the New West Cumber-

([211]) *Vide supra*, pp. 2, 15 16, 229, 232.

land Company, but from the fact that only recently a dam full of tailings from crushings treated in this plant, was re-treated at a profit, it is apparent that the loss in this case also was excessive. Clearly, then, with such treatment losses, whenever ore was crushed, conditions have been very unfavourable for the ultimate success of operations.

The actual production of tin oxide leads naturally to a consideration of the market price of that product. The accompanying table will be of interest in this connection; it gives an idea of the fluctuation in the price of the metal since the discovery of tin on the property.

The Average Price per Ton of Metallic Tin, Colonial (Australian) in the London Market for each Year from 1875 *to* 1914:—

Year.	£	s.	d.	Year.	£	s.	d.
1875	83	2	0	1899	123	7	9
1876	74	3	11	1900	133	19	2
1877	68	3	10	1901	117	16	8
1878	61	6	0	1902	120	17	6
1879	71	19	0	1903	127	8	10
1880	86	15	0	1904	127	7	2
1881	92	15	6	1905	142	13	0
1882	102	15	6	1906	181	1	1
1883	93	1	0	1907	173	3	6
1884	81	3	8	1908	134	4	5
1885	86	16	3	1909	135	5	2
1886	97	16	6	1910	153	16	9
1887	111	16	6	1911	190	0	0
1888	117	5	3	1912	209	6	5
1889	93	10	10	1913	206	5	7
1890	94	7	6	1914—			
1891	91	16	9	January	171	18	1
1892	93	15	4	February	181	11	1
1893	86	4	8	March	173	13	0
1894	69	7	4	April	163	19	3
1895	64	7	2	May	150	14	0
1896	60	19	2	June	138	18	1
1897	62	12	9	July	142	19	9
1898	75	13	0				

From years 1875 to 1911, inclusive, the prices are those of Colonial (Australian) tin in the London market, taken from a Home Office Blue Book: "Mines and Quarries: General Report, with Statistics, for 1911: Part III.—Output. Table 275, page 308."

The figures for 1912, 1913, and 1914 ([212]) are calculated from London prices quoted in "The Engineering and Mining Journal." These figures do not correspond exactly with the London prices quoted for Australian tin up to 1911, but the difference is slight.

The variation in any particular year is sometimes considerable; for instance, in 1912, the average London price was £191 10s. 4d. for January, and £228 7s. 1d. for October, according to the journal quoted above. These figures will give an idea of the extraordinary variations in price to which the metal is subject from time to time.

Judging from the reports of Mr. G. Thureau, most of the work carried out must have been completed between the years 1880 and 1884, when the price of tin varied from £81 to £102 per ton.

Another period of activity seems to have been marked by the years 1894-1895, when Messrs. Fowler and Dunn, and the New West Cumberland Company, were at work. At this time tin was under £70 per ton, and yet work was carried on at a profit, especially by the former party.

The low price of tin in former years has had its influence in retarding developmental work, by making investors diffident about putting money into a property which could not guarantee immediate returns. If the property were idle for a few years from such a cause, it would be more difficult to attract capital even to a genuine property, on a rise in tin, after such a period of enforced idleness.

A feature of past work which may be emphasised here, although it has been mentioned in the course of this report, is the element of chance which seems to have characterised certain of the work. It is safe to say that the results must have been surprising at times. One or two examples may be given. In driving the No. 2 Adit, the West Cumberland Company passed through fissured granite. At 100 feet in, a fissure was intersected which appeared in no wise different from many others passed through, but for some unknown reason it was decided to rise on this particular one, with the result that a body of rich tinstone was won. Again, after this was worked out, and the old workings deserted, the discovery of a second body of rich stone was the result of an accidental fall of roof.

([212]) June and July averages kindly supplied by Mr. Bischoff T.M. Co. Prices for succeeding months upset by the great European war.

The discovery of the rich pipe, which yielded such excellent results to a party of tributers, was also made by the chance sinking of a prospecting hole at a point where no lode was known to exist.

Another promising ore-body, which has not yet been prospected, was located near the Cumberland Dam by a chance prospecting hole sunk to test for alluvial wash.

The cutting of a shoot of rich ore in the Long Tunnel also appears to have been simply a matter of chance.

Other instances might also be given of a similar nature. But that the element of chance was not always rewarded is illustrated by the 570-feet level. Here a decided deviation was made from a lode which had been driven on for some distance, for no apparent reason, with the result that no other ore-body was located.

Spasmodic work is certainly not to be recommended, but the fact that many lodes have been located in the past at unsuspected places, and sometimes when carrying out prospecting work with a very different object in view, suggests that in systematically developing the property, other bodies of ore, at present unknown, may be discovered.

Present Position of Property.—The position at the present time is, briefly, that a promising property, on which thousands of pounds have been spent in the past, is lying idle for want of capital.

The condition of the mine has been fully described in the earlier portions of this report. The workings described are practically all available for inspection, excepting in a few cases where old stopes and passes have collapsed. In nearly all levels, rails are laid, and prospecting work could be continued immediately, if thought desirable. It seems that for some years several of the old levels were in a state of collapse, but these have now been picked up, and are in good working order.

With regard to the plant, however, a good deal of repair work and actual remodelling will be necessary before work can be carried on. The battery has been described, but the advisability of using it in its present condition is very questionable, and in the writer's opinion, not to be recommended. It is out of date; the stamps are too light for this class of ore. The screwed tappets are now replaced by keyed ones in more modern batteries. Perhaps, worst of all, is the arrangement by which the whole 20 heads are driven off the one cam shaft. This means

that if any accident happens to one stamper, the whole battery is thrown idle until the damage has been repaired. Preferably, the heads should be grouped, five in each mortar-box, each group having its own separate cam-shaft, belt-driven from a main power-shaft; then, if one stamper be accidentally thrown out of action, only one group will be affected, and 15 heads will still be available for continuous crushing.

The Frue vanners in the present plant are not in working order. In some instances the frames require repairs and renewals; the belts in some cases are perished, and after a fairly close examination of the more sound-looking ones, it seems to the writer that the rubber is too perished, after the long period of idleness of the plant, to stand the strain of further work, and that new belts would be required throughout, if it were decided to continue using this type of concentrator. Before going to such an expense, the claims, from the point of view of efficiency, of more modern types of tables should be carefully considered.

The Peltons are in good order.

The fine crushing adopted previously should not be continued. A good deal of the tin is actually finely divided, but it frequently happens that crystals of small size occur in groups and aggregates, and so actually behave as though the tin were coarse. It sometimes does also occur in coarser crystals. It would appear, then, that by first of all crushing coarse, and concentrating, say, by jigging, a fair proportion of the tin could be saved. The classified tailings would be distributed—the fines to concentrating tables, the coarse to grinding-pans, classifiers, and tables. An attempt should undoubtedly be made to save as large a proportion of the tin as possible before reducing the product to slime. A certain amount of sliming is unavoidable, but with an up-to-date plant and capable supervision the percentage recovery should be high.

Broad outlines only as to reconstruction of plant are here indicated, but it is obvious that capital is required for this work, and that the work is essential to future economic working.

Reference has been made to the main inclined tramway connecting the Western Workings with the battery. This, at present, is in a state of disrepair. Rails are lying along most of the length, but the sleepers are completely perished, and new ones are required throughout, with bal

lasting, before the line can be utilised. Ropes, also, will have to be supplied, with accessories.

The horse tramway, winding round the northern and north-western slopes of the hill, and connecting the Central Workings with the inclined haulage from the Western Workings, can scarcely be regarded as more than a temporary expedient for dealing with the big body of ore exposed by the Central Workings. No rails are laid at present, and so sleepers ballast and rails will be required here, before any use can be made of the line.

A new race will be necessary, from the Cumberland Dam, and a recent survey has shown that the length would be 94 chains, and that nearly 20 feet could be gained in vertical height, owing to the unnecessarily steep fall given in the old company's race. About 1100 feet of pipe-column would be necessary to connect with the battery.

Reference has already been made to the Cumberland Dam, and the advantage accruing from the raising of the present embankment. This work, in fact, will be necessary to ensure a permanent water-supply in dry seasons, if a big plant is to be kept running continuously. Incidentally, the level of the by-wash, as well as the main embankment, will have to be raised.

With regard to mine timber, attention has been called in an earlier part of this report to the fact that abundant excellent timber for all purposes is available near at hand. The method employed in the past for obtaining this (*i.e.*, direct haulage by horse-power over a rough track), will have to be superseded by a light tramway into the timber belt, when the demand increases. A saw-bench will also be found necessary for dressing the timber to meet various requirements of constructional, as well as of direct, mining work.

Recommendations.—It seems advisable to make a few suggestions as to the laying out of future work on the lodes.

Reference has previously been made to the number of outcrops of quartzose and quartz-tourmaline rock on the property, in the form of veins and dykes in the granite, traceable sometimes for considerable distances on the surface. These have certainly been formed in a similar manner to some of the proved tin-bearing formations, and themselves may or may not carry tin values. It is advisable that, in conjunction with other work, these outcrops be systematically prospected, the results, even if negative,

being tabulated for future reference. In carrying out this work, it is important to keep in mind the actual occurrences of tin ore in the lodes already partly opened up. The richer ore frequently occurs in shoots of limited length, and it appears that different shoots may be separated by low-grade material; if, then, payable tin be not found at one point of an outcrop, it does not necessarily follow that shoots of richer ore do not occur at other points along the line of outcrop. Hence, to be of maximum value, any work carried out should be systematic, and not spasmodic.

Surface work, however, should not claim primary consideration, since the underground work carried out has generally been on, or in the vicinity of, known tin-bearing lodes, and extensions of some of these workings should first be carried out.

In connection with the Western Workings, definite work may be carried out in several directions with advantage.

A description has been given of the rich shoots of ore won in the vicinity of Messrs. Fowler and Dunn's workings, and the opinion expressed that probably faulting has been responsible for the sudden cutting out of the ore-bodies. If so, there is a reasonable prospect of picking up extensions of these bodies with a little further work. With this object in view, it is recommended that the No. 2 Adit be driven north about 40 or 50 feet, and crosscuts put out east and west. A crosscut west is particularly desirable, to try and locate the body of ore slightly exposed on the western side of the open cut. If intersected at this level, about 140 feet of backs would be available for stoping. There is the possibility of intersecting, not only the particular ore-body referred to, but other portions of the rich shoot already worked out.

Before this work was carried out, or while it was in progress, a crosscut might well be put in from the western side of the open-cut, to expose the body of ore for a few feet, which is known to exist there. Such a crosscut would be very shallow, and, consequently, of no value for stoping, but would serve a very useful purpose in indicating the nature, size, and general course of the lode, and such particulars would be valuable in planning underground work.

No. 1 Adit.—The ore-body exposed in the face of the main drive should be cut through by continuing the main drive a few feet, and as the locality is favourable for a

shoot of good ore, being at the intersection of two cross-veins, the main formation should be driven on east and west to enable an idea of its nature to be formed.

The lode-formation from which the bismuth was won in the earlier history of the mine also merits further attention.

Yates' Level.—Further prospecting work is desirable from this level. Two lodes appear to have been cut, but little has been done to prove their extent. Drives should be continued on the course of these, to prove the existence or otherwise of shoots of payable ore within a reasonable distance of the level, systematic samples being taken during the course of prospecting work. The shoot of bismuth ore exposed in this level is very promising, and should certainly be opened up.

No. 3 Adit (500-feet Level).—A short crosscut should be driven through the pyritic lode partly worked by tributers from this level, in order to expose its full width and value, but it is advisable rather to concentrate prospecting work on the lower adit (No. 4) than to do much here at the present time.

No. 4 Adit (570-feet Level).—From the description given of the work done on this level, it is obvious that further prospecting is highly desirable. A lode-formation carrying fair tin values in places has been driven on, but for a considerable distance even its width has not been exposed. Crosscuts should certainly be driven at intervals, preferably both north-west and south-east, but particularly north-west. Suitable points would be about 130 feet, 200 feet, and 372 feet from the entrance, or at least the first and last mentioned. At 372 feet the adit makes a sudden and inexplicable deviation from the lode, at a point where it looks very promising. In addition to the crosscuts—which, however, should claim first attention—the drive might with advantage be continued for a time on the course of the lode. There are grounds also for believing that a pyritic formation may be exposed by continuing the main drive in its present direction for a few feet, as solutions leaching from the present face are depositing a good deal of limonite.

Tributers' Workings.—This group of workings on a pipe of rich ore of irregular shape is certain to form the scene of further activities. Not only has very rich ore been won, but much remains at the present time to be extracted from the borders of the old workings.

Apart from this aspect, however, the pipe itself is likely to be continuous, and its further prospecting and exploitation must form a feature of future work. The upper portion of the pipe has been very tortuous, and there is no ground for believing that it will become more regular as a greater depth is attained. Consequently, the planning of future prospecting becomes difficult. The changes in the dip from vertical to almost horizontal, and also the changes in direction, have in the past been so sudden and unexpected, and guided by factors which so far are not definitely recognisable, that it seems that the safest way to prospect the pipe is to follow it down on its course, connecting up at intervals with systematic levels and crosscuts, if the size and value of the pipe are sufficient to warrant the driving of these. At the present stage, in order to connect with the pipe exposed in the face of the branch drive extending south-west from the main pipe (described in detail in an earlier part of this report), it seems advisable to continue the south crosscut from the main tributers' level, about 15 feet south, and then rise to connect. This rise would not only give ready access to this part of the workings, but would serve as a pass for handling the material. The small branch pipe exposed on the south wall of the offshoot, 18½ feet from the present face, should also be prospected, as it carries rich tin at this point. This should be followed down, for it is not unlikely that it will widen, although on the other hand it may not be a "feeder," but only a short offshoot. Should any quantity of ore be won from here, the suggested pass could be utilised in handling it, and if necessary an intermediate drive put in when its course had been ascertained.

With regard to the main pipe, which is showing good tin in the face of the intermediate drive, and where a winze was commenced but abandoned on account of the water, the question arises as to how best to continue work. As a temporary expedient a crosscut might be driven south from the end of the present main adit, and a rise put up to connect; but when it is remembered that such a crosscut would be about 65 feet long, and the "backs" obtained only about 10 feet, it is obvious that some other solution of the problem must be found. The same applies to the portion of the ore-body referred to above as the "branch-pipe," for even if the crosscut and rise suggested were put in, the relief would only be temporary.

In attempting to plan for the future, two alternative methods suggest themselves:—

(1) Sinking a shaft and driving crosscuts to connect with the workings.

(2) Driving a deeper level adit, and rising to connect with the workings.

(1) The former would probably be the most direct method of getting out the ore. Two methods of working might be suggested, either sinking from the surface, or sinking from the present tributers' level, after working the ore above. Either plan is open to grave objections. The constant expense of hauling even to the present adit, increasing with depth, with the added cost of raising any water which may be encountered (although this is not likely to be heavy) scarcely need comment. But the form of the pipe it is desired to work must be kept in mind. It is utterly impossible to predict what direction it will take a few feet ahead, or at what angle it will dip. The only certain way of determining these important facts is to follow the course of the pipe for some distance, and then lay out the work. But if its behaviour in the past can be taken as any guide at all of its behaviour in the future, then this method would be open to the objection that a slight increase in vertical depth of the shaft would mean a very considerable increase in the length of crosscut necessary to connect with the pipe. Basing calculations on the past behaviour of the pipe, if this were constant, at 100 feet vertically below the present face of the main pipe, it would be necessary to drive 363 feet to intersect it. Obviously, the more nearly vertical became the dip of the pipe, the shorter would be the crosscuts required to intersect it.

(2) In considering the question of a lower adit, it is at once evident that the objections raised by the irregularity of the pipe of ore, and the increased length of drive necessary to intersect at a greater depth on a flat dip, apply here also. Hence arises the necessity for finding out by prospecting something about the course of the pipe. In connection with an adit, one naturally looks to some of the workings to see if a connection is possible. The only one to be considered is the No. 2 (530 feet) Adit. It is unfortunate that in the immediate vicinity of the Tributers' Workings, the hill does not fall away very rapidly. However, the No. 2 Adit has been driven for 113 feet, and from the face a drive might be extended

due east, to come under the present workings. No accurate plan is available at time of writing, but it appears from field observations by compass and aneroid that about 450 feet of driving would be required to come vertically under the present face of the intermediate drive. where pipe-material is still showing, and it appears that this drive would be about 180 feet vertically below the present face. If further prospecting proves that the pipe still dips south at a flat angle, it will probably be better to commence a fresh adit on the opposite side of the creek, to cut the ore at a satisfactory depth without such a long drive as would be necessary in utilising the No. 2 Adit. A contour survey of this portion of the property is highly desirable before finally deciding on the exact location of the new drive, for it appears from the field observations of the writer that a fresh adit driven from a point east of No. 2 Adit would reach the same point as that suggested from the present face of No. 2, with about an equal amount of driving.

Such an adit as that proposed would do valuable prospecting work, and any lode-formations exposed should be carefully tested, and if promising driven on for a short distance, and thus opened up and made available for sampling.

The advantages of working from such an adit in preference to a shaft, scarcely need detailed mention. There would be no pumping and no hauling of ore, which would be loaded into trucks underground, run around the hill on a properly graded tramline, and sent direct to the treatment plant without further handling by the main inclined haulage. The rich ore previously won from these workings, and that at present opened up, certainly justify active prospecting of this portion of the mine.

Black Face Line of Lode.—This large and important body of ore has been described, with the work done upon it in the past, and as it promises to be the biggest ore-producer on the property in the near future, its development and future working need consideration.

It must be recognised at once that little is known of this ore-body at the present time, and that further prospecting is necessary to learn something of its structure at a greater depth. But surface prospects are so encouraging that further work is certainly justified, and should be carried on as soon as possible. Whether this huge mass of ore is a purely local development at the intersection

of a favourable set of fissures, or whether it will maintain its size and value as a greater depth is attained, the future alone can decide, but progressive work should be carried out without delay, in order to provide reliable data for the planning of future work. The writer is of opinion, after studying the formation, that a strong and well-defined lode will be encountered, and that it will be permanent to a very considerable depth.

Even in its present state, a large body of ore is available for economic mining by open-cut methods. But it is advisable, in order that it should not be a burden, that developmental work should be carried out while the quarrying of the ore at the surface is in progress.

It is natural, then, to examine the various underground workings carried out in the past, and find out whether any of them can be advantageously utilised for further prospecting.

The 220-feet level, driven from the northern slope of the hill, was apparently commenced with the object of intersecting this lode, but abandoned without reaching it. If continued on the course it was driven for 200 feet, the drive would cut the lode at a point vertically beneath Munro's shaft; over 200 feet of backs would be available for stoping. As the dip of the formation has not yet been determined, the length of drive necessary to intersect it is rather uncertain, but unless the dip is steep, it would be cut with about 200 feet of driving. If, however, the level were continued on its present bearing, the lode would be cut a few feet south-west of the No. 2 Bench, and about 140 feet of backs would be available. Moreover, the driving necessary to intersect the formation should not exceed about 80 feet. This work is recommended. The drive should be continued to cut through the formation and expose its true width, and then it would be desirable to extend drives north-east and south-west on the formation, preferably for 50 feet in each direction, before again crosscutting from wall to wall. While driving along the course of the lode, it would be advisable to rise on the formation and break through to the surface. Such a rise would not only give useful information as to tin values, but would improve ventilation, and could be utilised as a pass for ore from the surface and stopes if it were decided to temporarily utilise the horse-tram while a permanent connection with the battery was being made, either by continuing the present inclined haulage, or driving a main working adit. If work on the lines

here indicated were carried out, it would afford valuable information as to the nature of the ore-body, which would serve as a guide in planning out future work.

A piece of work which will prove very valuable in the opening-up of this Black Face lode is that carried out by the old Cumberland Company, and now known as the Long Tunnel. This adit, driven from the southern slopes near the Cumberland Dam, has already been described. As has been stated in the description given of the work done, the correlation of the lode-formation cut in the tunnel, with a surface outcrop, is uncertain. It is probably not the same line of lode as the one under discussion.

If the present tunnel be continued on its present bearing, the Black Face line would be cut probably in less than 100 feet, but about 2 chains south-west of Munro's shaft. The formation on the surface is not so wide here, but it must be remembered that the drive is about 320 feet below the surface. This renders any prediction of distances at which the formation should be cut uncertain, since the dip is not known. This will be evident when it is stated that a dip of only 10° from the vertical would result in a horizontal displacement of 56½ feet at a vertical depth equal to that of the Long Tunnel, below the top of the hill. Of course, if the dip be towards the east, as it appears to be on the hill, the drive will be correspondingly shorter.

The question then arises as to the advisability of continuing the main drive on its present course. By deviating, and driving on a bearing of about N. 5° E., the drive would, in 180 feet, be vertically below Munro's shaft. As has been explained, the lode might be cut with less driving than that mentioned. Although it is advisable to find out a little more concerning the formation before finally deciding on the course to be pursued, in the light of information available at the present time, the writer would rather favour the idea of driving to cut the ore-body beneath a known tin-bearing portion of the outcrop, even with the added expense of a rather longer drive. If this big body of ore has really been formed at the intersection of two distinct fissures in the granite, as appears to be the case, then the nearer to this intersection it is cut, the more favourable will be the conditions for locating a good shoot of ore.

When intersected, the lode-formation should be driven on, particularly towards the north-east, but preferably, in

both directions along its line of strike, the full width being exposed at intervals. At a favourable spot, a connection should be made with the surface, preferably by rising from the Long Tunnel and sinking from the surface to connect. From such a rise, which would ventilate the deeper workings, intermediate levels could be driven, and the lode-formation systematically developed.

Work such as that indicated would render available for extraction a large tonnage of ore, and the handling of this ore cheaply therefore becomes an important consideration The Long Tunnel is not very favourably situated to form a main working adit, although it could be made to serve as such by constructing a tramway round the southern and western slopes of the hill, and connecting with an inclined tramway to the battery. The question then arises, as to what is really the most suitable position for a permanent adit, to serve as the main working adit for the mine.

The main considerations to be kept in mind appear to be—

(*a*) Minimum length of drive.
(*b*) Maximum amount of backs.
(*c*) Most central position to suit workings on various lodes.
(*d*) Most suitable position for connecting with battery.

From the topography of the locality, two sites are possible—one on the northern slope of the hill, and one on the western.

The northern slope is steeper than the western, hence an adit to give a certain amount of backs would be shorter in the former case, and conditions (*a*) and (*b*) would be satisfied. A tunnel could be driven from the northern side to come vertically below the Black Face workings in about 800 feet, and such a tunnel would give about 400 feet of backs. A continuation of this drive could, if desired, be made to serve the Air Shaft line, but would not serve the Western Workings. Also the entrance would not be in a convenient position for direct connection with the inclined tram to the battery. About ½-mile of well-graded tramway would have to be constructed to make this connection.

In the case of a main adit from the western side of the hill, a longer tunnel would be necessary. Such an adit commenced from near the present Tributer's Tunnel,

some distance above the top of the old haulage line, would be about 300 feet below the Black Face, in about 1600 feet of driving. Going further west still, the hill-slope becomes steeper, and from a point below the present No. 2 (530 feet) Adit, nearly 600 feet of backs could be obtained from a drive of 2000 feet. An adit from such a site would have the advantage that it could be directly connected with an inclined haulage-line to the battery. If driven from the Tributer's Tunnel, it would not serve the Western Workings, but would do so to advantage if brought in from a lower level. The country passed through here, judging by surface indications, is rather more promising for the location of other ore-bodies than that on the northern slope. This aspect is rather important, for the prospecting work done by such a deep-level adit as the one proposed, would be very valuable. In planning this work it is important also to keep in mind future requirements. Although 400 feet of backs would provide ore for some time, the writer believes that the deposits will be found to carry satisfactory tin values beyond this depth, and an adit constructed in the near future should preferably form but a unit in a complete scheme for the development of the property on systematic lines.

It may be thought advisable to continue the Long Tunnel, and eventually connect with the main working adit from the western side of the hill.

The writer would urge the advisability of further work upon the Black Face lode before finally deciding upon the most suitable position for a main working adit. Only in the light of further developments can such work be carried out to greatest advantage. It is hoped that the foregoing remarks may be of assistance, but it must be remembered that they are written with little definite information of the important Black Face lode, the only sections available at the present time being those exposed by the surface works described.

In addition to what has been said, there is scope for further prospecting in places which scarcely call for more detailed comment here. The Eastern Workings, the soft tin-bearing formation exposed on the southern boundary, near the Cumberland Dam, the lodes cut in the north-east crosscut from the Long Tunnel, and Gray's Lode on the western slope of the hill, all of which have been described, should be prospected. All show very promising features, and certainly merit further work being done upon them.

Future of the Property.—The future of the property is still a matter of some uncertainty, owing to the small amount of real developmental work which has been carried out; this has largely been the result of want of sufficient capital to carry out the work required, particularly when such work did not promise an immediate return on the outlay incurred. Unfortunately the mine is hampered at the present time for the same reason. It may be of value, then, to notice some of the general considerations on which the future depends, and see how they are likely to affect the property.

The future depends on—

(1) The lodes: (*a*) value, (*b*) size, (*c*) permanency, (*d*) composition, (*e*) structural features.
(2) Mining and treatment facilities.
(3) Accessibility.
(4) Management.
(5) Price of tin.

These factors will be briefly considered under separate headings.

(1) *The Lodes.*—This is, of course, the essential governing factor, and may for convenience be considered under the various sub-headings mentioned above, all these aspects being important.

(*a*) Value.—The tin content of the lodes, considered apart from the actual market value of tin, is of little real use as a criterion: the latter will be considered under a separate heading. In estimating the tin content, two methods are useful, and one should always, where possible, supplement the other. These are the actual battery returns of ore treated, and assay values of samples taken systematically as work progresses. The battery returns from bulk parcels treated in the past have, I understand, been quite satisfactory. Actual returns from the operations of the old Cumberland Company are not available, but it is known that rich ore was treated. From the No. 2 Adit and Messrs. Fowler and Dunn's workings actual returns were between 5 and 6 per cent. tin oxide. The Whip Shaft workings produced about 330 tons of stone, from which the battery return was 1·1 per cent. From the Black Face workings over 700 tons of ore yielded about 1 per cent. metallic tin. It must be clearly borne in mind that these

figures represent actual battery returns, and that in all cases, owing to the unsuitable plant, losses in concentration were much heavier than would be the case with a modern plant under efficient management. The small amount of work done on the property has been noted, yet as a result of this work, over 200 tons of tin oxide have been produced since the commencement of operations. The writer did not systematically sample the mine. He did, however, take occasional samples at doubtful points, and at others had prospects washed to satisfy himself as to the actual tin content. As a result of this, with a study of results obtained during previous official examinations, the writer satisfied himself that, so far as tin values are concerned, the property is thoroughly genuine. Viewed as a whole, it is unlikely that the mine will maintain a continuous output of rich ore, but that rather it will prove (if worked on proper lines) a big low-grade proposition, keeping up for a long period an output which, if the market price of tin be not too low, should yield a satisfactory margin of profit over working expenses. Rich shoots of ore have been found in the past, and it is certain that prospecting will reveal others, but these will not prove the mainstay of the mine.

(*b*) Size.—This feature of the lode-formations is important, as rich tin veins might exist, which are not payable because of the narrow width. But on this property, the size of the lodes must be considered as very satisfactory, and values quoted are certainly over payable widths. It seems superfluous to again quote the actual sizes of the various formations which have already been described in detail, but there is no question as to the size of the lodes.

(*c*) Permanency.—This aspect is of the utmost importance in considering the probable future of the property. As has been indicated in the course of this report, most of the work carried out up to the present has been surface work. The deepest level driven (the Long Tunnel) has not been continued far enough to cut the lodes

exposed on the hill over 300 feet above, although shoots of rich tin ore have been cut in this tunnel and are undoubtedly continuing strongly underfoot. The veins cut in this tunnel are in no respect different from those exposed on the surface on other parts of the property. The 570-feet level also exposes a lode which can be traced on the surface for a considerable distance, and the tin contents at the greater depth have suffered no appreciable diminution. Although mining has not given much positive information as to the behaviour of the lodes at a depth below the present surface, indications are all favourable to the permanency of the lodes and of their contained tin values, to considerable depths. The main branch of Packer's Creek, which traverses the south-western portion of the property, has cut through a quartz-tourmaline lode which outcrops for a considerable distance on the surface. In the creek it is between 600 and 700 feet vertically below the highest point on the outcrop. The nature of the stone exposed here is exactly similar to that higher up: samples do not appear to have been assayed, but the tin value does not appear to be high, a fact which is no argument against the permanence of tin values to depth, as the tin is known to occur in shoots, and the point in question may be beyond the limits of a definite shoot. In the branch of Packer's Creek to the north of the property, too, a lode-formation is shown to be continuous for between 400 and 500 feet vertically.

In referring to the surface as it exists at the present time, it must be borne in mind that the actual surface at the time the lodes were formed was very different, and that a considerable thickness (hundreds if not thousands of feet) of overlying rocks have since been removed by the long-continued operation of weathering agencies. Thus rocks which were originally deep down below the crust are now at the surface. It should be remembered that the tin lodes have been formed at a certain distance from the heart of the granite mass whence they were derived. Ultimately, if a vein were followed

down the vein itself would disappear on reaching the rock which represents the now solidified acid heart of the magma, since this was molten up to the time when the vein-forming constituents were expelled, but solidified simultaneously with their expulsion. It is of the utmost importance to enquire, then, whether, in the long-continued period of denudation referred to, the heart of the granite mass has been so deeply dissected that only the roots of the tin deposits remain. If so, the tin values would be found to cut out at a comparatively shallow depth below the present surface. The writer is decidedly of opinion that such a state of affairs does *not* exist on the Federation property. A careful investigation failed to reveal any evidence for this excessively deep dissection, but rather pointed to the opposite fact. The texture of the granite is medium and often fine, but never very coarse. The width of the contact metamorphic zone indicates that the granite dips at a shallow angle under the surrounding sedimentaries: the line of contact is about a mile and a half distant, and a hypothetical restoration of the original granite surface points to the fact that the amount of denudation of the granite itself has not been excessive, and that the present surface is not very much below the original granite surface. The abundant quartz-tourmaline nodules seem to indicate crustal cooling rather than deep-seated cooling in the heart of the magma. The very abundant veins and dykes, and fissures cutting the granite, many of the latter filled with tourmaline, appear to the writer to indicate contraction cracks, which would rather be expected in earlier cooled and solidified crustal portions, although such cracks might continue to very considerable distances, and this criterion is therefore not insisted on. The fact that sometimes the nodules of quartz-tourmaline mentioned above, were noticed cut through by tourmaline-filled fissures, which are continuous for some distance in the surrounding granite, certainly proves that this granite, with the nodules, had solidified prior to the fissuring and

introduction of the tourmaline; this again indicates a crustal rather than a deep-seated habitat for the rock under consideration. If this evidence be accepted as bearing on the essentially crustal nature of the granite, the theory that excessive denudation may have removed all but the roots of the tin deposits, is at once put out of court. This means that there is sound reason for believing in the continuity of the tin shoots to a depth. What evidence is available from actual mining and from natural exposures owing to topography, points also to continuance of the lodes at least to several hundred feet below the present surface, and the deepest mining work carried out shows satisfactory tin values.

The writer is of opinion that the lodes and their contained tin values will be permanent within the limits of economic mining.

(*d*) Composition of the Lodes.—This aspect is of importance, for a lode may be carrying fair tin values, be of satisfactory size, and permanent to depth, and yet it is conceivable that the ore might be so complex as to prohibit economic treatment. Viewed from this standpoint, the lodes cannot be regarded in any but a favourable light. The mineralogical composition is generally simple, consisting in most cases where ore-bodies have been opened up, of quartz, tourmaline, and cassiterite. It must be understood, however, that this is not, in most cases at any rate, true primary ore. In the latter, pyrite will generally be found in more or less abundance. In the upper zones which have been subject to the effects of oxidising agencies, most or all of the pyrite originally present has been removed in solution, leaving the ore of the simple composition mentioned above. Should the ores carry pyrite at depth, they would offer no serious hindrances to successful metallurgical treatment by modern methods, although of course the cost of treatment would be increased. It is likely, however, with country so well drained as this appears to be, that large tonnages will be available for mining, which will be simple quartz-tourmaline-cassiterite ore.

With regard to impurities other than pyrite, it is possible that small amounts of other sulphides will be found in the primary ore, but not to any appreciable extent. Bismuth has been located in one shoot of ore with cassiterite (and in one shoot apparently without cassiterite), but does not appear to be present in any other shoots exposed on the property. Its presence in the shoots noted, however, is likely to prove of importance in the future working of the property, for there are indications that it occurs in payable quantities, and these indications are sufficiently encouraging to warrant further work and exploitation of these shoots as ores of bismuth. Only assays will show whether the tin occurs in sufficient quantities to be regarded as of economic importance in these shoots. Wolfram has been found, associated with tin, in a formation on a property adjoining the Federation Mine, but not *in situ* so far on the mine itself: an occurrence in alluvial, which may lead to a shoot of wolfram ore being discovered, has already been described in the course of this report: such has not yet been located.

A general reference may also be made to the nature of the tin in the ore: this matter has already been touched on in dealing with the different lodes. The tin varies a good deal in texture from point to point, and is sometimes extremely finely divided. Even this slime tin, however, should be saved by suitable concentrating appliances, especially if the product from the battery be properly classified before concentration be attempted.

Of gangue minerals, quartz and tourmaline are by far the most abundant: a little fluorite is present in ore from the Long Tunnel workings: muscovite mica is sometimes present, and pinite and kaolin from the Tributers' Workings. Hæmatite is also present in some of the oxidised ore exposed in the Western Workings.

Thus, so far as composition is concerned, there is no reason why the ore should not be successfully treated.

One point which has not been dealt with, is the secondary enrichment of the ore. Strictly

speaking, no actual enrichment takes place, but owing to the oxidation and removal of pyrite in the upper levels, the residual ore is lighter bulk for bulk than the primary sulphide ore, and so the actual assay value would be higher, the *actual* tin content remaining constant.

(*e*) Structural Features.—It may happen that a lode is so shattered by faulting due to earth movements since its formation, that its economic exploitation is impossible. On this property, however, such is not likely to be the case. Faulting does appear to have caused slight displacements of portions of one or two of the ore-bodies, but in many instances the outcrops can be traced on the surface continuously for long distances, showing that here, at any rate, there has been no lateral displacement. In other cases an outcrop can be traced for several chains, when it ends abruptly, and another parallel outcrop is traceable, a few feet on one side of the original. The same may happen with this second line. In such cases there is obviously simple faulting. Systematic prospecting work will render such of minor importance, and there is no evidence up to the present to indicate that economic working will be seriously hampered by any displacement of lodes by faulting.

The structure of most of the lodes is simple and they may be opened up and worked by ordinary methods. In the case of the pipes, however, it is not so. Until they have been followed for some distance and the general behaviour ascertained, it is impossible to lay out permanent works. The structure of the only pipe so far worked on the property has been previously described, and recommendations made for its future economic working.

On the whole, the structural features of the lodes are such as to favour economic working.

(2) *Mining and Treatment Facilities.*—The future of the property depends, not only on the lodes themselves, but to a less extent on the facilities which the property presents for economically mining and treating the ores. It is proposed in this section merely to deal in a general way with this aspect, as details have been given in previous sections.

(*a*) Mining.—The facilities offered for economically mining the ores are undoubtedly excellent. Large tonnages are available for working by open-cut methods, the advantages of which need scarcely be enlarged upon. It has been pointed out that there is a considerable quantity of detrital material lying about the surface forming deposits several feet in thickness in places, which carry excellent tin values, and are available for immediate battery treatment, without any mining whatever.

Even where underground mining becomes necessary, the property offers unusual advantages for cheap mining. The topography is such that prospecting and developmental work may be effectually carried out for a long time to come, from adits, and shaft-sinking will not be necessary in most cases. It is quite unlikely that heavy water will be met with in this class of country, so cut up by gorges, but even should it be troublesome in any particular locality, adits will obviate the necessity for pumping, unless, perhaps, it be necessary to temporarily raise water from winzes.

The advantages of working from adits in preference to shafts need not be enumerated in detail.

Mining timber may be cheaply obtained.

(*b*) Treatment.—Treatment facilities also are excellent. The configuration of the surface allows of economical transport of ore from mine to battery. There is also a splendid machinery site, from which there will be no trouble in disposing of tailings. The Cumberland Dam has been described. The facilities offered for the conservation of water at a considerable elevation, and the generation of cheap motive power, are almost unique, and treatment costs should be reduced to a minimum. Certain precautions are necessary to guard against a possible shortage of water in dry seasons, as previously noted. Thus the mine offers unusual facilities for economically mining and treating the ore.

(3) *Accessibility.*—The accessibility of the property, which affects the ease (or difficulty) with which stores and necessaries may be got in, and tin oxide taken out, will also have a bearing on the future of the mine. At the present time it is not very favourably situated in this respect. It is connected with Zeehan and the railway by a road about 14 miles in length. The pack-track over the south-western saddle of Mt. Agnew shortens this distance by about 3½ miles, but is not available at its best for heavy work, being steeply graded, and at the time of the writer's examination it was not available for horse traffic at all. Reference has previously been made to the main road. It is in bad condition, owing largely to neglect, rendering carting somewhat costly. The writer was informed that the maximum load which could be carried from the mine to Zeehan was 30 cwt. The mine will not be served by the present North Heemskirk tram, but the question arises as to the practicability of constructing a tram line into the mine in the future. This is scarcely to be recommended at the present time to serve this mine only, although it may be warranted by future developments. Other properties in the vicinity, however, are being prospected, and a tram would serve these, too.

The country is a good deal "broken" in the vicinity of the mine, and along the route, but the writer is firmly of opinion that a practicable route can be found. At the present time the 2-feet tram, constructed by the Government to the Comstock, extends to within about 7 miles of the property, and connection would be established with this tram rather than direct with Zeehan. The advantages of a tram connection are obvious, but caution must be exercised, as such a piece of work will require a considerable capital outlay. The past history of the Heemskirk field affords eloquent testimony to the inevitable result of spending available capital in surface works before underground works are far enough advanced to ensure that the mine itself is on a permanent footing. When development work has been carried on far enough to enable the owners to form definite estimates of tonnage of ore available for extraction and its value, the owners will be in a position to consider seriously the question of a tram.

(4) *Management.*—The factor of management will have an important bearing on the future of the property. Many a mine with distinct natural advantages has been

ruined by inefficient management. The mine is in such a state at the present time that the planning and carrying out of development and mining operations in the near future in an efficient manner will mean much to it. A few suggestions have been offered in the course of this report, which may serve as a slight guide in opening up the property, but naturally the scope of such a report is limited, and the planning and control of operations must devolve on a manager appointed by the owners. While no amount of careful management can transform a worthless property into a paying one, the greatest care is necessary in the selection of a suitable manager to direct operations on a property with such splendid possibilities as the Federation Mine undoubtedly possesses.

The question of efficient management applies equally to treatment, as well as mining operations, with finely-divided tin oxide, even with an up-to-date treatment plant, the margin between profit and loss may depend upon the supervision exercised on the running of the plant, and where big tonnages are being treated, as is likely to be the case here, the question becomes of great importance.

Examples of the result of inefficient management are not wanting in connection with the past history of the South Heemskirk District, hence the reason for calling attention to this factor, so important in the development of any mine.

(5) *Price of Tin.*—To some extent the future of the property must depend upon the price of tin. Reference has been made in the course of this report to the fluctuation of prices in the past, and the effect of this fluctuation on the past history of the mine. A table has also been included showing the variations in prices for many years past.

The writer is not in a position to predict with any degree of accuracy what is likely to happen in the future. To show what connection the price of tin will have on the future profitable working of the mine, it is of interest to note that assuming 1 per cent. ore, and a basis of 80 per cent. extraction, the average 1913 price (£206) would give the ore a value of 33s. per ton. If the price went back to £135 (the average for 1909) the same ore would be worth 21s. 7d. per ton.

A further discussion of this factor seems unnecessary here. The price of tin is beyond the control of any conditions which affect this property in particular. The fact

that this property has been worked at a profit in the past with tin at a very low figure is encouraging. It is to be hoped that in the future the metal will remain at a sufficiently high figure to ensure at least a reasonable margin of profit to those concerned in the development of the mine.

Conclusion.—Although the Federation Mine at the present time can scarcely be called a well-developed and thoroughly equipped mine, it is one which offers some distinct inducements to the investor. For the small amount of development work done, about 200 tons of tin oxide have been sent away. Several distinct tin-bearing lodes have been partially opened up. A large tonnage of ore is available for immediate extraction by open-cut methods. A large amount of backs can be rendered available for extraction by stoping, by adits of moderate length. There is a considerable quantity of detrital material lying about the surface, which is estimated to carry highly payable values. The writer considers that the tin values are likely to be permanent in depth, that there is no reason for believing that the ore will become more complex at depth (excepting that pyrite will be present in at least some of the lodes), and that structural features are not likely to hinder economic working.

There are exceptionally fine facilities for economically mining and treating the ore.

Although rich ore has been won in the past, it appears more likely that the mine will become, on further development, a big low-grade proposition, rather than a small producer of rich ore.

Progress has been hampered in the past, and the mine is at a standstill at the present time, largely for lack of capital to carry out the necessary developmental work. One of the chief reasons why the necessary capital has not been forthcoming, appears to have been that the property happens to be situated in a mining field which was boomed some years ago. In the boom time large amounts of money were subscribed, and wasted mainly in unwarranted and unsuitable surface works. Very little genuine mining work was carried out, and the inevitable crash came. Public confidence was severely shaken, and the few genuine properties have felt the effects ever since.

The time is not far distant when confidence in the Heemskirk tinfield will be restored, and the Federation Mine is one of the properties which certainly deserves further development. If developments continue to be

satisfactory—and the writer believes they will—the necessary remodelling of surface plant can be confidently undertaken, and the future of the property should be assured.

(2)—*Allison's Workings (near Federation Mine) and Vicinity.*

About 20 chains north of the old Prince George (R. Clarke's) Mine, and about the same distance south-east of the south-eastern corner of the Federation lease 3917M, is a shaft on a formation which deserves mention. The shaft is on the summit of a ridge on the coastal peneplain, and a few chains north of the Trial Harbour-Corinna Road. In the district the shaft goes by the name of "Allison's Shaft," after the man responsible for the work.

The shaft is 24 feet 6 inches deep. From the bottom is a drive of 8 feet south-east on the formation, which strikes N. 35° E., and dips south-east at a steep angle. The width of the formation is 10 feet. The country rock is white granite of fine to medium texture, carrying nodules of quartz-tourmaline, and is decomposed where exposed in the shaft. The ore occurs really as a lode-formation, and not as a simple vein. A zone of granite has been mineralised by solutions introduced through several small fissures. There are irregular veins and masses of quartz and tourmaline in a limonite-stained quartzose groundmass, merging on either side into decomposed granite. Several soft bands of kaolin were noticed. Some of the veins are nearly horizontal, and others very irregular, forming large nodular masses at intervals. Some of the stone carries abundant green tourmaline, and a little of the black variety, and looks very favourable for tin, while at times the white quartz shows no tourmaline at all. The whole formation is traversed by narrow vertical veins of tourmaline. The limonite indicates that pyrite may be expected at depth. Some rich tin ore is said to have been won from this shaft, but very little work has been done to prove the continuation of the shoot of ore. The lode-formation can be traced for about 4 chains north from the shaft.

About 30 feet distant is a trench exposing 5 feet of banded ore, similar in general appearance to that in the shaft, consisting of veins of quartz-tourmaline stone and of white quartz.

About 3 chains south of the shaft, some alluvial tin was won from the bed of a small creek. These workings are known as Allison's alluvial workings. The material is detrital, derived from outcrops in the vicinity, and although shallow, the patch worked yielded some good tin ore.

In the granite bottom exposed by the working of this patch of wash is a pyritic tourmaline vein, striking N. 58° E., along the strike of which the creek flows. There is a central vein of tourmaline from 1 to 2 inches in width, with pyritic material on either side, with parallel veinlets of tourmaline, this pyritic material merging into granite. The vein was not tested for tin.

A few chains north of Allison's Shaft, and 1 chain west of the foot track to the Montagu Mine, is a shaft sunk to 9 feet, on the summit of a spur, on a lode-formation which only outcrops for about 2 chains on the surface. The strike is N. 77° W., and dip about vertical, the width being about 3 feet. The walls are well defined, the country-rock consisting of decomposed fine-grained granite. There are two parallel veins of tourmaline about $\frac{1}{8}$-inch in the centre of the formation, with quartz and fairly large crystals of black tourmaline, in addition to aggregates of the green variety, on either side of the central veins. The formation is promising.

About $1\frac{1}{2}$ chains west of this shaft a trench and shaft on the line of strike expose several narrow parallel veins. From about 10 feet in depth is a small drive a few feet south, but the main formation does not appear to have been cut. White mica is seen in some of the surface stone at this point.

On the slope below these old workings, several "nuggets" of cassiterite, weighing up to 3 oz., were picked up on the surface by the writer. The mineral is jet black, and is very pure, showing no attached gangue, consisting of an aggregate of short prismatic crystals It is not certain that these nuggets were derived from the outcrop noted above, although it seems most probable they have been.

(3)—*Section* 3276M *(2 Acres), R. Clarke. (The Old Prince George Mine.)*

This section, comprising 2 acres. is being held and worked by Mr. Richard Clarke, who has also a water-right, 1452w. for five sluice-heads on Packer's Creek. The mine is situated about $\frac{1}{2}$-mile south-west of the Federation south-

west corner, the Trial Harbour-Corinna Road passing through the north-western corner of the section. The western boundary touches Packer's Creek a few chains below the junction of two main branches, the southern one draining the western portion of the Federation lease, and the northern branch a good deal of country to the north-west of the Federation Mine.

The workings and plant are by the roadside, about $13\frac{1}{2}$ miles from Zeehan. The state of the road has been commented upon elsewhere, and the cost of getting supplies out and of carting tin oxide into Zeehan are not light.

The section includes part of the property known as the old Prince George Mine, worked by the Great Western Company in the early history of the field. In fact, it has been stated that tin was first found in the district on this property.[213]

Very little work appears to have been carried out by the old company, but the present owner has proved payable tin to exist.

On the roadside descending into Packer's Creek is an old shaft sunk to a depth of about 40 feet by the old company. The formation is said to be tin-bearing at this point.

The main work has been carried out on a quartz-tourmaline-cassiterite vein, which strikes N. 63° W. Packer's Creek here flows about south-west, and has consequently cut through the vein, which outcrops on both banks, and has been prospected to some extent on either slope. The main work was being carried out on the south-eastern side of the creek, where the vein averages 2 feet 6 inches in width. An open-cut was being taken into the hillside at the time of the writer's visit, along the course of the vein, and had extended for a length of 50 feet. Payable stone had been encountered for this length and continued in the face.

From a little above creek level, a lower adit was driven in on the course of the vein, on a bearing of S. 63° 30′ E., for a distance of 131 feet. The width at the mouth of the adit is 2 feet 6 inches, and along the course of the drive it varies somewhat from point to point, as is to be expected with a vein of this class. In the face mica makes its appearance, giving the vein-rock the character of a

[213] "The Wild West of Tasmania," by Wilberton Tilley (Evershed Bros., Publishers, Zeehan), 1891, p. 9.

greisen, which merges into normal white granite. At 75 feet from the entrance is a vein junctioning with the main vein on the north side of the drive. It is worth prospecting for a few feet to determine its nature. At 105 feet 6 inches from the entrance, a winze has been sunk to a depth of 38 feet on the vein. This was inaccessible at the time of the writer's visit, but is said to be on tinstone.

The structure of the ore-body is typically that of the quartz-tourmaline-cassiterite vein. There is a central seam of very rich ore, with sometimes 2 inches of massive cassiterite, but with usually some tourmaline (either green or black, or in some cases both varieties), and at times a little quartz, although the latter mineral does not appear to be abundant. This central vein (or vein-stone) is bounded on either side by vein-rock composed of quartz and tourmaline. Quartz predominates in this stone, and black tourmaline becomes more common than green. This vein-rock carries cassiterite, but in smaller quantities than the vein-stone. The cassiterite is massive to granular, and usually dark-brown in colour.

About 3 chains south of these workings is a shaft about 15 feet deep on another outcrop of promising-looking stone. The outcrop is traceable for some chains on the surface, and is worth prospecting. Tin oxide shows freely in some of the surface stone, which consists of crystalline masses of quartz with a little green tourmaline. The cross-lode strikes N. 18° W., and is of considerable width. The width is not fully exposed. Prospecting is particularly to be recommended at the point where this lode junctions with the main one being worked. Its very quartzose nature indicates that it is an intermediate variety between the quartz-tourmaline-cassiterite and the quartz-quartzose types described. The formation warrants prospecting. The outcrop crosses the road, and it is probable that the specimens said to have been kicked up by pack-horses, leading to the discovery of the first tin (according to the authority quoted above), may have been derived from this outcrop.

The ore is treated by a small plant in the bed of Packer's Creek. A battery of 3 heads is driven direct from a water-wheel 11 feet in diameter, the water being brought from Packer's Creek by a race about 3 chains in length, having its intake just below the road crossing. Thus, variations in the supply of water available directly

affect the crushing capacity. The crushed ore from the mortar-box passed into a well, into which additional water was introduced by two vertical pipes leading to the bottom of the well, causing a constant "boiling" effect. The tailings passed through a sluice-box, in which the cassiterite was concentrated in the usual way. It is questionable whether losses were not heavier than they should have been under this system, owing to the sliming of a certain proportion of the tin oxide, and the angular nature of the crushed mineral. A Wilfley table was afterwards installed, and is said to have given great satisfaction. The vein being worked was very rich, and the returns from crushing undoubtedly good. Under such conditions extreme care should be taken to reduce tailings losses to a minimum, and to aim always at a high *percentage* recovery from the ore treated. In this instance, the writer had no evidence to show that a high extraction was not being obtained.

The property is certainly a sound one, and one which, with careful management, should yield profits to a small working party for some time to come, provided the price of tin does not fall too low. The length of the shoot of ore being worked had not been proved at the time of the writer's inspection. It must be expected that it will be limited, but prospecting along the line of strike may reasonably be expected to locate other shoots. It is advisable, as far as possible, to keep ahead of the actual workings with prospecting work. No forecast can be attempted as to the depth to which the ore-shoot may be expected to continue. From a study of the ore-deposits of the district, however, and the factors governing their distribution, the writer is of opinion that shoots of tin ore may be expected at considerable depths below the present surface. As has happened in other properties on the field, the present shoot may cut out at no very great depth, but prospecting should be undertaken at greater depths. Such work will necessarily have a certain element of speculation and uncertainty, as, for instance, with regard to the depth at which the next shoot will be cut, its extent, value, &c.; but indications are sufficient to warrant a limited expenditure on such operations.

The backs available from the lower adit are limited, and arrangements will have to be made in the near future for working from a main shaft. This will, of necessity, increase working costs, and only future prospecting can determine how far such work should be carried.

Surface prospecting and sampling of the cross-lode is also recommended, and if surface prospects warrant it, a prospecting shaft should be sunk to obtain further information as to the nature and value of the formation at depth.

On the north-western bank of Packer's Creek, but apparently a short distance outside the western boundary of the section just described, and in the south-eastern part of Section 1650M, 20 acres, an adit has been driven for 41 feet on a bearing N. 62° W. Although the outcrop is not traceable continuously on the surface, it is probable that the formation exposed is, in reality, a continuation of that on which work has been done on the opposite bank of the creek. The adit was driven for 10 feet on the course of a narrow quartz-tourmaline veinlet; granite appears in the roof. At 10 feet the vein widens, and has been driven on for another 31 feet. In the face is a promising vein 3 feet in width, containing quartz, tourmaline, and white mica, apparently an intermediate type between the quartz-tourmaline-cassiterite and the greisen vein-types. The white biotite granite shows tourmaline in places.

The vein is very likely to carry shoots of ore, and is worth prospecting on the surface further up the hill to the north-west, and sampling where exposed, to determine the distribution of the cassiterite.

(4)—*Section* 6660M, 20 *Acres. E. Mulcahy and M. Bullen. (Old Montagu Mine.)*

This section was previously numbered 1362-91M, and is now charted as above, in the names of E. Mulcahy and M. Bullen. It comprises the heart of the property formerly known as the Montagu Mine, and includes all the important workings of the old Montagu Tin Mining Company. On this account the property is still known locally as the Montagu Mine.

The Montagu Mine was one of the earliest worked on the field, and the company did important work in conjunction with the old Cumberland Tin Mining Company (whose property is now incorporated in the Federation Mine) in constructing the Cumberland Dam. From this reservoir water was drawn by both companies for power and dressing, but the company's old pipe-line has long since disappeared. In the early history of the property an

expensive plant was erected by the Montagu Company, which is thus described by Mr. Thureau, in his report of 1884 ([214]):—

"A branch of pipes from the main supplies a smaller service reservoir constructed about 200 feet below the former. From the bottom of a "clearing" tank filled from the smaller reservoir, another string of pipes has been laid (partly on the surface and partly on trestles), tapering from 9 to 5 inches in diameter giving a head of water of 560 feet vertical, thus conveying at present the largest and most powerful available water-pressure for motive-power in Tasmania. The lower 5-inch wrought-iron pipes connect direct with one of Leffel's (American) vertical turbines, 4 feet 6 inches in diameter at the outer rim, and 3 feet diameter for the working part. By means of a pulley and gear, an endless Manila rope, working in five-grooved pulleys, instead of a belt, works the main gearing, 60 feet distant. The present plant, which, with the almost unlimited water-power secured by this company can be considerably added to, consists of 15 heads of stampers (with provision for five more), six classifiers, twelve of Sterry Hunt's (American) double-acting jiggers, two rotating and two slime tables ditto, or buddles (cemented bottoms), sizing boxes, labyrinth ditto, gyrating tubs and strakes, and other fixed ore-dressing appliances."

This description is interesting for comparison with a modern tin-dressing plant. The cost of bringing this machinery on to the property (*via* Trial Harbour), and erecting it, must have been very considerable. The machinery has all been removed, but the excavation for a battery-site on the creek bank, and the building of a substantial retaining-wall for about 200 feet in length, to a height of about 15 feet above the creek, the concrete battery floor, and battery frame of sawn pine (12 by 10, and 13 by 8 inches, still standing) all indicate that a large amount of money has been spent. On good authority, the writer was informed that £30,000 was spent by the old Montagu Company. Unfortunately, the bulk of this money was spent in machinery and surface operations generally, and the proportion allotted to genuine development of the known tin lodes must have been very small. It seems that the battery treated quite an insignificant amount of stone before funds were exhausted, and the

([214]) "Report on the Western Mining Districts," by G. Thureau, June, 1884, p. 6.

mine closed down and it does not appear ever to have been re-opened. At the time of his examination of the property in 1902, Mr. Waller was unable to inspect any of the workings, and had to rely essentially on information supplied by gentlemen who were conversant with the mine in its early history. The writer was similarly situated, and as no work beyond a little surface fossicking had been carried out since Mr. Waller's visit, and as the present writer had to draw on the same sources of information as those which were available to Mr. Waller, the two reports must necessarily correspond.

The 20-acre section, 6660-M, now held by E. Mulcahy and M. Bullen, is situated on the coastal peneplain, at the foot of the Heemskirk Range, about ¾-mile south of the Federation Mine. It is about ½-mile north of the Trial Harbour-Corinna Road, with which it is connected by a branch road. The western portion of the section is traversed by a creek flowing about south-west, known as the Montagu Creek, which has cut through one of the main tin-bearing formations, and which has itself been worked for alluvial tin.

There appear to be two main lode-formations on the property, both stanniferous and belonging to the pinitoid vein-type, although merging in places into greisen veins. At the intersection of the two formations, rich tin occurred.

What is known as the main lode has an average strike of about N. 75° E. Values taken at different points exposed varied from N. 74° E. to N. 84° E. It is on this formation that most of the work has been carried out, and it appears to have carried rich tin in places. The width varies a good deal, and in places appears to be as much as 12 feet. It consists of several parallel veins of the pinitoid vein-type, varying from 3 inches to about 4 feet in width, showing a central vein of tourmaline (usually black) quartz and cassiterite, with quartz, tourmaline, and micaceous aggregates (pinite) in the adjoining vein-rock. The central seam (vein-stone) may be as much as 9 inches in width, as for instance where it is exposed in the bed of the Montagu Creek.

The formation has been prospected at intervals for several chains, although little real work has been done on it. This work will be referred to later.

The second lode-formation, and that on which most of the company's work was carried out, is known as the cross-lode. It strikes N. 5° E., and has been traced on the

surface for about 4 chains. It also is of the pinitoid vein-type, and appears to vary in width from 1 to 4 feet. It outcrops for some distance in the bed of the Montagu Creek, where it intersects the main lode. Unfortunately, the intersection is not available for inspection, as the ore has all been worked out, and no statement can be made as to the relative ages of the two intersecting vein systems. It seems clear, however, that rich ore occurred at this intersection, and that no appreciable displacement took place. The cross-lode carried rich tin in places along the line of outcrop, and after surface prospecting, it was decided to test the formation at the point of intersection with the main lode, almost in the bed of the Montagu Creek. Accordingly, a prospecting shaft was sunk by the old Montagu Company on a shoot of rich tin ore at this point, but the shoot of ore appears to have cut out at no great depth. A main shaft was then sunk from the creek bank, a short distance to the south of the old prospecting shaft. This shaft is now full of water, but is seen to be lined with sawn timber, and to have been a three-compartment shaft. Hoisting is said to have been carried on by means of a whim, and pumping by means of an 8-inch draw lift-pump, operated by a Pelton wheel. This pump is said to have been able to cope with the water without any trouble. This shaft was sunk vertically through fine-grained white nodular tourmaline granite to a depth of 118 feet, and at 100 feet from the surface a level was driven a little to the north of west, to intersect the cross lode, and this was done with about 50 feet of driving. The cross lode was cut some distance to the south of the prospecting shaft, and at this point is said to have been about 2 feet in width, but to have carried only low tin values. The vein here appears to have carried a little pyrite, but reports on this point are conflicting. The level was not continued to cut the main lode, but a drive was extended along the course of the cross lode to its intersection with the main lode, when a rise was carried through to the surface. The main lode at this point is said to have been from 12 to 15 feet in width, and to have carried a little pyrite. A drive was extended east for about 15 feet on the main lode, and although the ore is said to have been very promising in appearance at this point, work was stopped. No driving was done along the course of the lode-formation to the west. Surface prospects show that this formation does carry good shoots of tin ore, and it is to be regretted that more driving was not done on the 100-feet level.

The cross-lode is said to have carried excellent tin values at the intersection with the main lode, although the latter was very low grade. At the intersection a rise was put up to connect with the prospect shaft from the surface, and although the tin ore appeared to have cut out in the bottom of the shaft, the rise disclosed rich ore below, evidently another shoot. The width of the cross-lode at the intersection is said to have been 3 feet 6 inches at the 100-feet level, and to have carried an average of 3 inches of solid tin oxide north of the junction. Mr. Bullen states that at the junction the richest ore was in the form of the letter L, carrying about 10 inches of massive cassiterite, and extending for a length of about 10 feet along each leg. This ore is said to have merged into massive tourmaline with cassiterite. The rich shoots of ore are said to have been stoped for a length of 36 feet, the width of the formation varying from 1 to 4 feet. The old stopes were worked to within a few feet of the surface, and the remaining ore in the back of the stopes was afterwards underhand stoped from the surface. The richest ore was bagged, the seconds crushed and concentrated. There is still a good deal of ore scattered about the surface, too poor in tin to pay for hand treatment, but showing a good deal of cassiterite. This gives a good idea of the class of ore, which consists essentially of radiating aggregates of green tourmaline in a quartzose groundmass, with scattered crystals and aggregates of crystals of pale resinous brown cassiterite. The amount of quartz present varies considerably, this mineral being sometimes almost entirely absent. Small geodes lined with small prismatic crystals of quartz are noticeable in some specimens. Small crystals of transparent green fluorite were noticed lining a vugh in one specimen. This stone indicates that the formation belongs to the quartz-tourmaline-cassiterite vein-type.

Apart from this main group of workings little has been done to really prove the value of the property, although prospecting work has shown that tin values exist at different points. Most of this work has been to the south-east of the main shaft, as described below.

In the creek near the prospecting shaft referred to above a narrow vein sunk on for 5 feet is said to have yielded seven bags of tin oxide. At the head of the workings in the creek, about 2 chains north of the old prospecting shaft, is a pyritic vein cutting across the creek-bed, 18 inches in width, strike N. 58° E. This vein looks promising for tin and is said to carry good values. About 10 feet to the south-

west is another parallel vein apparently of the pinitoid vein-type.

On the western side of the creek a shaft was sunk on the hillside on the main lode to a depth of perhaps 15 feet. This shaft is now inaccessible, but the tin values are said to be very low at this point: no further work has been done to the west, although a lode-formation consisting of green tourmaline, a little quartz, and good tin values, has recently been exposed by some alluvial workings in a creek-bed about 10 chains further west. This may be the same line of lode, but more work is required to definitely settle the point: the strike here appears to be N. 61° E.

East of the prospecting shaft, the main lode has been underhand stoped from the surface for about a chain along the line of strike, to a depth of about 10 feet, only the richest ore being extracted: this ore was treated by hand, and is said to have yielded 4 tons of tin oxide. It is clear that there are shoots of rich ore in this formation.

Further east some trenching has been done over a length of about 3 chains, the width of the vein being about 2 feet 6 inches. The stone here looks promising, carrying green tourmaline, quartz, and white mica, in addition to sheaves of black tourmaline. It is a good deal stained with limonite in places, and there can be little doubt but that the primary ore will be found to be pyritic. The strike at this point is N. 75° E.

About 1½ chain up the hill to the east, is a shallow shaft on a stanniferous vein which appears to be about parallel to the main lode. This vein is from 12 to 18 inches in width. The vein-stone is from 3 to 5 inches in width, and consists of dense aggregates of radiating green tourmaline. This central vein is bordered by ½ to 1 inch of bluish-black tourmaline, outside of which is a band on either side varying in width from 3 to 6 inches, consisting of hard quartz and black tourmaline. This quartz-tourmaline vein is said to carry good tin somewhat lower down the hillslope: an old shaft here is completely overgrown with dense scrub.

A short distance higher up the hillslope to the south-east is a prospecting shaft, depth 8 feet, on the main lode, which is here 18 inches in width. The stone is promising quartz-tourmaline rock with limonite, which again suggests the presence of pyrite in the primary ore. This stone is said to carry between 5 and 6 per cent. tin.

About one-half chain further up the hill, and one-half chain north-west of the old Montagu Road, on the crest of

the ridge, is a shaft sunk to about 40 feet on a quartz-tourmaline vein 18 inches wide. This is probably on a parallel vein, and not on the main lode.

On the summit of the ridge a patch of rich detrital ore was discovered and worked. The cassiterite in this stone was very black. Prospecting revealed a rich tin vein, on which a shaft was sunk to about 25 feet. The vein was about 2 inches wide at the surface, the width increasing to nearly 3 feet at the bottom of the shaft. This stone is said to assay 2 per cent. tin. The presence of gossan (limonite) in this stone indicates that pyrite may be expected at depth. This is probably on the main lode.

A short distance to the north of this is another shaft, sunk by the old Montagu Company, and said to be on good tin: this shaft has some water in the bottom, but its depth is probably less than 20 feet.

Thus it will be seen that although the prospecting work carried out on this main lode has met with encouraging results at certain points, nothing has been done to open up the ore-body.

Reference has already been made to the underground work carried out on the cross-lode (striking nearly north and south) and to the surface work at the intersection with the main lode, in the creek-bed. Very little has been done on this line of lode to the south of the intersection, and the formation has not been traced beyond a bend in the creek to the south-west of the prospecting shaft, in spite of the encouraging features where work was carried out. The cassiterite in this stone was usually reddish, the ore itself carrying abundant black tourmaline, while green tourmaline was the more abundant in the main lode.

In addition to the work described above, which has been carried out on the lode-formations on the property, some alluvial ground has been worked with good results. It was found by the old Montagu Company that in the bed of the creek traversing the section, now known as the Montagu Creek, was a deposit of alluvial and detrital material which carried good tin values. A narrow strip along the creek-bed was worked for a few chains: it is reported that the wash consisted of 4 feet of overburden and 2 feet of stanniferous material, and that from this small patch 5 tons of stream tin were won by the company. The tin oxide was both free and in quartz-tourmaline vein-stone: much of the cassiterite is said to have been grey in colour. Much of the tin oxide won from the creek must have been derived from lode-formations on the hillside which have

not yet been located. The creek was found to carry tin beyond the boundaries of this section, and has been worked for most of its course between this property and the sea-coast. Since the old company ceased work on the property small patches of alluvial material have been worked, and it is doubtful whether any of the remaining patches will pay for treatment: the resources of the property are practically exhausted so far as secondary tin ores are concerned.

Reviewing the position with regard to this property, and its prospects for the future, one is forced to the conclusion that although a great deal of money has been spent in the past, the outlay has not been to best advantage, and that although it has some very promising features, the mine has never had a fair trial. The two main tin veins both carry rich ore in places, but the small amount of work carried out indicates that the rich ore occurs in shoots of small extent, both horizontally and vertically, although this can scarccely be regarded as more than an indication. If this indication be accepted, then it is clear that the value of the property as a commercial proposition will depend mainly on the richness of these shoots, and the frequency with which they occur. The shoots located up to the present have certainly been rich, and the fact that two were located so close together in the underground work carried out is certainly promising. There is no sound geological reason for believing that shoots of tin ore will not be found to occur at considerable depths: this aspect has been discussed at some length in another part of this report, and the writer is of opinion that shoots of ore may be expected within the limits of economic mining.

Surface indications point clearly to the fact that some pyrite may be expected to make its appearance as depth is attained. Although a drawback, the presence of this mineral is not an insuperable difficulty in the question of treatment at the present time. It is not improbable that some shoots may be almost free from sulphides.

The nature of the cassiterite occurring in the specimens of ore lying about the surface, indicates that much of the mineral is fairly coarse-grained, and should be comparatively easy to save with modern appliances.

It is of importance to note that the surface prospecting work carried out has shown not only that the main lode carries tin values away from the intersection with the cross-lode (the only point where any underground work has been carried out), but has shown that at least one parallel vein exists which also carries fair values at certain points near

the surface. Any plan of underground work for the future should embrace systematic developmental work and prospecting not only of known formations but of the adjacent country-rock for parallel lodes: it is not improbable that other shoots of ore may be thus located.

With regard to facilities for working, although an adit might be driven on the main lode either east or west from the creek if surface values warranted it, it is questionable whether such work will be justified, as the amount of backs available is small. The main work will have to be carried out from a shaft, and probably the site of the old main shaft would be suitable. This work will of necessity be more expensive than working from adits, but the nature of the country will render sinking unavoidable. Water will be encountered in the position of the old main shaft, but is not likely to be sufficiently abundant to cause serious trouble. It is reported that an 8-inch draw-lift pump was used by the old Montagu Company to sink to 118 feet, and that it was difficult to keep the pump working slowly enough to cope with the water met to this depth.

It must be borne in mind that at the time this mine was worked, the price of tin was very low, and this factor doubtless influenced the policy of the management, and hastened the shutting down of the mine.

When planning work for the future the lessons of past failure should be taken to heart, and the mine itself given a fair trial before too much money is spent on surface works, which can be carried out when underground development shows that they are justified.

Although no very definite opinion can be given, on account of the present unsatisfactory state of workings, from his examination of the property the writer is of opinion that the mine is worthy of a further trial.

Much of the above information concerning old workings was supplied by Mr. M. Bullen, to whom the writer would tender thanks.

(5)—*Old Montagu Extended Mine.*

About one-half mile to the west of the old Montagu Mine is a shaft sunk on the button-grass country forming the coastal peneplain. It is about one-quarter mile west of the main road, and is probably in the eastern portion of Section 1158, 40 acres. No very definite information could be obtained concerning this shaft, but it is believed to have

been sunk by the old Montagu Extended Tin Mining Company, in the early history of the field. The shaft is full of water, and its depth is not known, but it would appear from the dump-heap to be about 20 feet.

The ore on the dump-heap shows that a promising vein has been located. It consists of quartz-tourmaline, of a rather different nature to the normal quartz-tourmaline veins of the district. The groundmass is of crystalline quartz with varying amounts of tourmaline. The latter mineral occurs in fine needles and aggregates of needles, sometimes projecting into small geodes: it is of the black variety. Geodes several inches in diameter are not uncommon, lined with prismatic crystals of quartz, which themselves are frequently completely encrusted with very minute prisms of greenish-black tourmaline. Specimens are not uncommon showing aggregates of interlacing needles of tourmaline, without any visible quartz. Chalcopyrite shows rather freely in some specimens, and several pieces of chalcopyrite with aggregates of black cassiterite crystals of small size were noticed.

No information can be given as to the size of the vein, which would appear to belong to the quartz-tourmaline-cassiterite type.

A grab sample was taken from the dump-heap and submitted to the Government Assayer, Mr. W. D. Reid, for analysis. Mr. Reid reported—

Tin	0·93 per cent.

Qualitative tests showed the presence of copper, antimony, and bismuth, these metals being present in small amount only, but actual amounts were not determined. The ore was tested for wolfram, which was not present in the sample submitted.

As noted elsewhere, small quantities of sulphides of the various metals occur in tin veins of this type, and although they were not observed in the ore, it is almost certain that antimony and bismuth are present as sulphides (stibnite and bismuthinite respectively). As noted above, a little chalcopyrite was visible in the ore.

An old trench about 4 chains south of the shaft does not yield any definite information.

A definite opinion can scarcely be expected in view of the small amount of information available as to the prospects of the property. As all work would have to be carried out from a shaft, there is scarcely sufficient inducement to recommence work in view of the value of the ore.

(6)—*Section* 5093M, 80 *Acres (Old Empress Victoria Mine).*

The section is vacant, but comprises the workings of the old Empress Victoria Company. At the time of Mr. Thureau's examination (1884) the main workings were full of water, this gentleman remarking that " operations had ceased for some time previously." As nothing has since been done, little can be said about the workings at the present time, the shaft being full of water to the adit level, 53 feet from the surface.

The section is situated on the coastal peneplain, to the south-west of the old Montagu Mine, and about midway between that property and the coast. The Trial Harbour-Corinna Road passes within about 2 chains of the north-western corner of the section, and was connected with the workings by a branch track.

The shaft was sunk on a quartzose outcrop carrying rich tin, on a ridge overlooking the Montagu Creek, the bed of which has been worked for alluvial tin.

Mr. Thureau, in his report, stated:—([215])

" This company has erected the only steam winding and pumping plant on the West Coast, being supplied with steam from a Cornish flue boiler—multitubular—for a horizontal 12-inch cylinder engine driving a double winding gear and pumping gear with 7-inch lifts. The shaft has been sunk to a depth of 111 feet, and has been opened out at the 105-feet level. Water stood at the time of my visit at the 53-feet or adit level, operations having ceased for some time previously. I was informed by the mining manager left in charge that the last tin ore beneath their rich surface outcrop had been met with at a depth of only 27 feet in their main shaft, and that from this point the ' lode ' had been followed vertically without meeting any more ore. It would thus be seen that ore occurred from the surface down to 27 feet; none from there to the adit level (53 feet); and none to and at the bottom level (105 feet). . . . . The lode below the 27-feet level is described as nearly vertical, with an underlay of 1 in 3, and levels had been driven on its east-by-west course for a total length of 160 feet at 105 feet from the surface. In these levels at 36 feet ' in ' from the shaft, the supposed lode was found to be of the same size, measuring from the hanging-wall, as at the adit or 53-feet level, and that in the soft country to the north the anticipated junction with the north-and-south lode had not been met with." Mr. Thureau then advises prospecting at the 30-feet level, suggesting that as the nature of the ore below the 27-feet level is different from that which was tin-bearing near the surface, a fault may have displaced the true tin-bearing lode. Apparently this advice was not acted upon.

([215]) " Western Mining Districts," by G. Thureau, 1884, p. 10.

The machinery has long since been removed, and no opinion can be formed of the property in its present dilapidated state. The shaft is lined with sawn timber, and is divided into three compartments. Aneroid readings at the collar of the shaft indicate that it is about 500 feet above sea-level. Ore on the heap at the collar of the shaft indicates that the formation belongs to the griesen vein-type. Aggregates of white mica and coarse sheaves of black tourmaline, up to 3 inches in length, are scattered through a quartzose groundmass, through which is scattered a little pyrite. A little green tourmaline is sometimes present. The ore is traversed by irregular fissures at times, filled with black tourmaline. The stone does not look very promising for good tin values. The shaft has been sunk apparently at the junction of two lode-formations, the main one striking north and south, and outcropping for about one-half mile down the course of the Montagu Creek. West of the shaft is another quartz-tourmaline outcrop, visible for a short distance only, striking N. 60° E., which should junction with the main lode at the shaft, if continuous. The country-rock in the immediate locality is medium-grained " white " granite with quartz-tourmaline nodules in places, but this junctions a few chains south of the shaft, where a branch creek joins the Montagu Creek, with coarse-grained " pink " granite, which continues to the coast. It is of particular interest to note that the main lode continues without any apparent interruption from the white into the pink granite. The latter rock here carries veins of aplite, as illustrated in Photo. No. 9, which was taken in the Montagu Creek just below its junction with the branch creek referred to above.

About 100 feet north-west of the main shaft is a prospecting shaft about 20 feet deep and a shallow adit. There is some rather favourable-looking green tourmaline vein-stone on the dump-heap.

About 4 chains south of the main shaft is an old trench cut to a depth of about 12 feet across the ore-body: about 9 feet of stone has been exposed, but it is not certain whether this is the full width, as the trench is very much overgrown and partly filled with rubbish.

On the western bank of the creek, in a direction S. 52° W. from the main shaft, and distant about 4 chains from it, an adit was driven into the hill in a north-westerly direction, apparently to try and intersect a quartzose outcrop exposed on the hill above. An attempt was made by the writer to explore this adit, but the entrance was much overgrown and the air bad. The adit appears to have been driven for about 300 feet in a north-westerly direction through white granite with occasional quartz-tourmaline nodules, but without intersecting the formation. At about 250 feet two narrow parallel tourmaline veins were cut, and a drive extended south-west along their strike, but without encountering anything of a particularly promising nature. This work seems to have been quite futile, and with the gradual slope of the hill at this point, it is questionable whether the small amount of backs obtainable justified the driving of the adit, even had the nature of the surface outcrop warranted it.

It is doubtful whether any further work is justified on this portion of the property. The property would have to be worked from a main shaft, as the topography of the locality would not allow of economical working from adits: the backs obtainable would be insufficient to justify their use. There is no timber of any description in the immediate vicinity, even for domestic use, the nearest belt being on the slopes of the Heemskirk Range, about 2 miles distant.

North-west of the shaft and main workings described some further prospecting has been carried out on another tin-bearing formation, these workings being locally known as the White Face Workings. The bed of the creek separating the main shaft from the adit described above has been worked for alluvial tin. Ascending the western slope, there is a fair quantity of white quartzose detrital material, some of which carries visible cassiterite which is usually very black. The depth of this detrital material varies, but would appear to average between 12 and 15 inches. Crystals of black cassiterite set free from the disintegration of this material are not infrequently noticeable on the surface. Apparently this material could be profitably treated if water could be got cheaply on to the property, but this does not appear practicable, as the quantity of material available is not sufficient to warrant any considerable expenditure.

A trench on the hillside a few chains north-west of the old adit exposes a width of 10 feet of a white quartzose formation, which carries nests of tourmaline and of cassiterite. The groundmass apparently consists entirely of cassiterite. The tourmaline occurs in nests, radiating aggregates of fibres of greenish-black colour sometimes attaining a length of 3 inches, the groundmass consisting of fibrous green tourmaline. The cassiterite is very black in colour, and occurs in nests composed of aggregates of crystals in a groundmass of crystalline quartz, but without any other noticeable gangue mineral. These nests of cassiterite appear to be irregularly distributed through the formation. A width of 10 feet is exposed, but this does not appear to be the full width of the ore-body.

Higher up the hill slope, and about 10 chains north-west of the old Empress main shaft, is an outcrop on which a little work has been done. The lode material consists essentially of white quartz, and in consequence the workings are locally known as the "White Face" workings. They are situated in the north-western corner of the section. An open-cut has been made into the outcrop, this cut having a length of 15 feet, a width of 12 feet, the height of the face being 8 feet. The strike of the formation appears to be N. 64° W., and if continuous the outcrop would intersect the main lode-formation worked by the old company, in the vicinity of the main shaft. It cannot be traced for any distance on the surface, however, and does not outcrop in the old road about 2 chains to the west. The width of the workings is between 15 and 20 feet. The lode material is not unlike that exposed in the 10-feet trench lower down the hill. It consists of quartz, apparently of two generations. The groundmass is fine-grained, resembling a sandstone in general appearance, but consisting of crystalline quartz. Scattered through this are larger crystals of glassy quartz, and occasional nests of crystals of the same mineral. A small amount of a soft scaly micaceous mineral, apparently pinite, is present in the groundmass in places, and is particularly noticeable where cassiterite is developed. There is no appreciable tourmaline developed, but fluorite is present in dark amethyst to lilac, and occasionally in pale-green crystals, scattered through the quartzose groundmass. Cassiterite is present sometimes in scattered crystals, and also in nests of crystals, always very black in colour. Much of the stone carries no visible cassiterite, the nests of crystals being irregularly distributed through the formation. Wolframite is associated with the tin, and its mode of occurrence is similar: it is present in sporadically distributed crystals, and in aggre-

gates of small crystals lining vughs, associated with crystals of quartz and scales of mica. Occasionally slight stains of copper are noticeable, and the presence of limonite indicates that pyrite will be encountered at depth.

About 20 feet north-west of the White Face is a prospecting shaft sunk to a depth of about 15 feet, and now partly full of water. The lode material here is quartzose, and similar in general structure and appearance to that described above, but is pyritic. Chalcopyrite and pyrite are fairly abundant, disseminated through the quartzose groundmass, and a little finely-divided arsenopyrite is noticeable. The stone shows occasional irregular veinlets of tourmaline and vughs of prismatic quartz crystals, and green and black tourmaline, the latter being coarsely crystallised. No cassiterite is noticeable in any of the stone from this shaft.

From what has been said, it will be seen that the formation is of considerable size, but little has been done to prove its value. Tin and wolfram are undoubtedly present; although some rich stone is obtainable, the question to be decided is whether the average grade is high enough to pay for mining and treatment. Under present conditions charges would be rather high, and it is questionable whether the ore in bulk will prove payable. Although for a time open-cut methods could be employed, the ore to be won thus would be limited, and work would have to be carried out from a main shaft. There is nothing at present to warrant the erection of a plant, but a little further surface prospecting is warranted. The writer would advise a careful sampling of the exposed face, and assay for tin and wolfram. Two or three trenches to the south-east of the White Face along the line of strike of the formation would give some useful information concerning the size and value of the ore-body in that direction, and might result in the location of better shoots of ore than that which has been partly opened up.

(7)—*Section* 4653M, 5 *Acres—J. Campbell and H. Castle. (Old Cliff Mine.)*

This section is situated on the West Coast, the position of the south-west corner being actually out to sea. It is about 2 miles north-west of Trial Harbour, and about 15 miles from Zeehan. The Zeehan-Trial Harbour-

Corinna Road passes within about 2½ miles of the property, with which it is connected by a track over the open button-grass country, the track being of good grade, and available for cart traffic.

The section forms part of the property previously known and worked as the Cliff Mine. A battery and buddles were erected, and driven by a water-wheel, although the material mined and crushed appears to have been merely tourmaline granite, in which tourmaline was mistaken for tin. Of the old plant, a 5-head battery, with provision for an additional five heads (shafting, cams, &c.) still stands on the summit of the cliffs, 300 feet above sea-level.

The country-rock is white granite of Devonian age, here containing abundant black tourmaline, both disseminated through the rock in small tufts and aggregates, and also in nodules. The contact between granite and slate was noted less than ½-mile to the south-east of the property.

The tin-bearing vein now being prospected by Messrs. Castle and Campbell outcrops on the steeply-sloping cliff face, and has been prospected to a small extent only, by means of a shaft and adit.

Although the cliff face is almost precipitous here, at about 50 feet below the level of the old battery floor, a point on the outcrop of the vein was located, and a shaft sunk to a depth of 18 feet on rich stone, clean tin oxide being broken out by hammer and gad, and bagged direct. Two bags of tin oxide per week were won for some time by Mr. Tames, working alone, at this point, by the laborious method mentioned. No driving has been done here, although the tin-bearing vein continues into the cliff face. From the small exposure made, the vein appears to strike N. 58° W., and dip south at about 80°.

About 50 feet below the collar of this shaft, or 100 feet below the old battery, is an adit driven by Messrs. Castle and Campbell on the course of the vein. The bearing is N. 67° W., and the adit had been extended at the time of my visit for 36 feet. No crosscutting or stoping had been done. The adit is driven on a shoot of rich tin ore. The width is not exposed, but will probably be about 4 feet. There is a central fissure carrying soft kaolin and rich tin; less than 2 lb. weight of this material yielded, on vanning, a little over 2 oz. clean tin oxide. In close association with this is a well-defined band of varying width, of crystallised black tourmaline and rich tin. This

is very rich stone, and is flanked on either side by about 12 inches of quartz and black tourmaline, with tin oxide visibly disseminated through the stone. This, in turn, merges into quartz-tourmaline vein-stone, with a considerable quantity of muscovite mica, also carrying tin, merging into tourmaline granite.

The tin oxide is brown to black in colour, and of medium grainsize; it should be readily saved. In the face, rich tinstone was showing.

About 2 chains south along the cliff face, and at a point about 70 feet above sea-level, an old adit has been driven for about 15 feet in white nodular tourmaline granite. This adit does not expose any ore, and the reason for driving it is uncertain, unless tourmaline were mistaken for tin.

On the summit of the cliffs, near the old battery, is an open-cut in nodular tourmaline granite, from which, I understand, the material excavated was crushed, and an attempt made to save the black tourmaline, thinking it to be tin.

It will be seen from the above description that very little work has been done on the section up to the present although the prospects are undoubtedly bright. The length of the shoot of rich ore has not yet been proved. From the present adit, about 100 feet of backs are available for stoping. From the nature of the occurrence (*i.e.*, the type of vein and the country-rock in which it occurs) there is sound reason for believing that the lode-channel is likely to be continuous, not only for some considerable length, but that it will also continue to depth. The richer ore will probably occur in shoots. One such has been partially opened up. These are likely to be of limited length, but prospecting alone can show the distribution of values throughout the length of the vein.

Not only is the vein-type favourable for a permanent ore-body, but the nature of the ore is such that it presents no treatment difficulties. The ore is only moderately hard, and should be inexpensive to mine and crush. The tin, too, should not be difficult to save if a suitable treatment plant be installed. In the ore exposed up to the present, pyrite has not made its appearance. Such may occur in the ore at a greater depth, but there are no grounds for supposing it will be troublesome for some time to come.

With reference to mining facilities, the property possesses advantages which will greatly assist in the economic

development of the mine. Although from the present adit only about 100 feet of backs can be obtained, from a low-level adit a maximum of 250 feet should be available, according to heights determined by aneroid barometer. The driving of a low-level adit as soon as possible is to be recommended. No tedious driving through barren country-rock is to be faced, but the adit would be on the course of the vein from the approach.

For power, too, the mine is not unfavourably situated. Advantage should certainly be taken of natural facilities. Previously, the battery was erected on top of the cliffs and worked by water-wheel, water being obtained from three small dams, one below the other, in a small creek emptying over the cliffs a few yards north of the tin-bearing vein. The amount of water available from this creek in its natural state is small, but already races have been constructed to divert water from several branches of Packer's Creek, into this channel. There is a suitable site for a dam about 1½ mile from the property, which could be used for storage purposes. Although the amount of water available would not be sufficient to drive a large plant, it would probably suffice for the five-head battery it is proposed to utilise. Were this battery moved from the top to the bottom of the cliffs, a Pelton wheel could be installed to advantage, to make use of the available head of 250 feet. The ore, too, would be tipped direct from the adit into battery hoppers, without any hauling, such as the present position of the battery would involve. The pipe-line necessary would not be very long, on account of the steep slope of the cliff face. A site for the battery is available, although a limited amount of excavating and filling will be required.

The property is one which can be heartily recommended for further prospecting. The developmental work so far carried out is not sufficiently extensive to warrant too large an expenditure on treatment plant and surface works at the present stage. Although rich tin-bearing stone has been exposed, and still shows in the face of the adit, its extent is still a matter of some uncertainty. From considerations already mentioned, it will be seen that further developmental work may be carried out at a comparatively low cost.

While no definite forecast can be made as to the future of the mine, the outlook is undoubtedly very encouraging, and prospects appear bright. A vigorous campaign of developmental work is warranted.

(8)—*Section* 6206M, 80 *Acres—J. Campbell.*

Partly adjoining Section 4653M on the east, is an 80-acres section, 6206M, charted in the name of J. Campbell, which, I understand, it is proposed to work in conjunction with Messrs. Castle and Campbell's property, described above.

Traceable throughout almost the whole length of the section is the outcrop of a large lode-formation, which has a general strike of about N. 17° E., varying slightly from point to point. The lode is very quartzose, and carries abundant nodules of quartz and tourmaline (black and green), with some scattered aggregates of black tourmaline.

Very little work has been done on this line of lode, although it presents some very encouraging features. The width is not exposed, but is probably 15 to 20 feet.

About the centre of the section are some shallow workings, known as Spencer Brothers' workings. These consist of a trench on the lode about 30 feet long, 3 feet wide, and 4 to 5 feet deep, with a second shallow trench cut at right-angles for about 1½ chain. From this excavation, I am informed that between 2 and 3 tons of clean tin oxide were taken. On the heaps thrown out, some very rich specimen stone was noticed. The tin is very black, and occurs in masses of crystals occupying vughs in the white quartzose lode-material, frequently with prismatic crystals of quartz, and sometimes with crystals of green tourmaline also. It is usually of medium grain-size. The tin oxide is sometimes well disseminated through the lode-material, occurring also with tourmaline and white mica (muscovite). A striking occurrence noted here is that of rich tin in some of the green tourmaline nodules, quartz also being always present.

Ten chains south, along the line of strike, another trench, 15 feet long, by 3 feet 6 inches deep, partly exposes the lode outcrop.

Seven chains further south still, and almost on the southern boundary of the section, several narrow parallel pyritic quartz-tourmaline veins, some of which carry arsenopyrite, are exposed in the bed of a creek. These have a slightly different strike, viz., N. 11° E., and probably belong to a different lode-system to that described above. No tin was noticed in any of the veins, which aggregate 11 feet, over a total width (regarding vein and country-rock) of 20 feet.

Seven chains due north of Spencer Brothers' workings are some old workings, known as Wooding's. Here a patch about 150 feet square has been stripped and sluiced, water being brought by a race, about 1½ mile in length, from a branch of Packer's Creek. The material sluiced consists of detrital matter, and not true wash, and is composed almost entirely of round quartz-tourmaline nodules. Some rich specimen tinstone was noticed on the heaps of tailings, similar to that at Spencer Brothers' workings; although the depth is shallow, good tin is said to have been won from the alluvial treated. The source of this tin is not far to seek, for just above the sluiced ground, which is on a sloping hillside, is a well-defined lode outcrop, of similar character to that of the big lode described, being very quartzose, with abundant nodules, sometimes stanniferous. The outcrop is about 25 feet wide here, and apparently strikes north and south. On the western side of the outcrop the lode is pyritic, consisting of glassy quartz and scattered crystals of pyrite, in a fine groundmass of quartz, with a little green tourmaline; muscovite mica is sometimes present. On this portion of the ore-body a shaft was sunk, but is now full of water. From the amount of material on the surface the shaft is probably not more than about 20 feet in depth. No tin was seen in this pyritic ore, although it may be present. The outcrop of this lode does not appear further to the north. It is connected with the main lode previously described, although the outcrop cannot be continuously traced. While the main outcrop apparently lies about 3 chains to the east, it is seen, on plotting, that this lode, if continuous, would junction with the main channel in the vicinity of Spencer Brothers' workings. The rich tin occurring here may be at the intersection of two lode-systems.

About 3 chains east of Wooding's workings there is a lode outcrop on the summit of a low hill, about 25 feet wide, striking N. 13° E. Junctioning with this is another outcrop of nodular quartz tourmaline, showing on the surface for 2½ chains, and striking east and west. This has not been prospected.

It will thus be seen that beyond the old workings described as Spencer Brothers' and Wooding's, no work has been carried out on this section to exploit the known tin-bearing lodes. They certainly are worth prospecting. It is quite unlikely that payable tin values will be found along the whole line of outcrop, but the fact that in places

rich ore does occur, should stimulate further work. It is probable that shoots of good ore will be found. After locating them by trenching, further prospecting and developmental work will have to be carried out from a shaft, unless the lode can be traced to the cliffs, as the country is comparatively level along and near the outcrops.

The width of the main lode is considerable. Although at certain points the whole may be impregnated with tin to a sufficient degree to render the whole width payable, it is more likely that the payable tin will be confined to a smaller width within the ore-body. Obviously, too little has been done in the way of opening up the property to allow of any confident prediction being made as to its future, but the judicious expenditure of additional money is warranted by present prospects.

(9)—*Section* 3224M, 20 *Acres. (The old Cornwall Mine.)*

The main workings on this section are those of the old Cornwall Tin Mining Company, and were carried out in the early history of mining on the field.

As will be seen by reference to the general map of the district, the section is situated on the coast, at the mouth of Packer's Creek. The actual position of the workings on the section could not be determined, as no corner-pegs were available, but the work has been confined to the south-western portion of the area. The old Cornwall Company fell into the serious error (unfortunately, only too prevalent on the South Heemskirk tinfield) of spending a considerable amount of money on the purchase and erection of plant before having sufficiently developed their property to ensure a supply of ore to keep the plant working. From the description given below of the actual work done, it will be seen that the expenditure on surface works was certainly not justified. Further, the actual surface work done has not been carried out to the best advantage.

The plant of the old company was placed at the foot of the coastal cliffs. Of this plant, Mr. G. Thureau reported,(216) "An overshot water-wheel 40 feet in diameter, 4 feet breast, works a 10-head battery, from which the crushed ore is fed to two Frue's vanning concentrators. . . . The thereby impoverished sands are

(216) "Report on the Present Condition of the Western Mining Districts," by G. Thureau, June, 1884, p. 9.

then supplied to two of Borlase's buddles, the four arms of which are furnished with split canes, instead of bagging or iron scrapers, and finally, cleansing the ore and of slimes are effected on a third Borlase's or slime-table, followed by a treatment in a hydraulic "cleaner," and a series of settling-boxes."

The cost of such a plant must have been considerable at the time when it was erected, particularly when the inaccessible situation is considered. The old water-wheel has been burnt out, and the plant, as a whole, is in ruins.

For driving the water-wheel, water was drawn from Packer's Creek, which was dammed, the water being taken round the hill in a flume for 2 or 3 chains, and then through the hill by means of a tunnel about 80 feet long. Thence it was led to the plant, more than 100 feet below, no use whatever being made of the available pressure. Water could have been brought from both Packer's and Gap Creeks, and a head of probably 250 feet obtained for a battery on the sea-shore. Referring to the work carried out, it was noticed that the tramline by which ore was trucked from the open-cut to the battery, had an up-grade *to* the battery, involving unnecessary work. Again, one of the adits is driven on a *down* grade, but as it is only a short distance below the brow of the hill, water has not been heavy.

The section is situated well within the granite area, the rock here being medium-grained, and carrying abundant nodules of black tourmaline, and sometimes sheaves of coarse pencil-like crystals of the same mineral.

Advantage has been taken of the topographical features in carrying out mining work, although little real exploitation work has been carried out.

On the north-western bank of the creek, within a few chains of the edge of the cliffs, some open-cut work has been carried out on nodular tourmaline granite; no lode-formation is exposed.

On the opposite bank of the creek, and about 20 feet above creek-level, an adit was driven east. This is inaccessible, as a fall has nearly blocked the entrance, and the adit contains a considerable quantity of water.

About 40 feet higher up the hill is another adit, driven in a very irregular fashion on a down grade. The adit has a total length of 55 feet. Although of irregular width, the general bearing for a distance of 20 feet is S. 46° E., and for the remaining 35 feet to the face, the bearing is S. 63° E. Near the entrance, the drive cut through a

flat quartz-tourmaline vein of irregular width, whose dip cannot be definitely determined on the exposure available for inspection. It consists of hard stone, of white quartz, and disseminated black tourmaline, and nodules of the same mineral. The formation does not look very promising for tin.

At 15 feet from the entrance a mass of black tourmaline was encountered, and some of it appears to have been mined, and from the state of the heap outside, it would appear that it has been regarded as ore, and some, at least, of it has been sent to the battery. The full extent of this mass of tourmaline is not exposed. It is exposed for a height of 9 feet, and a width of 10 feet. The mass is intersected by veinlets of green tourmaline, with a general strike of about S. 50° E. The tourmaline occurs in aggregates, sometimes with granular white quartz, and often in masses of slender prismatic crystals radiating from a centre. These crystals sometimes attain a length of 4 inches, and these radiating and intergrown masses form very handsome cabinet specimens, the finest seen by the writer in a district where tourmaline is exceptionally well developed. Photo. No. 20 shows two specimens from this spot. The spaces between intersecting tourmaline crystals are sometimes occupied by small geodes of quartz, which are lined with minute prismatic crystals of the same mineral. No pyrite was observed, but a small amount of limonite suggests that it may be present.

The last 15 feet is driven through nodular tourmaline granite, with fissures on both walls, the latter being somewhat kaolinised, and showing some muscovite mica; no ore is exposed.

These workings are in very bad repair.

The reason for driving this adit at this point is not clear, for it would not yield more than about 20 feet of backs.

On the dump-heap at the mouth of the adit are abundant specimens of radiating black tourmaline in a groundmass of quartz and black tourmaline. To try and determine whether tin was present in the varieties of stone, a sample of the vein-stone, consisting of quartz and black tourmaline was broken from the stone exposed on the heap, and submitted to the Government Assayer, who reported—

Tin ... ... 0·48 per cent.

A second sample was broken from the exposed aggregates of black tourmaline, as distinct from the veinstone

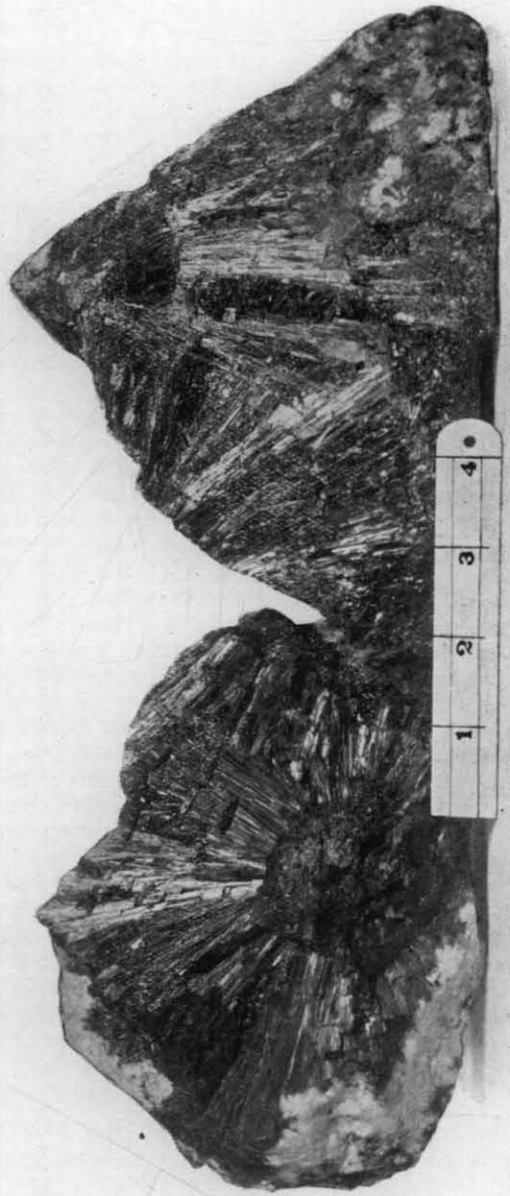


PHOTO. 20—RADIATING BLACK TOURMALINE FROM THE CORNWALL MINE, SOUTH HEEMSKIRK.
[L. Lawry Waterhouse, Photo.

referred to above, as it was reported that much fine tin was present with the radiating tourmaline. This sample was assayed by the Government Assayer, with the following result:—

Tin ... ... 0·24 per cent.

These values are certainly not encouraging.

On top of the hill are two trenches, exposing similar quartz-tourmaline stone, consisting of white quartz and black tourmaline, and rather more green tourmaline than is shown by the stone exposed in the adit below. The strike of this formation appears to be about north-west.

The ore from the workings described was taken across the creek in trucks, which were pushed on an up-grade to the tunnel, through the western hilltop, and through this tunnel to the battery below.

In this tunnel, which also provided a path for the water utilised for the waterwheel below, the granite is seen to be traversed by a number of narrow pyritic veins. About a dozen of these were noticed, varying in width from 3 to 12 inches, and approximately parallel, with a strike of N. 83° W. These are worth testing for tin.

On this hillside (the north-western) there has been a little desultory shallow trenching on a white vein of quartz, which carries nests of coarse radiating black tourmaline.

The tunnel mentioned above was utilised in recent years as a convenient channel by which the creek water was diverted. Then the natural bed of the creek below this point was worked, and some good alluvial tin won. This is not surprising, when it is remembered that the creek heads and flows during its whole course through tin-bearing country.

About 6 chains north-east from the workings described above, are several trenches on the bank of Packer's Creek, exposing a very promising-looking vein of quartz and green tourmaline. Some cassiterite was noticed in some of this stone, and the formation is worth exposing further.

(10)—*Section* 4323M, 80 *Acres.*

Some old workings were noticed at a point about 1½ mile north-west from the Cornwall Mine, along the coast. A hurried visit only was paid to the locality. Although no corner-pegs were seen, the workings appear to be on Section 4323M, and consist of a small open-cut, some

trenching, and a shaft (now full of water). Some of the quartz-tourmaline stone looks rather promising for tin, but it is worthy of particular note that molybenite occurs in some of the lode-material on the surface. It is disseminated through the rock in the specimens, no pure mineral being seen. It was not located *in situ*. A look-out should be kept in the vicinity, as rich patches may occur, but unless richer material occurs than that seen in the loose material referred to, it will not pay to work.

No information is available with regard to any tin won from the section.

(11)—*Section* 463 D.C.—*R. Clarke.*

This section is situated about a mile south of the Federation Mine, and comprises a strip 1 chain in width and 40 chains in length, along the course of the Wakefield Creek. It is on the button-grass plain, but at the foot of the Heemskirk Range, and immediately below the old Wakefield Company's workings. A small area of alluvial ground at the head of Mr. Robert Clarke's section was worked by the old Wakefield Company, and more has since been worked by the lessee. The ground varies in depth from point to point, but would, perhaps, average between 8 and 10 feet in the exposed portions. The overburden varies in thickness from a few inches to several feet. The surface is covered with a thick growth of button-grass, and scrub is fairly thick in places towards the head of the section, although the lower part is free from scrub.

The wash is of the usual nature in the district, consisting of sub-angular and rounded fragments of quartz and quartz-tourmaline, usually of medium to small size. No large boulders were noticed.

The tin appears to be present mainly in the lower layers of wash, which rest on a granite bottom. The tin is partly granular, varying from brown to black in colour, and partially-rounded nuggets of pure oxide are sometimes found. Specimen pieces of tin oxide, with attached quartz-tourmaline veinstone, indicate clearly the source of part, at least, of the tin values of the wash. It has been derived from tin veins in the surrounding granite. Some specimens show botryoidal cassiterite, very similar in appearance to some of that found at Mayne's Mine.

The extent of the wash is small, being confined to the bottom of the valley, and its average width would probably be less than ½-chain.

The supply of water available for working is small, being that of the Wakefield Creek, an insignificant stream in this locality. It heads in granite country, and the supply of water rapidly decreases in dry weather, being insufficient to enable work to be carried out on a proper scale. Even were water available, the extent of ground would not warrant dredging operations. The actual tin values are not known to the writer, but do not appear to be very high, and although rich patches may be found at intervals, it is unlikely that under the existing conditions the deposit will pay to work.

Reference may be made to the prevailing idea that certain clumps of bushes growing on the hillslope just above the alluvial ground described above, indicate the presence of further alluvial ground. After examining the locality, the writer is of opinion that there is nothing unusual in the occurrence of the clumps of bushes, and that they cannot be regarded as indicative of alluvial deposits.

(12)—*Old Wakefield Mine.*

The workings of the old Wakefield Company (now deserted) were visited by the writer. They are situated in the dense bush on the southern slopes of the range, about ½-mile south-west of the Cumberland Dam embankment, though at a considerably lower level, aneroid readings showing about 920 feet above sea-level at the old battery site. The workings may be reached by a track turning off the old Montagu Road, which was constructed at considerable expense up the steep hillside, being situated only a few chains to the east of this road.

Alluvial tin was found on the flat below, and this appears to have been traced up the spur until the lode-formation which has been worked was located. Some more recent workings in this alluvial ground are described below.([217])

The Wakefield Company acted as many other of the earlier-formed companies on the South Heemskirk field, and erected a plant to treat tin ore, which had not been sufficiently opened up by mining operations. As a result of this short-sighted policy, the same fate overtook this

([217]) *Vide infra*, p. 358.

company as overtook so many others in the district, and although a very promising tin-bearing formation was exposed, little real mining work was carried out before the available capital was exhausted. The plant has been removed, but consisted of a 5-head battery worked by a 10-horsepower portable engine, one buddle being used as a concentrator.

Lode.—The workings are but a few yards above the site of the old battery, and are partly open-cut, and partly underground.

The formation belongs to the quartz-tourmaline-cassiterite vein-type, although in places it carries a little white mica in addition to the three minerals mentioned in the designation of the vein-type. No pyrite was noticed. The strike of the vein varies a little from point to point, but on the average is north and south, and judging by the exposures available, the dip is about vertical.

On the western side of the open-cut is a vein left standing in several places, varying in width from 6 to 15 inches. It shows a narrow central vein of tourmaline, with vein-rock of quartz, green tourmaline, and some white mica on either side, which merges on either wall into altered granite, in which the felspars have been replaced by aggregates of green tourmaline. This mineral sometimes forms the bulk of the rock, and occurs in massive form. Some quartz is present, and the stone shows fairly abundant cavities, which may be partly due to the oxidation and removal of some constituent, although many are true miarolitic cavities, encrusted with minute glassy prismatic crystals of quartz.

On the surface above the adit, about 15 feet of lode-material is exposed. There is a narrow central vein, this vein-stone consisting of dense green tourmaline with a little quartz, succeeded on either side by a band from 3 to 4 inches wide, composed of quartz, with both black and green tourmaline, and in places of crystalline white quartz. This is followed on either side by vein-rock, composed essentially of dense green tourmaline, but with a little quartz, the latter frequently showing skeleton forms, apparently of felspar. These forms suggest that the outer portion of the felspar crystals has been replaced by quartz, the central portion by green tourmaline. The stone is quite similar to that which is exposed in the Eastern Workings at the Federation Mine. Outside this zone the vein-rock again alters somewhat in character, although still composed of quartz and green tourmaline. The latter

here occurs in aggregates, which clearly replace the felspars of the original granite, retaining the crystal form of the felspar crystals. The rock here contains scattered micaceous aggregates (pinite). This band is several feet wide on either side, and merges into soft, altered granite, carrying a little green tourmaline, this, in turn, merging into the normal granite of the district. Cassiterite shows freely in some of the stone, and the formation of the whole is very promising. At this spot it has been trenched along its course for about a chain, and partly opened up, but the scrub in the locality is dense, and the full width of the formation has not been exposed. It appears to be about 15 feet. A hole sunk to a depth of about 6 feet is said to have exposed good tin, but is now overgrown, and partly filled with rubbish.

Just above the site of the old battery is an open-cut, in the form of a long trench, on the course of the vein, taken out in several benches up to 9 feet in depth. For 57 feet this cut bears N. 10° W., when it bends somewhat to the east. On a bearing N. 12° E., it continues for 41 feet to the mouth of an adit continued on the bearing on the strike of the vein. Unfortunately, the bottom of the cut is not available for inspection, as it is partly filled with water and with surface rubbish. As nearly as can be judged, the average width of the vein has been about 20 inches in this part of its course. Reference has already been made to a vein left standing on the west wall of this cut. This appears to junction with the main tin vein at the mouth of the adit, forming a body of stone about 5 feet wide.

The adit is inaccessible, being partly collapsed, and holding a good deal of water in the bottom. Information given the writer by one who was familiar with the workings indicates that the adit was driven a total distance of between 45 and 50 feet; that it takes a bend to the east about 20 feet from the entrance; and that the vein in the face is about 3 feet wide.

No other work appears to have been done on this promising lode-formation. No record is available as to the tonnage of ore crushed, or the amount of tin won. The heap of tailings is not large, and some attempt has been made recently to re-treat them in a crude way, apparently with little success.

Alluvial.—The cursory examination made of the surroundings indicates that there is a good deal of stanniferous detrital material scattered about on the hillside

below the old lode workings, a good deal of which has been derived from the lode described.

About 6 chains below the old battery site a small area, about 1½ by 3 chains, has been worked in comparatively recent years. The writer was informed that this work was carried out by Mr. U. Gillham. The alluvial—or, strictly speaking, detrital—material varies in depth round the edges of the worked paddock from 1 to 2 feet, averaging about 20 inches. The material is angular and sub-angular, and consists mainly of quartz-tourmaline and quartz, resting on a soft, coarse granite bottom. Some good tin was won from here, some of it being fine, but the majority of it in the form of angular nuggets, and sometimes in slabs, grey to reddish in colour, without attached gangue, the largest slab measuring 5½ by 11½ inches, and being ⅞-inch in thickness. These slabs have evidently been derived from veins of cassiterite, freed during the degradation of the containing lode-formation. A good deal of the cassiterite has probably come from the lode-formation described, as narrow veins of cassiterite were noticed in the quartz-tourmaline lode-material. This patch of detrital material was ground-sluiced.

Although the thickness of material is not great, there is a good deal of tin contained in the detrital material lying about on this hillside which would pay to work if water could be got on to the ground cheaply. This does not seem practicable, however.

Facilities for economically working are fairly good, and although the vein was not sampled, it is sufficiently promising to warrant this work being carried out on the exposed portions. If values are sufficiently encouraging, the outcrop should be traced further than it is at present exposed, before commencing exploitation at a depth. No question of a plant should be considered until preliminary sampling and prospecting work have been carried out, and supplies of ore ensured by exploitation work.

(13)—*Section* 5426M, 40 *Acres.*

This section is on the Cumberland Dam plateau, about ¼-mile west of the embankment, and adjoins Section 5765M (J. H. S. Munro), on the south. The section is entirely within the granite area.

The only work done has been confined to a surface trench on a tin-wolfram lode-formation. About 8 chains from the northern boundary, and bearing about S. 32° E.

from the north-western corner-peg, is a trench cut into a white quartzose formation, which carries a little green tourmaline, and both cassiterite and wolframite, the former in small amounts only, so far as opened up. The trench has not been extended completely across the formation, the width of which cannot be definitely stated, but is about 60 feet. The outcrop is near the summit of a ridge, and the trench has been extended for 45 feet for a maximum depth of 9 feet, when 4 feet of stone is left underfoot, and the trench continued nearer the surface for another 8 feet in length.

Wolframite is not noticeable *in situ* in the trench, but some rich ore is lying on the heap, evidently won from one portion of the formation exposed. Some of this stone assays as much as 20 per cent. tungstic acid. The tin content would be about ½ per cent., although some rich specimens were noticed. The wolframite occurs in masses of crystalline quartz, and is in moderately coarse crystals. Cassiterite is in granular form in green tourmaline veins, and in small brownish crystals encrusting prisms of quartz, which project into geodes.

A more detailed description of the lode-material, and a discussion of the mode of origin, is given elsewhere. It has been shown that the ore-body is closely allied to the more normal tin veins of the district.

It will probably be found that the wolframite is not evenly distributed over the whole of the quartzose material, for that on the edges of the formation represents altered (silicified) granite. There may be one or more central veins filled with tourmaline or quartz and tourmaline, which represent the fillings of fissures by which the cassiterite and wolframite have been introduced, and the richest ore is likely to be found in the vicinity of these veins. A little pyrite may also be present.

The formation strikes N. 80° W., and, as exposed in the trench, it appears to dip south at 28°. It is, however, not certain that this is the normal dip of the formation.

No further work has been done on the formation. The outcrop east and west of the trench is covered with button-grass, but the well-marked ridge formed by the hard quartzose material is very distinct for about a chain east and 30 feet west.

Too little is known to enable a very definite opinion to be expressed, but the formation has distinct possibilities, and as a purely prospecting proposition is worthy

of a little further attention on the surface. It is worth while completing this trench and exposing the outcrop at one or two points east and west along the line of strike, to try and determine whether a definite shoot of ore exists, and what its length may be.

Underground work is not warranted at the present stage, but should surface prospects be sufficiently encouraging to justify such work in the future, the property is admirably situated to allow of exploitation by deep-level adits.

There are several other outcrops on the property which have not been prospected, but which may carry values. A parallel outcrop about 1½ chain south also strikes N. 80° W., and may represent a faulted portion of the formation exposed. It is well marked for 3 chains.

A few chains to the south-west is another similar outcrop, exposed for 4 chains, striking N. 29° E.

About 4 chains south from the wolfram trench is still another quartz-tourmaline outcrop, which bends into an arc of a circle. This does not appear to have been tested.

(14)—*Section* 5360M, 80 *Acres.*

This section is not held at the present time It is to the north-east of Sweeney's Mine, and is situated immediately to the south-east of, and adjacent to, the Cumberland Dam. The country-rock is granite, mainly of the pink variety, with veins and irregular nodular masses of aplite, and veins of tourmaline. The section is traversed in its northern portion by the pack-track connecting the Federation Mine with the main road near the Agnew Creek, and it is on the side of this track that the only work known to the writer has been carried out. This is a small cut of a few feet into a big pyritic formation about 2 chains within the northern boundary of the section. This formation strikes north-west, and appears to be from 30 to 40 feet wide, but has not been cut across. It cannot be traced on the surface to the north-west or south-east, but no further prospecting has been carried out. The lode-material is densely pyritic, the pyrite being in well-formed crystals. In the pack-track several narrow pyritic veins are noticed, striking north and south.

This formation is worth exposing and sampling in sections, and if values are satisfactory, it should be prospected for along the line of strike.

(15)—*Sweeney's Mine: Sections* 1141M, 1142M, 1187M, *and* 1188M.

As will be seen by reference to the accompanying map of the district, this property is situated on the southern slopes of Mt. Agnew, about ¼-mile south of the Cumberland Dam embankment. There are four sections forming a single group, comprising 80 acres. The individual sections are 1141M, 20 acres, and 1142M, 20 acres, each charted in the name of D. Sweeney, joined on the south by 1187M, 21 acres, and 1188M, 19 acres, each charted in the name of D. B. Sweeney.

Most of the work carried out has been about the centre of the group, and about on the boundary-line between 1141M and 1187M.

The country-rock is the normal coarse-grained pink granite of the district. As well as a little biotite, it carries aggregates of black tourmaline. Flakes of molybdenite have been reported from the granite on this property, although none was seen *in situ* by the writer. A coloured plate representing granite from this mine has recently appeared in a book on the "Building Stones of Australia."(218) The specimen figured was collected by the writer from Pyke's Creek, below the workings described.

The topographical features of the locality favour economical working, although making the property difficult of access. Near the northern boundary of the sections precipitous cliffs rise to a height of about 350 feet. Over these cliffs the water of the Cumberland Creek, being the overflow of the Cumberland Dam through the by-wash, plunges into the valley below. From this point the creek is known as Pyke's Creek. These falls have not been utilised for power purposes, since the flow of water would obviously vary considerably, and almost, if not entirely, cease if the dam were at all largely drawn upon by companies on the western slope of the range. Below the falls, however, a small race has been constructed, giving a head of 90 feet at the battery in the creek.

According to aneroid readings, the lower tunnel being driven at the time of the writer's examination is about 320 feet above the coastal plain, or, approximately, 1100 feet above sea-level.

Timber and scrub are abundant in the locality.

(218) "The Building Stones of Australia," by R. T. Baker.

Access to the property is given by a pack-track connecting with the Zeehan-Trial Harbour Road, a few chains west of the turn-off to Mayne's Mine, on the hill to the west of Pyke's Creek. This track is steeply graded after leaving the plain. Stores and tin, as the case may be, are packed or sledged up or down this track from the road. There is also a steeply-graded foot-track connecting to the north-west with the old Cumberland tramway, and so with the Federation pack-track. This route is seldom used.

A plant has been erected in the bed of Pyke's Creek, but is, unfortunately, in a bad state of repair. It consists of a 5-head battery (the stamps being rather light and of an old pattern, with screwed tappets) driven by a Pelton wheel. The latter is operated by water from the race referred to, under a head of 90 feet. A Wilfley table was used for concentrating, and was driven off an eccentric.

Lode-formation.—The lode-formation, upon which some work has been done, is of complex nature, containing abundant sphalerite (zinc blende) and pyrite, with small quantities of galena, stibnite, chalcopyrite, and cassiterite, the gangue minerals being quartz, siderite, fluorite, tourmaline, and chlorite. The formation occurs in granite, which has been altered by the ore-bearing solutions.

The lode-formation was located through the tracing of alluvial tin, which occurred in the bed of the creek. The work done on the alluvial is described below.

On top of a hill, rising a little over 100 feet above the creek, the formation was exposed in a shallow trench. This trench does not expose the full width of the formation, which may be from 15 to 20 feet. This trench is about 15 feet west of the corner-peg in the centre of the group of sections described. No other trenching has been done to expose the true line of strike, which appears to be about north and south. There is nothing to show the dip of the formation.

The ore, as exposed in this trench, consists essentially of black sphalerite in a groundmass consisting partly of quartz and partly of a soft brownish decomposed mineral.

A little crystalline pyrite is noticeable in some specimens, while in others fine radiating aggregates of stibnite (sulphide of antimony) are abundant with the sphalerite, the needle-like radiating crystals attaining a length of $\frac{1}{2}$-inch. These crystals are usually tarnished, and the ore is all a good deal weathered. Some of the sphalerite is tarnished to a purple colour, and has been mistaken for bornite.

Chemical tests show that traces of copper are present. It is worthy of particular note that this sphalerite ore carries tin. No cassiterite was visible in the ore examined from this trench, but assays have shown that tin is present to the extent of about ·75 per cent.

The hillside here slopes at about 30°, and at several points on the slope, almost along the east and west boundary-line separating Sections 1141M and 1187M, a little surface work has been carried out. This has taken the form of shallow trenching, and the cutting of one or two small cuddies in the hillside.

Although granite, which appears to be normal, is visible on the surface below the brow of the hill, lower down a formation has been cut, but not fully exposed, which appears to be about 20 feet wide. It carries abundant sphalerite and pyrite, but on the average is low in tin values. Aneroid readings indicate that this is about 60 feet above the lower tunnel, and it is probably continuous with the formation passed through in that adit. As exposed at the surface, the ore is evidently partly oxidised. Copper stains are noticeable in places, derived from the oxidation of a small amount of chalcopyrite and partly from the pyrite, which appears to carry traces of copper. The groundmass in which the crystals of pyrite and blende are embedded is mainly quartz.

An interesting occurrence on the hillside is that of a series of narrow veins filled with sphalerite and cassiterite, sometimes with pyrite, and a little galena is sometimes present. Quartz may or may not be present. The granite is usually altered in the vicinity, being kaolinised and chloritised. These veins may be as much as $1\frac{1}{2}$ inch in width, and assays up to 63 per cent. tin are reported in some instances. These veins appear to cut through the large pyritic formation referred to. The occurrence of cassiterite with sphalerite, pyrite, and galena is unusual.

A few feet above the creek level an adit was being driven at the time of the writer's visit, with the object of cutting at a depth the stanniferous sphalerite ore-body exposed in the trench on the summit of the hill. It is assumed that this will be intersected at 200 feet, but this is obviously uncertain, as the dip of the ore-body had not been determined. This adit had been driven 150 feet in a general northerly direction at the time of the writer's visit to the property.

For 4 feet from the entrance the adit bears N. 12° E., and for the following 45 feet, due north. It then bears

to the east again, and the bearing to the face was N. 9° E.

For 40 feet the adit was driven through normal pink tourmaline granite. This merges into an altered granite carrying abundant crystals of pyrite. From this point to the face, the granite is altered. Quartz grains are usually distinguishable, and occasional fragments of black tourmaline, but the groundmass of the rock is converted to a greenish-yellow mass of kaolin. In this rock very interesting nodular masses occur at intervals, containing tourmaline, siderite, fluorite, and quartz. These nodules have been described in greater detail in another part of this report.([219])

Where the alteration has been most intense in this zone, no quartz remains in the rock, which is thoroughly kaolinised In such cases, however, pyrite is usually abundant in well-formed pyritohedral and cubical crystals, and aggregates of amethyst-coloured crystals of fluorite are not uncommon. Sphalerite is sometimes present.

At 99 feet a short crosscut has been driven west for 12 feet in altered granite. At this point some promising tinstone was met with. It occurred as a narrow vein in the roof of the drive, and a few inches of rich tinstone in the floor. The cassiterite is very fine, and brown in colour. Associated with it is a very small amount of fine pyrite. The stone on either side of this vein carries abundant cubical and pyritohedral crystals of pyrite. The width of the formation appears to be about 3 feet. Its strike is north and south, and dip about vertical. Microscopical examination ([220]) has shown that the tin is extremely fine, and that it is disseminated through a micaceous groundmass, in which shreds of white mica, quartz, and a very small amount of tourmaline, are present. It is a pinitoid vein. The tin appears to have been introduced by a narrow fissure, and from this to have impregnated the rock on either side. Careful and systematic sampling is recommended to determine the extent of this impregnation, and to determine whether the tin values are concentrated over a width sufficient to pay for extraction.

From this point to the face of the drive, the granite is much altered. Tourmaline-siderite-fluorite nodules occur at intervals.

Some specimens of ore passed through in this particular zone were given the writer. Although not very wide,

([219]) *Vide supra*, p. 166. ([220]) *Vide supra*, p. 169.

these evidently are from a vein or veins, which may be continuous with the formation exposed on the hillside. The vein-filling is composed of black sphalerite, crystallised pyrite, radiating stibnite, and traces of chalcopyrite and cassiterite (the latter not visible, but shown by tests to be present), in a groundmass of light-brown siderite and amethyst fluorite. The ore is very striking in appearance. Reference is made to it in another part of this report. Tin is present, but apparently in small amount only, and it is questionable whether it will pay to treat, occurring in such a complex ore. Richer veins may, however, be intersected as work proceeds.

In cutting a channel for the water, on the opposite hillslope to that on which the work described had been carried out, a formation was discovered a few feet above the penstock. This is of considerable width, but had not been completely exposed at the time of the writer's visit. Fairly abundant sphalerite and pyritohedral crystals of pyrite are scattered through a chloritised groundmass, in which a little quartz is distinguishable.

The formation is certainly well worth trenching across and sampling to determine the tin content. The central fissure from which the mineralisation has taken place may be located, and it is not unlikely that it may be found to carry good tin values. The oxidised outcrop only was seen, but the formation appears to be of the same type as that on the opposite bank of the creek. It appears to be about parallel to the latter. If surface prospects warrant it (but not before the formation has been tested on the surface) an adit could be driven to intersect it at about 90 feet below the surface.

With reference to further work, the writer would recommend that attention be confined to the surface for the present. Systematic surface trenching along the line of strike of the lode-formation should be carried out, and underground work remain in abeyance until some further information has been obtained as to the behaviour of the formation at the surface. Information is required, not only with reference to the structural features of the formation, but also with regard to the lateral distribution of the tin values. In an ore-body of this particular type, it is possible that shoots of tin ore may occur which will be comparatively free from the sulphides occurring so abundantly in exposed outcrop, or in which at least the tin values may be higher than in the ore exposed up to the present. Such information would obviously be of

immense value in planning further underground work, and should be carried out without delay. It is warranted, and the occurrence of boulders of rich tin oxide in the creek (described below) should encourage such prospecting, as they have been derived from some formation not far distant, and their nature indicates that the formation may be identical with the one already exposed. Such a formation must be expected to vary from point to point, and while richer tinstone may be found, the ore may become also less complex.

If surface prospecting be not successful in yielding information which will enable further underground work to be planned, the lower adit being driven at the time of the writer's visit should be continued to cut the formation exposed on the hill above, and drives might well be extended along the course of the formation in both directions to determine the length of the shoot, and any variation in the metallic contents.

It is important in conducting such underground operations, to crosscut at regular intervals in order to make certain that no tin veins, which may be more or less parallel to the course of the drive, are missed. This applies particularly to the altered granite zone, to which reference has already been made, and the importance of crosscutting is emphasised by the rich tin vein which was intersected in the drive.

While it is unfortunate, from the point of view of treatment, that nature has been so lavish in concentrating so many metals in this particular formation, the property possesses some promising features, and work on the lines indicated is justified to try and determine whether the particular metal sought is not more abundant in shoots not yet located.

Alluvial.—A good deal of alluvial tin has been won from Pyke's Creek below this group of sections, although its winning has proved peculiarly difficult and even dangerous. The bed of the creek is choked with boulders of all sizes, some of them weighing probably 100 tons, and the creek for some distance flows underground. After examining the occurrence, the writer is inclined to agree with the explanation given by Mr. Waller to explain the cause of the creek having found an underground passage. Mr. Waller says:—([221])

"The granite has weathered for some distance below the surface, leaving great boulders of undecomposed rock as

([221]) "Report on the Tin Ore Deposits of Mt. Heemskirk," 1902, p. 40.

hard kernels in the otherwise completely decomposed granite. The creek has cut down its channel into the soft rock, sluicing away the fine detritus, and permitting the solid kernels to come together. These eventually formed a massive covering over the water-channel, and on the surface became covered up with soil and vegetation."

Mr. Waller describes([222]) an attempt which was made to work some of this ground lower down the creek by Mr. A. Tengdahl, by bringing a tail-race up between the boulders, working rich pockets, and catching a good deal of tin oxide after floods by ripples placed across the race.

Somewhat higher up the creek Mr. Sweeney won a good deal of alluvial tin from similar heavy ground. He worked along the bed of the creek for some distance below the huge boulders, hauling the alluvial to the surface: some rich pockets of tin were encountered and worked out, but the work was necessarily very precarious, and much of the tin present could not be removed owing to the dangerous state of the ground, and the risk of a sudden collapse.

Some of the tin won was granular, but a considerable number of nuggets and boulders of tin-stone, usually smooth but sub-angular, was recovered. Some of these nuggets are of pure cassiterite, a few of them showing botryoidal cassiterite similar to that occurring at Mayne's Mine. Others are evidently derived from veins of the quartz-tourmaline-cassiterite type. Some large boulders of tinstone, usually worn smooth, although angular to sub-angular, have been located from time to time, and some have been collected and crushed: one boulder was pointed out to the writer, which would weigh about 1 ton, and would assay about 15 per cent. tin. Some of the smaller specimens would assay as much as 25 per cent. tin. Most of these specimens contain a quartzose groundmass, and contain abundant cavities, resulting from the decomposition and removal of some constituent. Some of them are stained with limonite. Some of the cavities are encrusted with clear prismatic crystals of quartz. A study of the specimens collected convinces the writer that some at least of them have been derived from the lode-formation being opened up, or one similar in character to it. Some of the finer tin oxide may be derived from disseminated mineral through the groundmass of the granite, set free in weathering: some of the nuggets and specimen pieces are undoubtedly derived from tin-bearing formations in the drainage area of the creek. Although it is likely that small quantities will be

([222]) *Idem.*

won from time to time from accessible patches between the boulders, it is unlikely that it will ever pay to systematically work the creek, on account of the number and size of the granite boulders present. Small quantities of alluvial tin will continue to be washed down into the lower course of the creek by flood waters, and it will doubtless be found that from time to time sufficient will have collected to pay for recovery.

(16)—*Section* 124M, 18 *Acres—J. H. S. Munro (Mayne's Mine).*

This section is situated rather more than 2½ miles due south of Mt. Agnew, and one-quarter mile south of the Zeehan-Trial Harbour Road where the latter crosses Pyke's Creek: it is connected with the main road by a branch road running along the summit of a ridge to the west of Pyke's Creek which flows in a somewhat tortuous course through the section from north-east to south-west. The mine is about 8 miles south-west of Zeehan. The general topographical features are shown in Plate VI., which is, as the title indicates, a *sketch* map only.

The section includes part of the property which formerly was included in Mr. John Mayne's farm, and was in the earlier history of the field the West Orient Company's section. At this time the presence of the rich tin ore afterwards won was not suspected. The tin ore, which was of an unusual form and colour, was discovered accidentally. The rich detrital deposits must have been walked over scores of times: the history of their discovery is dealt with elsewhere,(223) and need not be repeated here. The rich ore near the surface was worked out in a comparatively short time, and the mine shut down without (in the writer's opinion) adequate prospecting having been carried out.

The area included in the section is slate and sandstone of Pre-Silurian age, considerably metamorphosed (particularly silicified and tourmalinised) by the intrusion of the granite *massif* of Devonian age, which outcrops within about 6 chains north of the northern boundary, and within 2 chains of the north-western corner: the approximate boundary of the granite is shown in Plate VI.

A good deal has been written in connection with the structure of the ore-bodies on this property in another chapter of this report,(224) which should be read in con-

(223) *Vide supra*, p. 234. (224) *Vide supra*, pp. 199–203.

junction with this section, which is intended to be rather descriptive of work done, with recommendations, &c., as to future operations. The reader is also referred to Photo. No. 21, and notes thereon in Appendix No. I.

The ore first discovered was on the surface, and very little prospecting was necessary to show that the surface rubble and soil carried payable tin values. In treating this material the outcrops of the lode-formations were exposed, and afterwards worked, as they were found to carry rich tin values.

Pyke's Creek, in this vicinity, after running due south on the northern boundary of the section, bends sharply east for 3 chains, then south for 5½ chains, and west for 5 chains. In the elbow thus formed is a projecting spur rising to nearly 100 feet above creek-level, composed mainly of indurated sandstones, forming the country-rock of the lode-formations. The northern, eastern, and southern slopes of this spur were found all to be covered with stanniferous detrital material and rubble which was derived from the lode outcrops immediately below, in the ordinary course of weathering. Naturally the tin oxide was not confined to the hillslopes, but much of it found its way into the creek-bed, which on this section and immediately below it, yielded handsome returns to working parties. The slopes of the spur were stripped of overburden, which was not of great thickness, and the soil and rubble treated in sluice-boxes. From descriptions given to the writer of this work, it appears that the sluicing both of this detrital material and later of the lode material mined, was not done in a scientific fashion, no attempt being made to classify the material, and the whole of the slimes allowed to go to waste. From the nature of the occurrence, the amount of fine tin oxide present must have been considerable. It seems that a dam was erected some little distance down the creek at one stage of the work, but that this broke away with a fresh in the stream, the whole of the contents being washed away. Nevertheless, by sluicing the detrital material a large quantity of tin oxide was won, much of it in the form of nuggets of tin oxide of a high grade. The depth of this detrital material varied considerably, but had all been worked at the time of the writer's visit: some of it appears to have been exceptionally rich.

In the report of the Secretary for Mines on the "Progress of the Mineral Industry of Tasmania for the quarter ending 31st March, 1902," in the first official reference made to this discovery, it is stated: "Out of a space 12 feet

square about £1500 of ore was taken. From a 14-lb. sample of dirt taken from the grass roots, 1 lb. 10 oz. tin ore was washed, assaying 74 per cent., and from 69 lb. clay, 5 lb. 4 oz. of 74 per cent. tin ore was taken. Large lumps of cement carrying half their weight in tin ore have been brought to town in specimens."

Mr. Waller visited the property shortly after work was commenced, and states[225]: "At the time of my visit a small piece of ground on the north slope was being stripped, and the surface soil and rubble therefrom was being washed in a couple of sluice-boxes. I tried two dishes of this wash which weighed together 26 lb., and obtained just 2 lb. weight of dressed tin ore. This prospect is equivalent to about 2 bags of ore to the cubic yard of dirt. The rubble on this side of the hill is rather shallow, and probably will not average more than 12 or 15 inches. On the south side of the spur several dishes were washed. . . . In each case both the amount of rubble taken and the prospect obtained were carefully weighed. The results were very uniform, the average coming to almost the same as that obtained from the rubble on the north slope. On this slope however, the depth of the rubble is much more than on the north slope. In no case has it actually been bottomed, although the deepest hole reaches a depth of over 3 feet."

Mention has been made of the fact that the cassiterite was of a rather unusual form. It is grey in colour, and amorphous in form, usually occurring in botryoidal masses. A few small pieces only were seen by the writer, and Mr Waller's description of the ore may be quoted[226]:—"The tin ore itself is grey in colour, and much of it is quite coarse-grained. Nuggets occur from the size of a walnut up to 20 lb. and more, and quite a large proportion of the tin won to date has been in this form. Most of the nuggets have on one side at least a curious botryoidal structure; the central portion is granular, but towards the outside the tin oxide has been deposited in thin concentric layers, resembling the structure of an agate; frequently the structure of the layers is radiating. In no case that I observed are the nuggets completely surrounded by these concentric layers. They are angular, and have the appearance of having been broken off from a larger mass. The nuggets contain no veinstone, nor any visible fragment of country-rock; they contain from 68 to 70 per cent. of metallic tin."

([225]) *Vide* "Report on the Tin Ore Deposits of Mt. Heemskirk," by G. A. Waller, p. 13.

([226]) *Op. cit.*, p. 13.

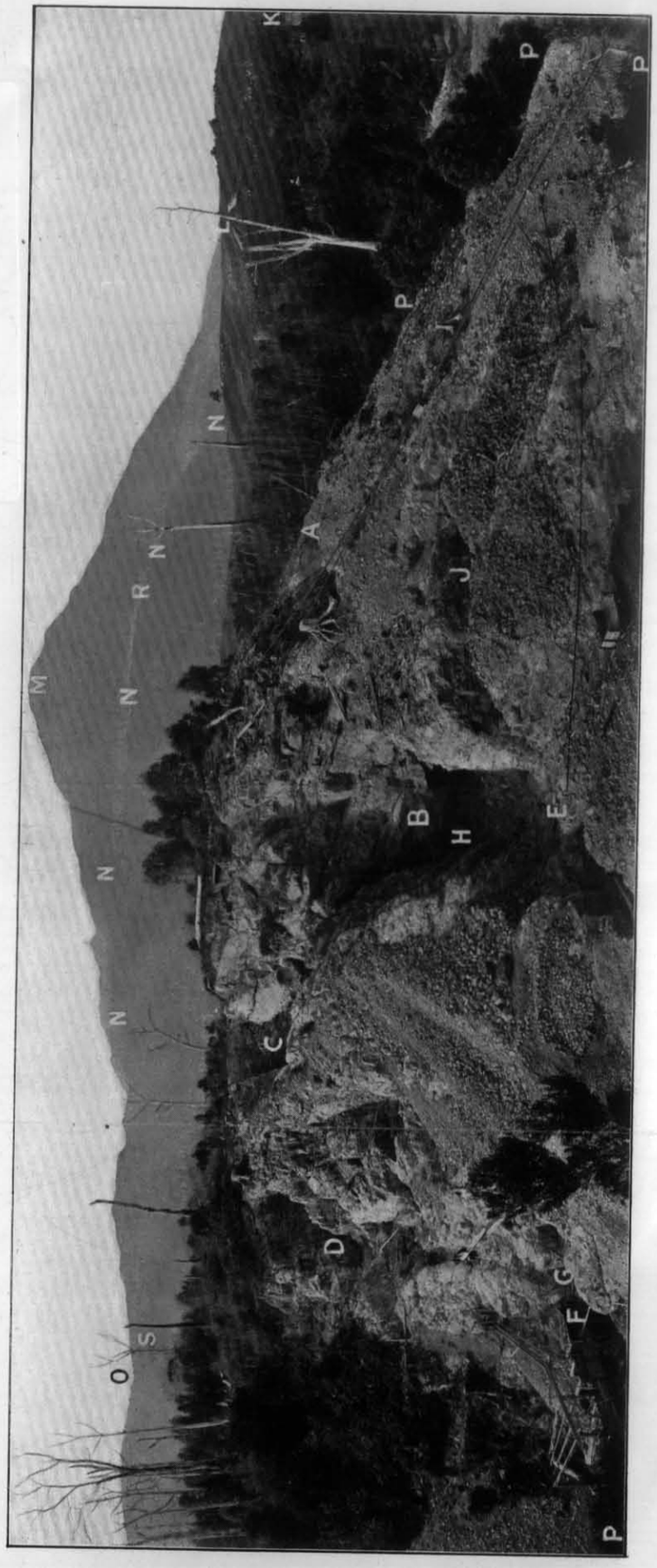


PHOTO. 21.—MAYNE'S TIN MINE, WITH MT. AGNEW IN THE BACKGROUND: LOOKING NORTH.

A microscopical examination of thin sections of this botryoidal cassiterite do not yield much additional information. The only gangue mineral present is tourmaline, and this is very scarce, occurring only in minute disseminated crystals included in the granular cassiterite. The bulk of the cassiterite is granular, but at intervals are open spaces lined with amorphous cassiterite, showing no sign of crystalline structure, but with a concentric structure which shows clearly owing to some of the layers being slightly more opaque than others; these are white in reflected light. These curved bands of cassiterite (sometimes semi-circular) at times show a tendency towards a radial structure, but this is not very marked: they merge into granular cassiterite at the base. Cross-sections of these " nodules " are more or less oval in shape, the central portion being filled with granular cassiterite. No quartz was present in the slides examined.

Very little prospecting was required after removing the surface rubble, to show that outcrops of tin ore occurred, which carried rich tin at the surface, and a start was at once made to work them. The ore was found to occur essentially in vughs of various sizes, the cassiterite being associated with kaolin and with green tourmaline. These vughs were followed and worked out as they occurred, and this led to a very irregular set of workings. With the exception of the tunnel through the hill (to be referred to later), and a few winzes, the work done was all from the surface by means of open-cuts. It is proposed to describe these open-cuts separately, in their present condition, and for convenience they have been numbered by the writer, No. 1 being that on the eastern slope of the hill, No. 2 the adjacent cut taken into the southern slope of the hill, No. 3 a branch of No. 2 to the north-west, extending almost to the summit of the hill, and No. 4 the most western cut, on the south-western slope, and connected with No. 3. No. 5 cut is on the south side of Pyke's Creek. The positions of these cuts will be made more clear by reference to Plate VI. and Photo. 21.

No. 1 Open-cut.—About 2 chains north of this cut is a promising green tourmaline vein which does not appear to have been prospected, about 9 inches in width. It strikes N. 74° E., and apparently has a dip of about 55 degrees, but it has not been exposed. It is not obvious for what reason the cut itself was driven: nothing remains to show the class of ore extracted. The length of the cut is 58 feet: height of face about 40 feet; width at bottom varies from

10 to 15 feet, average about 13 feet, and about 35 feet at the top. At 35 and 44 feet respectively from the entrance to the cut, two pyritic veins are to be seen: these are narrow, but may represent " feeders " to some of the vughs which occurred above. The walls are altered sandstones and slates: these are fissured in different directions, and it is noteworthy that they are traversed by occasional narrow thread-like veinlets of green tourmaline, which at intervals, when intersected by other fissures, bulge and form irregular shaped masses several inches across, or along their general course widen to lens-shaped masses of the same mineral.

No information was available as to the tin extracted from this cut.

No. 2 Open-cut.—This cut (well shown in Photo. No. 21) is of rather irregular shape, and the largest on the property. Some rich tin was won from this excavation. The length is 120 feet, width varies from 10 to 30 feet, and height of face about 55 feet. The cut appears to have been worked along the course of a main quartz-tourmaline lode, which widened to form vughs containing rich ore at intervals. Veins of green tourmaline with a very flat dip have been intersected at intervals, and from accounts given of the work done, it would appear that the main vughs occurred in connection with these flat veins. The writer's interpretation of these vughs has been giver elsewhere. They varied in size, for while some were only a few feet, others are said to have been " large enough to turn a horse and dray in." Always they appear to have carried rich tin. They consisted mainly of green tourmaline and kaolin, sometimes with limonite.

At the entrance to the cut, the ore has been taken out 5 feet below the level of the floor, and then a winze sunk from here, depth not known to the writer, but probably not more than 15 or 20 feet. The lode material appears to be pyritic at this point.

At 16 feet from the entrance to the cut on the eastern wall is a narrow pyritic vein of quartz and black tourmaline.

At 50 feet is a side-cut to the east, which cuts through a flat vein of green tourmaline, which strikes about north and south, and dips east at 10 degrees. The country-rock in this branch has been impregnated to some extent with fine, needle-like aggregates of green tourmaline, and also with quartz and black tourmaline. At 47 feet east from the wall of the main cut is a vertical shaft, now filled with water, whose depth could not be determined. Some rich

slime tin was noticed on the tip, having been concentrated by the action of water running over the heap since the material was mined. The width of this side-cut is 6 feet at the bottom, 15 feet at the top.

At 90 feet from the entrance, the main cut has been worked for a width of 34 feet, a big excavation being taken into the eastern wall. The masses of dense green tourmaline left standing carry a good deal of slime tin, and it is noticeable that blocks of included country-rock are enclosed in the lode material. The lode material has been worked out here to an unknown depth (probably not more than a few feet) below the level of the floor of the cut, leaving the overhanging wall rock. The old excavation has been filled up. There appears to have been a fairly large " make " of lode material here; it has been worked at intervals from this point to the face; the strike appears to be north-north-east, and underlay to the east at about 10 degrees.

At 110 feet from the entrance is a winze, apparently on lode material, sunk to 12 feet. Above this is a vugh 3 feet by 2 feet by 2 feet 6 inches, of rather irregular shape.

From the floor at the face of the cut, 120 feet from the entrance, a winze was sunk to a depth of 20 feet. The width at the bottom of the winze is said to be between 4 and 5 feet: almost vertically overhead near the surface, the width of the cut is about 50 feet, and it is said that most of this material was stanniferous. From this winze the lode material is pyritic; crystals of pyrite up to nearly one-quarter inch across occur with green tourmaline: the material is said to carry good tin values. In one instance a splash of molybdenite was noticed in lode material of this description, but apparently the mineral is uncommon. The width of the main quartz-tourmaline vein here is from 3 to 6 feet: its strike at this point is north-west, and dip north-east at 60 degrees. The walls are not well defined, but appear to merge into impregnated zones of country-rock. It is of interest to note that the flat tourmaline vein partly worked, and still showing on the eastern wall, does not show on the western wall of the cut, beyond the main vein. The latter appears to have been irregular in course and structure, consisting essentially of bulges or vughs of irregular size and shape, filled with green tourmaline and kaolin and carrying rich tin values. The vein stuff forming the walls of the vughs frequently carries dense masses of green tourmaline, and is usually encrusted with minute prismatic crystals of quartz: this lode material also carries fine cassiterite.

Little can be gathered as to the condition underfoot, owing to the accumulations of broken material, but it is to be expected that the winzes have been sunk on the most promising ore exposed.

In the face, the width of the softer tourmaline lode material decreased, and the country wall was hard quartzite, so this cut was not continued. Further to the north-west, along the line of strike, another mass of lode material has been worked, from what has been called No. 3 Cut.

No. 3 Open-cut.—As indicated above, this is divided from the No. 2 cut by a block of ore and mineralised country-rock. This block is 15 feet in width. The hard white quartzite of this band carries fairly abundant tourmaline: veinlets of this mineral show vughs in places, several inches in diameter, encrusted with abundant minute prismatic crystals of black tourmaline, and at times small prisms of quartz. This bridge of stone has been extracted to a depth of 15 feet from the surface.

The No. 3 Cut is the most northern of the group, and extends almost to the summit of the spur. The tourmaline vein appears to have consisted of irregular masses of black tourmaline and chalcedonic silica, and included blocks of white quartzite. It is said that vughs of green tourmaline carrying rich tin quite similar to those encountered in the No. 2 Cut were worked here, and there are remnants of such bodies of ore visible in some parts of the workings. A small amount of pyrite was noticeable in some of the black tourmaline in this cut.

The length of the cut is 86 feet from the bridge separating it from the No. 2 Cut: the width varies from 14 feet at the dividing bridge to 35 feet at the point where it connects with No. 4 Cut. For the last 34 feet to the northern face, however, the width averages 5 feet. As much loose detrital material has been tipped into the excavation the depth and condition of the floor material are unknown.

At 33 feet from the southern end is a narrow cut into the north-eastern wall, apparently on soft green tourmaline lode-stuff, which has been tested by a shallow prospecting hole in the face.

At 36 feet in, is a winze, now filled in, which gave connection with No. 4 Cut. Exposed in the wall of the cut above this winze is a vertical fissure striking about east and west, filled with quartz and black tourmaline, which intersects the flat vein on which most work has been done. It is noticeable that this vein widens in places to form small vughs carrying green tourmaline. There is no sign of

the continuation of this vein on the opposite (eastern) wall of the cut. It is not unlikely that this may be one of the "feeders" which have introduced some of the tin values. At 66 feet in, is a winze said to be 35 feet in depth: it was inaccessible.

From this point onwards to the face the lode material is said to have been stoped underfoot to 35 feet. The flat vein cut appears to strike about north and south and dip east at 20 degrees. There is a central vein of tourmaline, bounded on either side by tourmaline with masses of kaolin in places. In the face the main lode channel is not very well defined, and does not appear on the upper portion of the face: the ore consists of very soft kaolin and green tourmaline, with fine cassiterite, occurring in the form of rather irregular vughs. Very rich tin is said to have been won from here.

No. 4 Open-cut.—This is a very irregular excavation, forming the most western of the group of workings. For the sake of convenience in describing the workings, the offshoots from the main-cut are called side-cuts, Nos. 1, 2, 3, and 4. From one of these, as described below, a connection has been made with the No. 3 Open-cut. The length of the main cut is 90 feet; the width varies considerably, but would average about 20 feet. The height of the face is 32 feet.

The material excavated from the main-cut and side-cuts appears to have been largely altered country-rock, but in reality a flat tourmaline vein, similar in general respects to those met in the other workings, was worked, and good tin won. This occurred largely in vughs, as in other parts of the property.

At 26 feet from the entrance, the No. 1 side-cut is driven to the east, and extends for about 45 feet from the centre of the main-cut. A vertical tourmaline vein, with a general strike east and west, has apparently been driven on in this cut, at its intersection with a flat green tourmaline lode-formation, whose strike appears to be a few degrees west of north, and dip east at a very low angle. The latter is continuous throughout the cut, and appears to have been the main source of the tin won. It is exposed on the eastern wall. The normal width appears to be from 2 to 9 inches, but throughout the whole of its course it tends to bulge at short intervals, forming vughs, sometimes of considerable size. The flat vein consists of massive green tourmaline, with impregnations of quartz and black tourmaline on either wall. As exposed in this side-

cut, it sometimes appears as a mere thread, but often bulges to 3 feet or more. In such places it may include masses of country-rock converted to quartzite, traversed by veinlets of tourmaline. These included fragments are usually encrusted with small prismatic quartz crystals, and not infrequently with tourmaline as well. Cassiterite may also be present. In some cases these fragments are completely surrounded by green tourmaline, and this, in turn, by limonite, doubtless derived from the oxidation of a small amount of pyrite present in the ore. A good deal of fine tin is present in the green tourmaline. Kaolin is frequently present with the green tourmaline, and appears usually to be regarded as a favourable indication. The vertical vein referred to above varies considerably, as still exposed in the cut. At one point it is 4 feet wide, while 5 feet away it is only 1 foot. There is a well-defined central vein of fairly massive green tourmaline, and a little quartz, up to 18 inches wide, bordered with a vein-rock consisting essentially of quartz and black tourmaline, with fairly abundant green tourmaline near the central seam, and with geodes of chalcedonic silica. This vein-rock and vein-stone are hard, but carry good tin values in places. The No. 1 side-cut has apparently been driven to allow of the extraction of ore from the junction of these two veins, where good tin is said to have been found. The width of the side-cut is 5 feet at the bottom and 10 feet at the top. Near the face, a hole has been sunk a few feet, and filled in. In the face a comparatively narrow vertical vein appears to cut through the flat formation, showing a marked bulging vertically near the intersection.

At 57 feet from the entrance to the main cut is No. 2 side-cut, extending for 35 feet to the north-east, and connecting in the face with the No. 3 Open-cut. The average width is 6 feet, and height about 20 feet. This side-cut has been driven on the course of a flat tourmaline vein carrying tin values, although much of the material taken out was country-rock. At 20 feet from the main cut a large vugh was encountered extending to the south-east, and was extracted for 14 feet. Rich tin is said to have been won from this part of the workings. This mass of lode-material seems to have occurred at the intersection of two fissures. Exposed in the floor (which is 8 feet above the level of the side-cut) and face are masses of soft green tourmaline associated with crystalline quartz and aggregates of black tourmaline. The richest tin occurs in the soft masses of green

tourmaline. The walls of these vughs are lined with green tourmaline and crystals of quartz. This vugh of lode-material does not appear to have reached the surface. In the face of this south-eastern branch, the upper portion is hard white quartzite, traversed by three parallel veinlets of quartz and black tourmaline, about 7 feet apart, apparently striking a little east of north, and dipping east at 10°. A green tourmaline vein is exposed at the entrance to this branch, near the floor, and appears to be dipping west at a low angle. The lode-material worked in this branch apparently dips to the north-west. On the northern side of this No. 2 side-cut, opposite this excavation, on a big vugh of ore, a winze was sunk to a depth of 30 feet. Soft tourmaline lode-matter (with cassiterite) is said to have been passed through in this winze, being almost certainly a continuation of the vugh worked above. In the face of this side-cut is country-rock blocking the passage, which was broken through to connect with the No. 3 Open-cut.

At 57 feet in from the entrance to the No. 4 Open-cut, on the south-western wall, is rich lode-material, consisting of soft green tourmaline. This is about 15 inches wide, and occurs 3 feet above the floor.

At 86 feet from the entrance, and 4 feet from the face of the cut, a winze has been sunk to a depth of 28 feet. The floor of the cut here has risen about 12 feet in the length of the drive. The width of the main cut here is about 12 feet at the bottom, owing to a small side-cut taken in to the east. The face is in tourmalinised country-rock, said to carry a little tin.

No. 5 Open-cut.—This open-cut is situated on the opposite side of Pyke's Creek to the workings described above, *i.e.*, on the south side, and is distant about 2 chains due south of the No. 2 Cut. The length of the cut is 37 feet, with an additional 18-feet cut as approach to a tunnel which was driven in below the lode-material exposed in the cut. The width is 7 feet at the entrance, widening to 24 feet. The height of the face is about 25 feet. It is said that this work was done by tributers, who started sluicing, discovered a vugh of rich ore, and then commenced working it. The cassiterite is said to be very light-coloured, approaching white, and to have been so fine that it was difficult to save by sluicing. The tin won seems to have been from vughs of white kaolin and green tourmaline, and from what could be learned of

the occurrence, it appeared to be quite similar to those on the opposite side of the creek. From the south-western corner of the open-cut a winze was sunk, though the depth is not known. On the eastern wall a drive has been put in for 12 feet on a slope of 25°. Some tin appears to have been won from here. There is a narrow vein of tourmaline dipping vertically exposed over the entrance to this drive. In the face of the cut two tourmaline veins are exposed, about 6 feet apart, striking about north and south, and dipping east at about 20°. The upper of these shows irregular vughs of green tourmaline and kaolin throughout its course. From the lower end of the cut an adit was driven for a short distance, but has now collapsed. The approach is 18 feet. A tourmaline vein with a very flat dip, containing abundant limonite (apparently from the oxidation of contained pyrite) was cut in the approach, and is stanniferous.

In addition to the workings described above, a little open-cut work has been done on a pyritic formation on the north side of Pyke's Creek, at the southern entrance to the tunnel described below, and immediately below the entrance to the No. 4 cut. The strike is apparently a little south of east, and dip not exposed. The width is about 6 feet. The formation may be continuous with a pyritic body exposed further to the east, and on which a winze was sunk. The lode-material is banded, and consists essentially of green tourmaline and pyrite, with cassiterite. The tourmaline is green, and appears to be massive, but under a powerful lens it is seen to occur in minute needle-like prismatic crystals. The pyrite is abundant, and is in dense aggregates and in well-defined bands through the tourmaline. It is well crystallised, cubical, and pyritohedral forms being common, crystals measuring up to ¼-inch across. In some cases they line and project into open fissures. No crystallised cassiterite is noticeable, but a little very fine grey slime tin is seen in some specimens. Cross fissures are to be seen in places, also filled with pyrite. The walls are not well defined, but the formation appears to merge into slate impregnated with tourmaline. An open-cut, width 5 feet, has been taken along the course of the lode for 25 feet, and irregular workings for a further 10 feet. In the face of the cut is kaolin, with the tourmaline and pyrite. It is reported that this formation carries good tin values, and that an effort was made to treat some of it in a crude way by roasting on a flat sheet, but without great success.

Another piece of work carried out on the property has been the driving of a tunnel through the hill, below the surface workings. This tunnel was driven about creek-level, to connect two sharp elbows in the creek. The length is about 200 feet, and the bearing N. 27° E. Unfortunately, the whole of the southern half of the tunnel could not be examined, owing to the accumulated water, the outlet being blocked. The tunnel, so far as it could be examined, is through tourmalinised and silicified sandstones and slates similar to those occurring on the surface. Several veins have been intersected, some of which are tin-bearing, but no crosscutting has been done. Measuring from the northern entrance, at 23 feet in is a formation of small width striking about east and west, and dipping north at 73°. At 41 feet is a vein 1 inch in width filled with kaolin; also with a strike about east and west, and dip north at 41°. At 48 feet is a very promising vein of quartz and black tourmaline, with kaolin, width 1½ inches, dipping north at 59°. This is seen to be cut through by a vertical fissure filled with kaolin, without displacement. At 52 feet from the northern end is a formation, which should be tested, as it was found to carry tin. The strike is N. 72° E., and dip north at 45°. The width varies from 3 to 18 inches. There are two parallel veinlets of tourmaline, the wall rock being much kaolinised. Limonite indicates the presence of pyrite. This may be one of the "feeders" for the ore-bodies discovered above, and should be driven on. At 58 feet in, is a lode-formation 9 inches in width, striking N. 62° E., and dipping north at 47°. In this formation there is no continuous vein of tourmaline. There are impregnations of tourmaline at intervals, and masses of kaolin, with some quartz. The lode-material is soft, and carries tin. A little pyrite is present. This formation also is distinctly promising, and should be prospected. At 63 feet in is a narrow veinlet of green tourmaline, striking east and west, and dipping north at 52°. It is a matter for regret that the southern portion of the tunnel could not be examined, owing to the water which had collected in the bottom of the drive.

This tunnel served a very useful purpose, for it not only served to prospect the country-rock passed through, and disclosed several tin-bearing veins, but the creek was diverted through it, allowing the whole of the bend around the foot of the spur on which the rich detrital ore was found, to be worked without any trouble. A quantity of

rich tin ore was obtained from this portion of the creek-bed.

Method of Treatment.—Other than sluice-boxes, no plant was erected for the treatment of the ore on the property. No attempt was made to crush any of the ore From the description given above of the occurrence of the ore, it is clear that much of the richest material was soft and required little crushing, and this feature of the ore suggested the method of treatment adopted. The writer has had to rely on information supplied for these particulars. The material was broken in the face, water turned on, the coarse material trucked to spoil, likely-looking lode-matter being roughly broken. The coarser tin collected on the ground, the tailings being run through sluice-boxes, and the forkings rejected. Obviously, such a method of treatment was crude, and the loss must have been considerable. Records show that a considerable amount of tin was won, but naturally there are no records to indicate what the losses were. It must be borne in mind that no classification was attempted. It would seem that considerable losses must have occurred (*a*) from the slime tin, (*b*) from coarser pieces of country-rock with attached cassiterite, rejected during the operations indicated. The slime tin has apparently gone beyond recovery. The dam, which is said to have been constructed lower down the creek to store the slimes with their contained tin for future treatment, broke away with a fresh in the stream, and the contents carried down towards the Little Henty River. It is unlikely that any accumulation has occurred lower down stream, as the creek has, on the whole, a steeply-graded bed. The question then arises as to whether any of the tin rejected in specimen pieces can be recovered. The surface is covered with numerous dump-heaps, which must, in the aggregate, contain several hundred tons of broken stone. Undoubtedly, some of this is stanniferous. It appears from information supplied, however, that since regular work on the mine ceased, the property has been let on tribute, and the dump-heaps picked over. It is questionable, then, whether the average value of the stone, as it lies, would be sufficiently high to pay for treatment. Careful sampling is needed to definitely settle the point, but, in the writer's opinion, the heaps as they stand are hardly likely to carry high enough values when taken in bulk.

Tin Output.—Exact figures as to the tin output from the property are not available. Official records of the

Mines Department show that at least 164 tons of tin oxide are recorded as having been sent out from Mayne's Mine. In addition to this, for several quarters when the property was being worked no record is given of the output from individual mines, the amount being recorded as from "Heemskirk," or "West Coast," and given as a total amount. Forming an estimate for these quarters, based on the amounts produced in other quarters as compared with the total for the district, the writer estimates that about 200 tons of tin oxide have been produced from the property with the small amount of work which has been done.

The dividends paid, as officially recorded, amounted to £4875 between 1904 and 1906.

Future of the Property.—The fact that so much tin oxide has been produced from the property with so little work, immediately suggests that it may not have received quite a fair trial. Rich detrital ore-deposits were discovered on the surface. They were worked, and other deposits discovered *in situ*, which were also worked to a shallow depth. When these vughs pinched, work was stopped, a few winzes being sunk to comparatively shallow depths. In the tunnel driven through the hill, several very promising formations were intersected, which carry good tin values, but no attempt was made to drive along the course of these formations. From the shallower workings it is very probable indeed that other vughs would be met with at no great distance along the course of the veins. Even were other local vughs met with, however, the backs available would be small from such a drive, especially from a drive east from the tunnel. A drive west would prospect virgin country, and is recommended. If permanent work is to be undertaken, however, it will have to be from a main shaft. Before deciding on such work, the nature of the occurrence of tin ore, as described elsewhere, must be carefully considered. The presence of vughs of very rich ore, sometimes of large size, so near the surface, as disclosed by past workings, and the hope of locating other such vughs in future operations, certainly offer an inducement to further work. The writer would unhesitatingly say that the prospects of encountering other such vughs really are good. The lessons of past workings should, however, be kept in mind, which show that the vughs occur irregularly. The writer's study of the old workings, while indicating in a general way the factors governing the formation of the vughs, as explained else-

where,[227] did not give information which would enable any definite forecast to be made as to the occurrence of other vughs. By prospecting the more nearly vertical tin-bearing veins, several of which have been exposed, it is to be expected that whenever conditions are favourable—*i.e.*, when these "feeders" are intersected by other fissures, or themselves intersect beds which are more easily replaced by the vein-forming solutions—that vughs may be met with. The carrying out of costly mining operations merely in the hope of meeting enrichments is not to be recommended without reserve; but the "feeders" themselves, although frequently narrow, often carry rich tin, and the wall-rock has been impregnated to some extent. It is a matter of careful investigation, mainly of sampling and assaying, to determine whether some of these formations cannot themselves be profitably exploited. The key of the situation appears to lie here. If these formations can be exploited without expense, or with little expense, then the work should be undertaken without hesitation, for the almost certain occurrence of vughs at different points is likely to yield handsome profits. These "feeders," or tin veins of the quartz-tourmaline-cassiterite type, are likely to be permanent to a depth within the limits of economic mining. It must be expected that they will vary somewhat in size, and experience has shown that considerable variation may be expected in a very short distance, as the nature of the wall-rock has had an influence in determining the precipitation of the metals from the vein-forming solutions. The granite contact is not far distant, and it is not impossible, if systematic mining were undertaken, that it might be encountered at a depth. Without hesitation, the writer expresses the opinion that the tin veins are likely to continue from the slate into the heart of the granite, without interruption (possibly with the formation of rich ore at the junction), and that the veins will not cut out when granite is reached. In the granite the veins are likely to prove more regular, and assume more normal habits than they have done in the sedimentary rocks.

There are indications that pyrite will be encountered in several of the veins as depth is attained.

The pyritic formation near the southern entrance to the tunnel possesses promising features, and is worth investigating. The tin values and their distribution can only

[227] *Vide supra*, pp. 199–203.

be determined by sampling, and it is not unlikely that they may be high enough to cover the cost of treatment of the pyritic ore. The formation is of an encouraging width, and there is every indication that it will prove continuous, as in the case of the quartz-tourmaline-cassiterite veins described above, well into the heart of the underlying granite. This ore-body should be prospected. If it were decided to work it, such work would have to be carried out from a shaft, and it would naturally be exploited from the main shaft sunk to work the other ore-bodies on the property, if this shaft were determined upon.

With regard to surface prospecting, it is advisable to prospect further to the west and north-west, and try and pick up a continuation of the ore-bodies worked. A few surface trenches might yield valuable information, and such work is to be recommended.

In the south of the section, too, there are indications which should not be lost sight of. In the bend of the creek, below the tin store, and opposite the southern entrance to the tunnel, in the cutting for the fluming is exposed a nearly horizontal pyritic vein, which widens to form small vughs at intervals. This is a very promising vein, and might, with advantage, be tested. In the same locality are several vertical veinlets of green tourmaline, one of which showed tin oxide. The conditions here are clearly favourable for the formation of similar deposits of ore to those encountered on the opposite side of the creek.

Almost on the southern boundary of the section, at the mouth of the cut which has been made in the creek bed, similar indications were noted. Here a vein of dense pyritic material strikes about north and south, and dips east at 10°. Vertical veinlets of tourmaline were also noted, and conditions here are also favourable for deposits of tin ore. This portion of the section should certainly be prospected.

On the whole, the section is one which is full of possibilities, and further work upon it is justified, on the lines indicated above.

(17)—*Section* 3915M, 2 *Acres*—*J. H. S. Munro.*

This section forms a buffer strip about 2 chains in width between the Kelvin Mine (Section 6095M) on the north, and Mayne's Mine (Section 124M) on the south. No work has been done on the section, and its potential value lies

in the amalgamation with either its northern or southern neighbour. It is held by Mr. J. H. S. Munro, who also holds Section 124M.

The country-rock is silicified and tourmalinised slate and sandstone exactly similar to that on the adjoining sections, and it is probable that when the lode-formations are more fully prospected on those sections, some of them will be found to pass through this one. The flat veins at Mayne's Mine may do so, but their lateral extent has not yet been proved.

The section includes portions of both eastern and western slopes to Pyke's Creek, the creek flowing through the eastern half of the section.

(18)—*Section* 6095M, 40 *Acres—H. V. Williams, G. O'Brien, and T. Buckley (Old Kelvin Mine.)*

This section is situated immediately to the north of, and partly adjoining Mayne's Mine (Section 124M). The 2-acre section 3915M partly separates the two properties. The section is 2½ miles due south of Mt. Agnew. The Zeehan-Trial Harbour Road passes through the north-western corner of the section: the branch road to Mayne's Mine runs through the property along the top of a ridge on the western side of Pyke's Creek, but this eastern slope is steep and the workings are connected with the main road by a branch road running almost due north outside the eastern boundary of the section. Pyke's Creek flows through the section in a very tortuous course, entering near the north-western corner, flowing east-south-east until within 3 chains of the eastern boundary, when it takes a general southerly course (with several bends) to the southern boundary. A branch creek also flows about south, just within the eastern boundary. These creeks are cutting into the old peneplain, rendering the surface very uneven, and advantage has been taken of this feature in mining operations.

Reference should be made to Plate VI., in which is included a sketch map of this property.

This section includes part of the old Orient Company's ground, and some of the workings carried out by this company in the early history of the field are now within its boundaries. Later the property seems to have been worked for a time by the Kelvin Company.

The south-eastern corner of the property is on Pre-Silurian sedimentaries, the remainder being granite of

Devonian age, which has intruded the older sediments. The latter are much altered, being silicified and tourmalinised in a smiilar manner to those at Mayne's Mine. The old Orient Company's workings were mainly in granite (though never far from the contact), while those of the present owners have been almost entirely confined to the slate and sandstone country. Lode-formations occur in both areas, and in one instance a quartz-tourmaline vein appears to be continuous from igneous into sedimentary rock: this still requires proof. Speaking generally, the lode-formations in the granite are normal, while those in the sedimentary rock have many features in common with those at Mayne's Mine.

The workings and plant of the present owners are all situated in the southern portion of the section, and on the western side of Pyke's Creek. The workings consist of four adits, two open-cuts, some underhand stopes from the surface, and trenches.

At the time of the writer's visit work was only being carried out in the No. 4 adit, driven from a small (No. 2) open-cut, within about 2 chains of the southern boundary of the section.

No. 1 *Adit*, a little above battery-level, is inaccessible, and no information is available concerning it.

No. 2 *Adit*, higher up the hill, has been driven for 25 feet on a bearing N. 48° W., through altered sedimentary rocks. This was driven to connect with some surface workings above, and it was proposed to make it the main working adit for this part of the property. A narrow pyritic vein was cut in the face, carrying good tin values. An aneroid reading indicates that this adit is about 80 feet below the summit of the hill, but this figure needs checking.

On the hillslope above this adit are surface workings on good tin ore. About 25 feet above the adit is a surface cut exposing some rich tin ore. There is a narrow vertical seam with kaolin and cassiterite, and it was noticed that this intersected several narrow veins dipping only at a very flat angle: good tin values are said to have been obtained from the intersections. The main vein on the hillside in this vicinity, on which small open-cuts and narrow underhand stopes have been taken out, has a bearing of N. 65° W., and dip apparently about vertical.

On the same line near the top of the hill are workings for about 3 chains: rich ore occurred here, consisting of

grey cassiterite in green tourmaline, and has been taken out for an average depth of between 10 and 15 feet. The formation here is very promising, and is undoubtedly worth prospecting at a lower level.

On top of the hill are more shallow surface workings on good ore. A flat vein of green tourmaline about 12 inches in thickness has been partly opened up, and carries good values: there appears to be a vertical vein going underfoot.

By the side of the branch road to Mayne's Mine along the crest of the ridge, the shallow workings expose green tourmaline veins carrying good tin. Some specimens obtained here showed botryoidal grey cassiterite quite similar to that described from Mayne's Mine. The sandstones forming the country-rock in this vicinity are silicified and tourmalinised. The actual granite contact is distant about 3 chains to the west and about the same distance to the north, the line of contact making a bend in this vicinity. On the opposite (western) side of the road and distant 1 chain from the workings described, is a shallow trench, partly filled in with loose surface material, which does not give any definite information.

About 10 feet south of the No. 2 Adit, and on the same level, on the eastern slope of the ridge, is a small cut of 14 feet, and a drive 17 feet south, on a flat seam of tourmaline, which widened from 12 inches to 6 feet, and then appeared to cut out, although a vertical vein of green tourmaline continues in the face, with a strike N. 55° W. Rich tin was got at the intersection of the vertical with the flat seam. On the surface the outcrop of the flat seam indicates that it is dipping west at a low angle. In the face of the cut is a second vertical vein parallel to that met in the drive, which seems to be continuous through the cut. The nature of this occurrence does not seem to have been understood, but the bulge of ore which apparently cut out, was a vugh formed (by processes explained elsewhere) at the intersection of a vertical " feeder " vein with a flat fissure. Further prospecting in the vicinity may be expected to disclose other similar " makes " or vughs along the course of the vein.

No. 1 *Open-cut* is about 100 feet south of the occurrence noted above. The material from this cut was excavated by the Kelvin Company, who drove into the hill, got rich tin, and sluiced the lode material, which seems to have been oxidised. The cut extends almost to the summit of the ridge. At the lower end there is a narrow cut of 100 feet in length, probably representing the old drive: the

main cut then opens out to between 15 and 20 feet, the bottom being fairly level for 16 feet. From the edge of this level, the distance is 100 feet to the top of the cut, on a slope of 35 degrees, the width at the top being from 50 to 60 feet.

The lode-formation here appears to have been quite similar to that elsewhere on the property and at Mayne's Mine, viz., intersecting flat and steeply dipping veins of soft green tuormaline and kaolin, with vughs of various sizes at the intersections and frequently rich tin. The main " flat " vein driven on, appears to strike about east and west and dip north at 25 degrees: it is said to have varied from 2 to 6 feet in width, and to have yielded 6 per cent. of tin in the portion worked. It is reported that 14 tons of tin oxide were won by the Kelvin Company from this No. 1 Cut by sluicing. From the southern wall of the main open-cut is a drive, now collapsed, said to have exposed good tin values in a pyritic formation: this appears to be at the intersection of a flat and vertical vein of small width. From the south-western corner of the open-cut a drive was extended for 31 feet on a tortuous but general westerly course through a series of veins of tourmaline with kaolin and rich tin, apparently striking about north-west, and dipping north-east at 10 degrees. In the face of the cut is a narrow vein of green tourmaline striking N. 80° E., and dipping south at about 70 degrees.

From the northern side of the No. 1 Open-cut an adit has been driven on a pyritic formation, and this has been called the—

No. 3 *Adit.*—This was driven to prospect a pyritic formation which is said to carry an average of 6 per cent. tin. The workings are in a very bad state of repair, and the formation could not be examined in detail. The drive extends 24 feet north: at 16 feet from the entrance are crosscuts 5 feet east and 21 feet west. From the western crosscut is a drive 6 feet south, and from this again another drive 12 feet west to the face. Some stoping has been done, particularly from the end of the 21-feet drive west, but it is probable that the amount of ore taken out has been small. The lode material consists of kaolin with a little tourmaline impregnated with pyrite, which occurs in cubical and pyritohedral crystals rarely reaching one-eighth inch in diameter. The tin content is estimated by the owners at 6 per cent. Owing to the state of these workings, the structure of this formation was not clear, but it appears to be a flat vein with vughs at intervals.

No. 2 Open-cut.— This cut is also on the eastern hill-slope, about 90 feet south of No. 1 Cut, and about 1½ chain from the southern boundary of the section. Some good tin values were won from this cut, which is taken for 19 feet into the hillside. The width of cut is 25 feet, and height of face 15 feet. In the face are exposed three tin-bearing formations, two nearly vertical, and one with a flat dip to the east: the country-rock is tourmalinised quartzite. On the southern side of the cut is a vein of irregular width which reaches the surface, where its width is 12 inches. It increases to 18 inches in a few feet, and then splits and includes a " horse " of country-rock: the width of vein about 6 feet above the floor of the cut is 6 feet. The vein here has split, one branch extending to the surface, tapering out to a narrow veinlet. The lode material is of the usual green tourmaline variety, with some kaolin and a little limonite in places. The strike is east and west and dip south at 50 degrees. On the northern side of the face is another similar formation of irregular width. A drive has been commenced on this, but extended only 3½ feet. A second drive has been commenced in the face and taken in for 6 feet on a vein of green tourmaline, with kaolin and nodules of limonite (derived from the weathering of pyrite). This vein appears to strike about north and south and dip east at 40 degrees. Exposed in the face of the cut near the present floor is a vein carrying abundant green tourmaline and kaolin, with nodules of limonite, and fine grey cassiterite. This appears to strike about north and south and dip east at from 10 degrees to 15 degrees. In the south-western corner of the cut a winze was sunk 5 feet on rich tin ore of the variety described above. Over this winze an adit was being driven at the time of the writer's examination of the property, called the No. 4 Adit.

No. 4 Adit.—This was driven on the flat vein cut in the face of the No. 2 Open-cut near the floor of the cut. It had been driven 23 feet in a rather irregular course of 8 feet south and then 15 feet nearly west. The width of the formation exposed by this drive varied from 1½ to 5½ feet, and was similar in nature to that exposed in the cut. Nodules of limonite are not infrequent with the green tourmaline and kaolin, and these sometimes carry rich tin, usually finely divided. This limonite is almost certainly derived from the oxidation of pyrite which will be found to be present in the primary ore. A narrow vein exposed in the face was carrying good tin values: the strike was

north-west and dip south-west at 70 degrees. In this adit only the richest ore was being extracted. This was being wheeled in barrows to the edge of the open-cut, tipped into a chute, and again wheeled by barrow to the battery. The stone being crushed was certainly carrying good tin values.

On the summit of the hill above the No. 2 Open-cut, on the western side of the branch road to Mayne's, and within a chain of the southern boundary of the section, is a shallow trench running east and west, with a branch north and south from the western extremity. A good deal of surface material had accumulated in the trench, preventing a detailed examination, but no lode material appears to have been exposed. The sandstones are silicified and tourmalinised as on other parts of the property.

Most of the other workings on the property appear to have been carried out by the old Orient Company, but reference may be made to them, although little is to be seen in most instances at the present time.

The site of the old Orient battery is in the south-eastern portion of the section, and about 2 chains from the eastern boundary. All the machinery has long since been removed, and the battery site is a good deal overgrown, which is not surprising as it is 30 years since the old mine shut down. On the southern wall of the excavation is a promising ore-body exposed in the sedimentary rocks. This is a vein of the quartz-tourmaline-cassiterite type, apparently striking about north and south, and dipping about vertically. This vein appears to be worth testing. It cannot be followed on the surface, and it is uncertain whether it is the same formation which was intersected in the old " mica tunnel " a few chains south, which is referred to below.

On the northern side of the battery site some rich tin ore was located. It is said that 1 ton of tin oxide was taken from this spot. The old water-wheel was erected here, and one of the old bed-logs is resting in green tourmaline, which is stanniferous: at this point there are vughs similar to those on other parts of the property, connected with a flat tourmaline vein. There is a narrow cut, from the end of which a shaft has been sunk, and the cut itself continued in the form of a drive. This work was done on a massive green tourmaline vein of the type so favourable for tin in the locality, this vein having a strike N. 78° W., and dip about vertical. A shaft is said to have been sunk, a drive put in to connect, and the lode material above stoped to the surface, but not underfoot. It is 40 feet from the

entrance of the cut to the shaft, which is said to be 16 feet below the bottom of the cut: no work appears to have been done from the shaft below the present level. The drive on the course of the vein just beyond the shaft has now collapsed: this drive is said to have been continued from the face for 30 feet. The face is 20 feet high. The width of this vein as exposed varies from 3 to 6 feet. The ore won is reported to have been sluiced, with the result that 1 ton of tin oxide was recovered. This ore-body should certainly receive further attention: not only is the main vein important, but the presence of at least one flat vein near the surface, which carries good tin values, indicates that vughs of rich ore may be expected at intervals as work proceeds.

Mica Tunnel.—This is so called because of the large masses of mica encountered. The adit was driven about east into the hill from a point on the creek-bank about 2 chains a little south of west from the old Orient battery site. Unfortunately the adit has now completely collapsed, and there is only the old approach and dump-heap to indicate that such work had been carried out.

Mr. G. Thureau, Government Geologist, examined the Orient Mine in 1884, and in the course of his report gives the following description, which apparently refers to this adit, as no other was noticed by the writer which would correspond in position, as referred to the battery.

([228])" Their deep adit, which has been started considerably below the hoppers at the battery, has been driven for a distance of 300 feet, and it will eventually give 50 feet under the present bottom of the whim shaft in this drive. Thorne's lode, it is believed, was cut at 250 feet, very regular and fairly tin-bearing; further on the Wheel lode, which was exposed when making room at the hillside for the ore-crushing and dressing machinery, was intersected at 250 feet in from the entrance for a width of 12 feet, carrying a little tin ore, but not at all tested further. Another small lode, one foot wide, designated the Dam lode, also somewhat stanniferous, and at the end of this adit promising spurs 3 inches thick were discovered. . . It should be mentioned that the Wheel lode, where intersected in the deep adit, though greatly decomposed and containing much soft argillaceous vein-matter, still yielded fair prospects of ore."

([228]) *Vide* "Report on the Western Mining Districts," by G. Thureau, 1884, p. 11.

This information is interesting and points to the advisability of an investigation of these ore-bodies. The only other information available was contained in a letter to the writer concerning the old Orient Mine, with which he was familiar in the early days of its history, by Mr. Luke Williams, who states:—"There is a strong lode which was cut when putting up the battery; it carried payable tin at the battery, and in the tunnel driven from the creek (Pyke's Creek) just below the battery, the lode was from 9 to 12 feet wide, mostly rank-smelling iron pyrites and much mica, but only carrying traces of tin. This lode is worth further prospecting." This description apparently refers to the lode-formation in question. The specimens on the old tip are interesting, and it is a matter for regret that the formation from which they were derived was not available for inspection. There are three varieties of material, two of which are obviously connected, and from the same formation, the other appears distinct. A striking feature is the occurrence of large masses (up to 12 inches in diameter) of aggregates of phlogopite mica. This mineral occurs in hexagonal plates reaching 1½ inch across. The only noticeable mineral present with the mica is a little white tremolite. Specimens are usually partially weathered from lying exposed on the heap for so long. Attached to some of the aggregates of mica is white quartz with finer crystals and aggregates of phlogopite disseminated through it. This forms the connecting link with the second class of material on the heap, viz., translucent white quartz, showing at times a crystalline structure, with disseminated phlogopite, which sometimes becomes abundant, fluorite both lilac and greenish, in aggregates, and molybdenite in crystals up to one-quarter inch diameter scattered through the mass of quartz or in small crystal plates with fluorite, lining the walls of fissures which traverse the quartz. The occurrence of molybdenite is of particular interest, but unless further work shows it to be more abundant than it is in any of the specimens seen, it cannot be regarded as of economic importance. The richest specimen collected would not assay more than 1 per cent. molybdenite. The third class of material on the heap consists of a dense aggregate of greenish crystals forming a dark-green rock, with scattered pyrrhotite distinguishable. The green mineral was determined as hornblende in hand specimens. Occasional crystals reach a length of one-half inch and width of one-quarter inch, while in some specimens crystals cannot be distinguished in the fine-grained black

aggregates impregnating quartzite, evidently the country-rock. A thin section was prepared from a variety of medium texture, and a microscopical examination showed that the bulk of the slide was occupied by hypidiomorphic crystals of colourless to very faint-greenish amphibole. Aggregates of olivine crystals with irregular outlines are common, showing rough cracks along which incipient serpentinisation has taken place. Magnetite is abundant in ragged grains and aggregates, frequently included in both the other minerals mentioned: associated with the magnetite are aggregates of pyrrhotite which sometimes includes small quantities of chalcopyrite. No quartz or mica are present in the slide examined. The rock is not derived from a normal tin-vein, and would appear to be more closely allied with the contact metamorphic deposits. Whether it is derived from the same formation as the quartz-mica-fluorite rock described is somewhat uncertain, but the matter must be left in abeyance until some exposure of the material *in situ* is available.

The amount of backs available from this adit would be small, unless a fairly long adit were driven, but a little further prospecting of the formations is justifiable to determine their nature. Although molybdenite was not present in any quantity in the specimens on the tip, richer bunches may occur in the formation, which appears to be very favourable for its development. Tin may also occur.

About the centre of the section, on the eastern slope towards Pyke's Creek, a very promising lode-formation has been exposed in the granite country, within less than 2 chains of the contact. Below the water-race a cut has been put in for 10 feet on the course of the formation: this is the only work done. At this point the strike is N. 70° 30′ W., and dip vertical. The width varies from 4 to 6 feet, but will probably average 4 feet 6 inches. The ore-body is a typical quartz-tourmaline-cassiterite vein. The central veinstone varies from 6 to 9 inches in width, and is composed of an intimate mixture of black and green tourmaline, bordered on either side by 12 to 18 inches of green tourmaline. This material carries no visible quartz: the central seam is sometimes intersected by horizontal veinlets of green tourmaline which may attain a width of 1 inch. The outer portion of the vein-rock consists of hard quartz-tourmaline. The quartz grains are fairly coarse, and both green and black tourmaline are present in dense aggregates: the green variety in places is pseudomorphous after felspar, while the black not infrequently occurs in radiating

aggregates. The walls are fairly well defined. The granite in the vicinity is the medium-grained white variety, carrying disseminated black tourmaline and narrow veinlets of the same mineral.

A few feet above the race the outcrop has been exposed again, but no work done. The outcrop cannot be traced further west. This vein should be sampled at the different points exposed, and if surface indications warrant it, an adit could be driven from creek-level along the course of the formation, and would yield valuable information with regard to the shoots of ore.

What appears to be a continuation of the same formation, is an outcrop exposed on the summit of the ridge to the east. The outcrop has not been cut across, and it is impossible to tell its width or structure in detail. Masses of green tourmaline with vughs of crystalline quartz occur, also harder quartz-tourmaline stone with abundant green tourmaline and a little of the black variety in sheaves and radiating aggregates. The outcrop is said to carry good tin values at this point. The position of this outcrop is shown in Photo No. 22, on the summit of the hill in the left centre of the picture. There is more quartz-tourmaline rock showing, about 2 chains north of this, which has not been prospected.

On the western slope of the hill towards the branch of Pyke's Creek which traverses the eastern portion of the section is an old adit driven by the Orient Company in granite. This is about 1 chain inside the eastern boundary, and 9½ chains from the south-eastern corner. The old adit has collapsed and partly filled with water, and was quite inaccessible. Its bearing is N. 42° E. On the tip is pyritic ore, consisting essentially of quartz with a little scattered tourmaline and some pyrite. In the old race above, a quartz-tourmaline vein 18 inches in width has been cut, but no work done on it.

Several outcrops occur on the summit of the hill just east of the eastern boundary of the section.

Exposed on the northern boundary of the section in the road cutting is a series of parallel quartz-tourmaline veins striking about east and west. One of them attains a width of 3 feet, and carries pyrite. The locality is worth a little prospecting.

Plant and Treatment.—A small treatment plant was erected by the present owners of the property on the western bank of Pyke's Creek at the foot of the hill, and about 4 chains west of the old Orient battery site. A

general view of the plant is shown in Photo. No. 22, which was taken facing a little east of north. Water is brought from Pyke's Creek by a race which has its intake on the northern boundary of the section. The water is utilised to drive a water-wheel, which in turn drives a small three-head battery, which has very light stampers. Hand-feeding is employed for this battery. The pulp is fed on to a small Wilfley table, also driven by the water-wheel. A fairly high grade product is produced, the middlings being re-treated, and the slimes passing over a canvas table, thence into a box sump, overflowing to waste. The fine slime tin from the canvas tables is found to be purer than that from the Wilfley. Mr. Williams states that the former assays about 70 per cent. tin, and the latter over 60 per cent. The chief impurity is iron oxide (limonite) from the nodules occurring in the ore. With regard to quantities treated, Mr. Williams stated that in April, 1914, the plant had been crushing for about eight months, that 300 tons of ore had been treated, producing concentrates worth approximately £800 net.

Future of the Property.—This property is worth the attention of investors. It has been shown that on more than one part of it formations carrying good tin values exist, although practically no developmental work has been done to open them up and allow of any estimate being formed of quantities available for treatment. The erection of a crushing and concentrating plant to treat the ore is certainly an advance on the sluicing methods previously employed, and is to be commended. But the present plant cannot be regarded as satsifactory for continuously working the property. The battery serves well as a purely prospecting mill to test small parcels of ore, but it will not be found economical when mining is undertaken on a larger scale. The question of available power was not closely investigated, but it seems likely that it could be utilised to better advantage by installing a Pelton wheel instead of the water-wheel at present in use. This would enable the Wilfley to be run at a higher speed, with the result that a cleaner separation would be possible. It is advisable, too, to instal a classifier to deal with the crushed battery product, as a concentrating table cannot efficiently deal with an unclassified product: comparatively large lumps of the impurities will always tend to find their way into the concentrate with smaller fragments of the cassiterite, since two particles of unequal size of minerals of very different specific gravities may have the same weight.

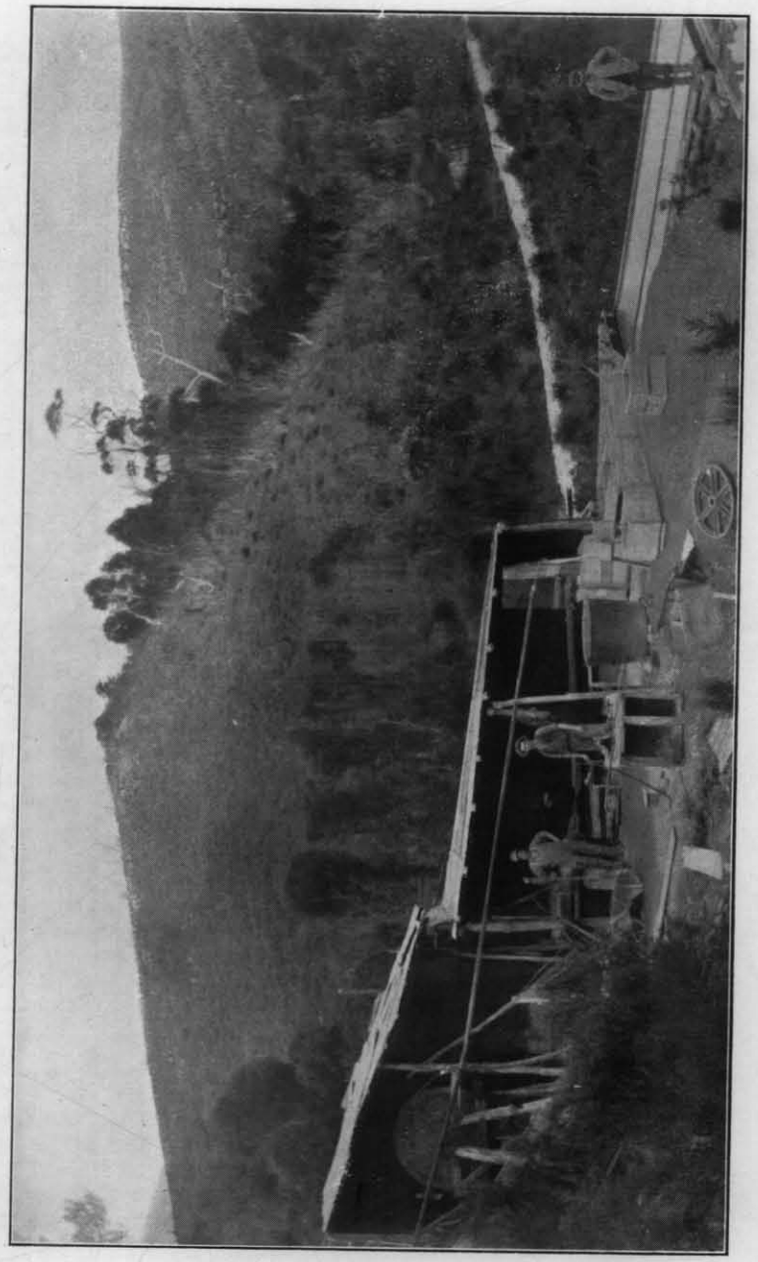


PHOTO. 22.—BATTERY AND CONCENTRATING TABLES, KELVIN TIN MINE.

[L. Lawry Waterhouse, Photo.

The canvas strakes employed at present are saving a good deal of very fine slime tin, but the writer would advise a careful test being made without delay to determine definitely the tin oxide still present in the slimes going to waste. These were not sampled by the writer, but it will probably be found advisable to instal longer tables.

The present system of working out only the very richest patches of ore, leaving all the rest for future treatment, is to be deprecated, particularly when the profits from such treatment are not being utilised in developing fresh bodies of ore, or providing for a more efficient treatment plant. Such a policy if continued is likely to end disastrously.

Mining can for a time be carried on from adits, but when serious mining operations are commenced, provision will have to be made for sinking a main shaft. It is scarcely possible at the present stage of the work to select the most suitable site for such a shaft, so that it could serve the greatest number of ore-bodies. Further work on these will indicate more clearly their relative value.

With regard to the nature of the ore, there are indications that in most cases the primary ore will prove to be pyritic, but this fact, while increasing the cost of treatment, does not under modern conditions prove an insuperable barrier. There is nothing definite to indicate at what depth pyritic ore will be encountered in those ore-bodies which at present are being exploited in the oxidised zone, but apparently the depth will not be great.

The structure of the ore-deposits in the sedimentary rocks on this property is apparently quite similar to that of the corresponding deposits on Mayne's Mine adjoining to the south, and the remarks made in connection with that property as to the structure, continuation to a depth, &c., apply with equal force to this section. While vughs of rich ore may be encountered at any time, the conditions governing their occurrence cannot be determined with sufficient accuracy to enable any forecast to be made as to where they may be expected: in planning future work, therefore, no allowance should be made for such vughs, when estimating the probable amount of ore available.

In the immediate future a main adit will have to be driven into the western slope, from somewhere about battery-level, and this work should not be delayed too long until all the rich patches of free milling ore near the surface are exhausted. At the same time, as opportunity offers, the other ore-bodies on the property should be prospected and sampled: that at the old Orient battery site in the

sedimentary rocks, and that crossing the race on the western side of the creek, in granite rock, are worth immediate attention.

Thus the property, while not yet beyond the prospecting stage although it is producing tin ore, has very decidedly encouraging prospects.

If it were possible to effect an amalgamation between the Kelvin and Mayne's Mines, including the intermediate 2-acre section held by Mr. J. S. Munro, it seems to the writer possible that both properties might be systematically prospected, and eventually worked, in a more comprehensive way than would be possible with each mine in a smaller way independently.

(19)—*The Old Orient Mine.*

Part of the workings of the old Orient Tin Mining Company are now included in Section 6095M, held by H. V. Williams, G. O'Brien, and T. Buckley (the old Kelvin Mine), which has been described above. The workings within the boundaries of that section have already been described, and it seems desirable to refer briefly to other workings which were examined.

Some interesting particulars concerning the old Orient Mine have recently been furnished to the writer by Mr. Luke Williams, who was on the mine in the early days of its history. As Mr. G. Thureau, Government Geologist, described the property as he found it, in his report of 1884, it seems scarcely necessary to rewrite this description. Mr. Williams states, "Like all the other mines at Heemskirk it [the Orient Mine] was not a success. The tin did not live more than 30 feet below the surface in the surface shoots of ore, and sufficient development work had not been done, consequently, with the high freights . . . and tin at about £45 per ton for oxide . . . . the mine could not be worked at a profit. . . . The lodes were strong and well defined, but only carried, as a rule, from ½ per cent. to 1 per cent. metallic tin, but the prospectors had 'estimated' them at 4 per cent. metallic tin."

The writer of this letter goes on to say that the shareholders refused to believe that their property needed developing, and insisted that a battery and treatment plant should be erected to treat the ore they were satisfied existed. As a result, this battery was the first on the field to start crushing, early in 1884. Mr. Thureau, in his report, states, "360 tons of ore gave 55 bags, or 2 tons 15 cwt. of cleaned ore."

With regard to the workings other than those described in connection with Section 6095M, little is to be seen at the present time.

About 5½ chains south from the north-eastern corner of Section 6095M, and about 1 chain east of the eastern boundary, is a short adit driven into the western slope of the hill. This is in granite country. The workings were in a state of partial collapse, and could not be examined in detail. The adit has been driven for about 40 feet on the hanging-wall side of a quartz-tourmaline vein, which strikes N. 62° E., and dips south at 65°. At 30 feet from the entrance was a rise to the surface, only about 15 feet. From the stone exposed in the approach there appears to be a narrow central vein of black and green tourmaline, with quartz-tourmaline vein-rock on either side. This is rather close-grained, with abundant green tourmaline, scattered radiating sheaves of the black variety, and some of a light-brown colour. Occasional geodes occur lined with small prismatic crystals of quartz, and not infrequently geodes lined with chalcedony, a rather unusual occurrence in these veins. Some fine brown cassiterite was noted in one specimen. Some of the stone on the tip is pyritic.

This formation outcrops on the hillside for 5½ chains, the width varying from 6 to 10 feet. At about 3 chains from the adit are a trench and shallow shaft on the formation, and this appears to be the only prospecting work carried out on a promising vein.

About 3½ chains on is another quartz-tourmaline outcrop, which does not appear to have been prospected, striking N. 40° W.

On the summit of the hill is a big quartz-tourmaline outcrop, striking N. 50° W., probably that called "Thorne's Lode," by Thureau.

There is a good deal of lode-material lying on the surface, about ½-chain south. This is not seen definitely *in situ;* and may represent either (*a*) loose detrital, (*b*) a parallel formation, or (*c*) a faulted portion of the main lode.

About 9 chains east of the north-eastern corner of Section 6095M is an old shaft by the side of the branch road into the Kelvin Mine. This shaft is timbered, but no information is available as to its depth, or the work carried out from it.

Another shaft a few chains east may have been the main shaft of the old company. The tip is of considerable size. The shaft itself is in disrepair. The quartz-tourmaline stone on the tip carries white mica, indicating that a vein of the greisen type has been intersected.

On the edge of the timber is another shaft, which shows pyritic quartz-tourmaline vein-stuff on the tip. An old road was constructed to this vicinity. To the east is rather low-lying swampy ground. About 3 chains to the north-west are some old alluvial workings. The area worked is about 2 chains by 1 chain. The wash appears to have been about 2 feet deep, and to have consisted of sub-angular quartz-tourmaline vein-stone, with abundant green tourmaline and occasional geodes of quartz crystals. On the southern edge of this worked patch (which discloses a granite bottom) is a bold quartz-tourmaline outcrop, which is promising for tin, and is worth sampling.

It will thus be seen that little information can be obtained from an examination of the old Orient workings, as they are at present, and no opinion can be expressed as to its future.

(20)—*Section* 3555M, 25 *Acres.*

This section is immediately to the south of Mayne's Mine (Section 124M), and was formerly known as Connor's Section. No work is being done on it at the present time, and the section is not held.

Pyke's Creek flows through the western portion of the section, and the bed of the creek was found to carry rich alluvial. This is not at all surprising when the nature of the occurrence at Mayne's Mine, a few chains to the north, is remembered. The tin won was quite similar to that at Mayne's, and there can be no doubt of its having been derived from the same deposits, and gradually washed down stream and concentrated by natural agencies. The deposits appear to have been detrital, rather than true alluvial, and of no great depth. Official records show that at least 8 tons of tin oxide were recovered, but the amount was probably greater than this, as for several quarters the whole output from the district was given in one figure, and was not allocated to the several mines which were working. Although these deposits have been worked out, the section is certainly worth prospecting, as conditions are favourable for deposits of tin ore, similar to those on Mayne's, being located. The country-rock is sandstone and slate of Pre-Silurian age, silicified and tourmalinised.

(21)—*Section* 1392M, 40 *Acres.* (*Wolfram-Bismuth Mine, south-east of Mayne's Tin Mine.*)

The exact position of these workings could not be located. They are about east-south-east from Mayne's Tin Mine, a distance of about $\frac{3}{4}$-mile. They are on the Little Henty fall, just above creek-level, on the south-western bank of a creek flowing about south-east. The mine is probably about in the northern portion of Section 1392M, 40 acres. The workings are in a state of disrepair, and no detailed examination of them was possible. A trench was cut for a length of between 60 and 70 feet, about 6 feet deep and 3 feet wide. This trench was covered with timber, and mullock and ore stacked on top. It is only partly accessible for examination. A shaft was sunk at the western end of the trench, but is now full of water. The depth is not known, but it is probably not very great. A few feet to the west of the shaft a small open-cut was put into the hillside, and after taking this in for a few feet, two small cuddies were driven from it, apparently only a few feet in. These are in a state of collapse, and the entrance only was available.

The country-rock is slate and sandstone of Pre-Silurian age, a good deal metamorphosed. To the north-west the sediments are silicified and tourmalinised. At the workings, lime-silicate rocks are abundantly developed, and although they form a fairly broad belt, and were traced down the creek for 2 chains, their extent could not be ascertained on account of the dense scrub. Reference is made to these rocks elsewhere.([229]).

The trench is cut through hard, greenish tremolite rock, with magnetite and pyrrhotite. Traces of chalcopyrite are noticeable in places. The quartzose ore showing on the dump-heap on the surface does not appear to have been cut in the trench, and probably came from the shaft, which is quite inaccessible. Lenses of dense granular magnetite of small width have been cut in places. The limonite present in places indicates that pyrite is present, although it is not noticeable in hand specimens. The mineral is present in microscopical slides examined to determine the true nature of the lime-silicate rock.

In the entrance to one of the cuddies put in from the open-cut a few feet west of the shaft, a dense pyritic body, with quartz, has been cut. The width appears to be 2 feet, and the strike about north-east. Little information

([229]) *Vide supra*, p. 129.

can be obtained owing to the collapse of the cuddy. Specimens of the pyrite collected oxidised very rapidly. Marcasite may be present with the pyrite, although none was seen.

A careful examination of the dump-heaps gave some indication of the reason for this work, which could not be determined from an examination of the workings available. Much of the material is lime-silicate rock, varying in colour from fine-grained to moderately coarsely crystalline, sometimes showing granular magnetite. Most of the material on the heaps has evidently been lying about for years, and shows signs of weathering.

A striking feature is the presence of fairly abundant fragments of quartz, almost invariably showing crystalline structure. Many of the pieces show massive fragments coated with projecting prismatic crystals, varying from almost microscopic size to about ⅓-inch in diameter. sometimes fragments are coated on two sides by such crystals, and may also contain small geodes within their mass. This has evidently been the "ore" worked, as metallic minerals occur associated with the crystalline quartz. Soft black masses representing decomposed pyrite are common, with occasionally fragments of the fresh mineral. Occasional crystals of wolframite are present, and the same mineral sometimes occurs in more massive form round the base of the quartz crystals. In some of the geodes, very fresh plates of bismuthinite (sulphide of bismuth) occur, always associated with wolframite. Although it might be expected to occur in such an association, no sign of any cassiterite was seen on the property.

An old puddler and sluice-box indicate that an attempt was made to treat some of the material on the spot. An examination of some of the material from the old box shows that wolframite is present.

The writer could obtain no information as to whether any concentrates had been sent out from the mine.

On the north-eastern side of the creek is a shaft a few feet deep on limonite and magnetite. This appears to be a contact-metamorphic deposit of iron ore, and does not present any very promising features as exposed.

A grab sample was taken from the heap on the surface, and submitted to the Government Assayer, Mr. W. D. Reid, for analysis, who reported:—

Tin	0·32 per cent.
Tungstic acid (WO_3) ...	0·105 per cent.
Bismuth	Trace

While this sample was not taken in bulk in such a way as to determine the true average value of the heaps, the result is useful as indicating the presence in material in which none of the ore-bearing minerals was noticeable, of tin, wolfram, and bismuth. The values are not very encouraging.

A sample was taken from the dense pyritic body west of the shaft and submitted to the Government Assayer, who reported:—

Tin	0·46 per cent.
Tungstic acid (WO_3) ...	0.047 per cent.
Bismuth	0·012 per cent.

Although these values are low, it should be worth while trying to trace the outcrop of this pyritic body for a short distance on the surface, expose it by trenches, and sample at other points, to determine whether shoots of richer ore do not occur.

Little can be said about the prospects of the property, as the ore was not seen *in situ*. Nothing can be said as to the width of the ore-body. The lime-silicate rocks, with magnetite and pyrrhotite, exposed in the trench, cannot be regarded as ore. The cassiterite, wolframite, and bismuthinite, with their accompanying crystalline quartz, appear to have been formed by pneumatolytic agencies, and are connected with the intrusion of the granite. The minerals are primary, and cannot be regarded as having been formed near the surface only, but would continue to depth. The question of treatment of tin-wolfram-bismuth ores appears to have been at least partially solved, and marketable products can be produced by subjecting the ore to electro-magnetic concentration. The presence of magnetite and pyrrhotite, however, both magnetic minerals, is to be noted, though these could probably be separated by a lower-power magnet. Under existing conditions there cannot be said to be much inducement to work the property, beyond a little surface prospecting, as recommended above.

(22)—*Section* 6743M, 80 *Acres—C. Brumby.* (*Healey and McIvor's Mine.*)

This section was formerly charted as 4393M, E. Healey, J. McIvor, C. Brumby, and O. J. Reiher, and was known as Healey and McIvor's Mine. It is on the southern slopes of the Heemskirk Range, and about 1 mile a little

east of south from Mt. Agnew. The section is heavily timbered, and carries thick undergrowth, making a detailed examination difficult. The country-rock is granite, and the mine is situated about a mile from the line of contact.

Access to the property is given by the pack-track which branches off the main Trial Harbour-Zeehan Road on the flats near the Agnew Creek crossing, and continues through to the Federation Mine. This track enters the section at the south-eastern corner, and crosses and recrosses the southern boundary several times before bending south-west out of the section. The elevation of the point near the southern boundary where the ore chute crosses the pack-track, as determined by aneroid readings, is 1340 feet above sea-level. The northern portion of the section is considerably higher.

The steep slope of the surface offers facilities for economical working, which have been taken advantage of. The work carried out has been by open-cut, and adits driven into the hillside.

The lower adit, nearly 100 feet above the track, is inaccessible. The entrance was blocked, and the tunnel used as a dam for the storage of water. The adit was driven about north, and is said to have intersected a tin-bearing quartz-tourmaline vein, but to have been discontinued without being extended far enough to intersect the lode-material exposed higher up on the hill. This adit is within a few chains of the southern boundary of the section.

About 2 chains north of the lower adit are the main workings. There is an excavation connected with the surface by a short tunnel. This cut is about 35 feet long (north and south) by 6 feet wide at the bottom, and 50 feet by 40 feet at the surface. The depth is about 30 feet. The structure of the lode-formation which has been worked is not clear from the present excavation, but it would appear to have been a zone of granite impregnated with tourmaline and cassiterite, and probably pyrite, from several intersecting fissures. Fairly abundant kaolin is present, and the granite itself is altered and decomposed. These changes are probably due to the action of the mineralising solutions, and not merely to atmospheric weathering. A feature of the exposed faces is the presence of nodular masses of varying size. One of these, which was very well defined was oval in section, and measured 18 by 24 inches. It consisted of a rim of limonite and gossanous material 4 inches in thickness, with a soft kernel of kaolin and tourmaline, carrying good tin values. There is much quartz-tourmaline stone on the tip, but only narrow veins appear *in situ*. The strike of what appears to be the main vein is N. 18° E. On either side of it are vughs with much limonite-stained kaolin and a little tourmaline, with crusts of hard limonite. Another vein strikes N. 75° E., and an examination of the exposed faces shows that the granite is traversed by a series of intersecting veinlets. In one narrow vein there was a well-defined central seam of soft kaolin, with tourmaline and cassiterite, bordered by normal hard quartz-tourmaline vein-rock. Fissures traverse the granite in various directions, some of which show slickensides, indicating that some movement has taken place.

A small drive was extended from the floor-level into the southern face, and another drive into the northern face of the cut, but these were both inaccessible.

It is reported that a large quartz-tourmaline outcrop occurred on the surface above where the main cut now is, that the company holding the property at the time sank a shaft between 25 and 30 feet on this, and drove about 10 feet east into granite. This shaft is said to have passed through soft tin-bearing gossan, as well as hard quartz-tourmaline stone. Tributers then drove the small tunnel and excavated the present cut. As mentioned below, the lower adit which was commenced by the company was not driven far enough to come below this cut. The quartz-tourmaline stone on the heap contains abundant green tourmaline in aggregates of very minute prismatic crystals. These sometimes occur projecting into miarolitic cavities, which are rather common in the stone. These cavities frequently contain clear crystals of quartz, which is also fairly abundant in glassy crystals throughout the mass of the stone. Doubly-terminated prisms of quartz are noticed in some of the cavities. Kaolin is frequently present in aggregates through the stone, and occasionally filling narrow veinlets. Irregular masses of limonite indicate that pyrite has been present in the unaltered stone. Much of the stone is traversed by narrow parallel fissures filled with minute needlelike prisms of dark-green tourmaline. Gossanous nodules are not uncommon on the heap.

Specimen pieces showing cassiterite indicate that it occurs in aggregates of very minute crystals of a light

brown colour, frequently encrusting the sides of geodes. It is usually closely associated with green tourmaline, and sometimes with crystalline quartz.

Two chains west of the main cut is a small cut into dense green tourmaline. The width of the formation is not exposed. A little quartz is showing in places, and some specimens show a little fine tin oxide, but the bulk of the lode-material is soft, massive, green tourmaline.

About 50 feet further west is the western adit. This is, unfortunately, inaccessible, the workings being used as a reservoir by blocking the entrance and allowing water to accumulate. The adit is driven about north, and is said to be 150 feet in length. No crosscuts, winzes, or rises appear to have been carried out. It is reported that no granite was met with, the drive being in ore all the way, and that the quartz-tourmaline vein was cut through in all directions by flat and inclined veins from 1 to 4 inches in width, of soft kaolinised material rich in tin. On the tip is a considerable quantity of quartz-tourmaline stone. There is little variation in the stone exposed; it is hard, and comparatively fine-grained, consisting of about equal quantities of quartz and green tourmaline. The grains of quartz appear to be embedded in a groundmass of tourmaline. Occasional fragments of a dense green tourmaline, with small geodes of quartz crystals, are to be seen.

To try and obtain some idea of the tin content of this quartz-tourmaline stone, a sample was taken by chipping pieces off from stone over the whole heap. This was submitted to Mr. W. D. Reid, Government Assayer, who reported—

Tin ... ... 0·14 per cent.

This value is lower than one would have expected from the class of stone, and is not encouraging. Unfortunately, no samples could be taken from the lode-material *in situ*.

The width of the formation at the western adit is not exposed, but it must be considerable. Similar stone to that on the heap outcrops higher up the mountain slope, but here, again, the width cannot be determined from the available exposure.

The formation is about parallel to that worked at the open-cut, but has no connection with it.

This is the extent of the work done on the property, which had been idle for some time when the writer inspected it.

An attempt was made to treat the ore on the property. The stone from the main cut workings was sent down to the 5-head battery erected near the southern boundary of the section, below the pack-track, by a wooden launder, into which it was shovelled and kept wet by a jet of water. The slope of this ore chute was 27°. No particulars are available with regard to quantities treated by the battery and concentrating table, or the results of this treatment.

It is probable that the fine tin oxide present in the kaolin and gossan would need careful attention. The great difficulty appears to be that of getting water on to the property, and this has not been overcome. Although the section is traversed about its centre by the Agnew Creek, this is a very small stream, and the volume of water carried by it is too small to be of much practical use. No examination was made of the slopes above this section, in the absence of any tracks through the dense timber and scrub, but it seems improbable that any storage basin exists which could be utilised. It is possible that there may be small water-falls over some of the cliffs observed from the coastal plain, but the volume of water would probably be too small and too intermittent to be of much practical value. The first question to be decided is whether payable ore exists in sufficient quantities to warrant such expenditure, and if satisfied on this point, to choose between (*a*) a steam-driven plant, (*b*) sending the ore to a more suitable spot by some cheap method of transit, such as by an aerial tram, and then utilising water-power at this site. In the writer's opinion neither course is justified in the present state of the mine.

With reference to the ore-bodies on the section, unfortunately little information is available upon which to base a decided opinion. The body of ore taken out from the main cut appears to have been formed by the alteration and replacement of a mass of granite at the intersection of two or more fissures, by mineralising solutions introduced through those fissures. It is likely that if prospecting work be continued, other bodies of ore will be located, and these bulges may occur both laterally and vertically. The quartz-tourmaline vein traversing the cut with a strike of N. 18° E. appears to be the main "feeder," and the writer would recommend that a winze be sunk for a short distance from the bottom of the cut on the course of this vein, to determine whether any improvement takes place within a reasonable distance.

Where vughs are formed, such as those worked out, they are irregular, and no prediction can be made as to their occurrence. Very few feet of sinking may be required to locate another mass of ore below the present workings, while, on the other hand, a fairly extensive barren zone may be passed through. The risk is worth taking. This work will give some clue as to whether the lower adit should be continued. The writer is not aware how far this has already been driven. It may be so far in that it would be preferable to continue driving rather than commence sinking, and this should certainly be done if much water be encountered in sinking. But work should not be confined to this one point, and prospecting is recommended north and south of the present cut to try and determine whether other shoots of ore do not occur along the line of strike of the main vein. The comparatively large amount of limonite present in the ore worked indicates that pyrite may be expected to make its appearance at a greater depth. If tin values are sufficiently high, however, this fact should not discourage further work.

Should developments warrant the work, deeper adits could be driven to obtain a larger amount of backs. This work is not justified at the present stage.

With regard to the formation on which the western adit is driven, the position is unsatisfactory. The value of a single grab sample over a heap of ore must not be exaggerated; it may be unreliable. It is possible that in a length of 150 feet several shoots of ore may have been passed through, and that the material now lying on the surface of the heap is from a low grade area between good ore-shoots. Careful sampling, at regular intervals, of the ore exposed in the adit is recommended before undertaking any further work here. Surface samples along the line of outcrop should also be taken to determine whether well-defined shoots of ore occur, and what may be their extent and value. If this work gives no encouraging information, the continuation of the adit in the hope of finding better ore is not recommended. It is advisable, however, to crosscut east and west at intervals to expose the full width of the formation. It is possible that the adit may have been driven in a poor portion of the ore-body, and that richer zones occur. Short crosscuts would determine this point. A lower level adit can be brought in, if warranted, to prove this formation at a greater depth.

The treatment problem need not be considered until a reasonable tonnage of ore has been opened up. When this stage is reached, the enquiry will follow the lines indicated above.

Probably other outcrops may occur on the property, but it is difficult to locate them in its present condition.

While not a developed mine, this property has prospects which justify some further work being carried out upon it, on the lines indicated above.

(23)—*The Old Globe Mine (Section* 4735-M, 10 *Acres).*

The old mine, known as the Globe, and afterwards as the Agnew Mine, was visited, but could not be exactly located on the chart. It is from ½-mile to ¾-mile north of the Trial Harbour Road where the Agnew Creek crosses, and an old track branching off the Federation pack-track leads to the mine, which is situated on the southern slopes of Mt. Agnew, about 970 feet above sea-level, and about 350 feet above the Agnew Flat on the road. The mine appears to be on Section 4735M, 10 acres, which is vacant.

The ore-body is situated within the borders of the normal Heemskirk granite, but the exposed contact with Pre-Silurian sedimentaries cannot be many chains to the east, though hidden by the surface soil and dense undergrowth of the locality.

The "mine" consists of an adit driven into the hill-side, but now inaccessible. It is unfortunate that such an interesting occurrence should not be available for inspection. Some time was spent in carefully examining the material lying about on the dump-heaps to try and form a true idea of the nature of the ore won, and the conclusions arrived at resulted from this inspection.

Brief reference was made to the vein-type represented, by Mr. G. A. Waller, in his report of 1902,([230]) but no description was given of the property or its prospects.

Reference has already been made to the occurrence by the writer.

The adit from which the ore was won is inaccessible. It is driven in a direction about N. 75° W. The ore-body as cut is said to have been 5 feet wide, and to strike about north-east and south-west. The drive is said to be over 200 feet in length, and the shoot of ore which was worked

([230]) *Op. cit.*, pp. 9, 10.

to be about 30 feet long. Whether any attempt was made to locate other shoots, and whether any crosscutting was done from the main adit, could not be learned.

The minerals present are galena, tetrahedrite, chalcopyrite, blende, pyrite, cassiterite (?), quartz tourmaline, siderite, and fluorite.

No treatment plant was erected, but the ore was hand-picked, and two grades of ore produced and sent away for treatment—(*a*) galena and fahl-ore, rich in silver, (*b*) chalcopyrite. Quantities of ore despatched are not available, nor prices obtained. The fact of this separation into ores of different grades being possible, clearly indicates that the minerals did not occur intimately mixed, and the same feature is exhibited by specimens collected on the dump-heaps. There is a tendency in some specimens for the galena to occur with tetrahedrite, a little blende, and sometimes pyrite, with or without acicular crystals of quartz lining vughs in the lode-matter. Many of the fragments, however, show a banded structure, which may indicate crustification in the lode itself. In some specimens the ore consists of alternate bands of quartz, quartz and green tourmaline, and then metallic minerals—galena, tetrahedrite, blende, and pyrite. The characteristic gangue mineral accompanying the abovementioned metallics, is siderite. Vughs occur in quartz with coarsely crystalline siderite, and the metallic minerals mentioned. Similar vughs also occur in massive green tourmaline. In several of these vughs nests of green and amethyst fluorite were noticed. Tetrahedrite is present in irregular scattered masses, with siderite, in a fine-grained quartzose groundmass. It is also noticeable in veinlets with crystals of pyrite and prismatic crystals of quartz, in masses of green tourmaline. Pyrite occurs in crystals in this groundmass, which show the forms of the cube and the pyritohedron. A crystalline mass of quartz sometimes forms the groundmass for scattered crystals of galena, blende, pyrite, and siderite, and amorphous masses of tetrahedrite and chalcopyrite. No cassiterite was noticeable in any of the specimens examined.

A grab sample was taken from the heap of ore lying at the mouth of the adit, and submitted to the Government Assayer, who reported:—

Tin	0·37 per cent.
Silver	29 oz. per ton
Gold	Nil

Unfortunately, owing to the fact that the workings were not available for inspection, little can be said with regard to the future of the mine.

It is likely that other shoots of ore will be found, but it is doubtful whether the general character of the ore will vary much. The ore is likely to be complex in character, owing to the overlapping of the vein-types, but it is not improbable that patches of ore may be located, which would well pay to extract. Shoots of tin ore may be encountered in driving on the course of the formation.

The fahl-ore is held to be primary, and not merely a mineral formed by the recognised processes of secondary enrichment. Thus, the silver values may be expected to be more permanent than could be looked for in a lode-formation which has undergone secondary enrichment.

(24)—*Contact Metamorphic Deposit on the Agnew Creek, North of Trial Harbour Road.*

The exact position of the deposit to be described could not be determined, but it is approximately shown on the accompanying map. It is on the Agnew Creek, at a bridge on an old track branching off the Trial Harbour Road to the north, near the junction of the present pack-track to the Federation Mine.

Very little work has been done, and the object of this work is not clear, unless merely to determine the nature of the deposit. The outcrop is exposed in the bed of a small creek, near an old dam, and a small water-race has its intake at the outcrop.

A small cut into the creek-bed is the only work done.

The width of the mineralised belt is apparently about a chain, but it has not been fully exposed. The general strike is about north and south, and the deposit shows a well-defined banded structure, corresponding with the stratification of the country-rock, some bands of slate being unreplaced, others only partially replaced. The deposit is a contact metamorphic replacement deposit. Although it is in sedimentary rocks, the actual line of contact with the intrusive granite is only about 100 feet distant. The granite is coarse-grained pink granite (white on weathered outcrop), with abundant tourmaline-filled fissures.

The surface ore is coated with limonite, and fresh faces are necessary to determine its true nature. The metallic

mineral most abundantly represented is pyrrhotite. The mineral is magnetic as usual, and occurs sometimes in rather massive bands, but usually distributed in aggregates throughout the ore-body. With the pyrrhotite are small amounts of pyrite and chalcopyrite: the latter mineral occurs in little more than traces. Magnetite is not abundant, but occurs in granular aggregates in some bands, and very finely granular masses in the groundmass of other parts of the deposit: the mass as a whole affects the magnetic needle, and renders it useless in any attempt to determine direction. There may be a small amount of blende present, but the determination is not quite certain, and if present at all, the mineral is only in traces.

The most abundant gangue mineral is a very pale-greenish amphibole, this mineral with pyrrhotite forming the bulk of the deposit. Biotite is present abundantly in some bands, but on the whole is subordinate in amount to the amphibole. A noteworthy feature is the presence of fluorite in appreciable amounts. This mineral is usually colourless and transparent, but is sometimes tinted green: it occurs sometimes in coarsely-crystalline masses in certain bands, or in granular aggregates with the other minerals. In one fissure crystals of fluorite were noticed, while closely associated with it, and lining the walls of the fissure, are abundant radiating aggregates of green tourmaline crystals. A close look out was kept for cassiterite, but none was seen. The absence of quartz is worthy of note.

The occurrence of the fluorite and tourmaline in fissures suggests that these minerals have been introduced subsequently to the consolidation of the main deposit.

Reference is made in another part of this report([231]) to the result of a microscopical examination of thin sections of several specimens: in addition to the minerals mentioned above, talc is present in abundance in certain bands of ore.

A comparison of this deposit with that of the Mt. Lindsay Mine, Parson's Hood, is interesting. The latter has recently been fully described by the writer([232]).

From the description given above, it is fairly clear that the deposit cannot be regarded as of any great economic value. The only mineral detected which might conceivably render the deposit of economic importance, is chalcopyrite, but this is an accessory mineral, occurring only in traces, and there is no sound reason for believing that it will increase to any appreciable extent.

([231]) *Vide supra*, p. 131.
([232]) Geol. Surv. Tas. Bulletin 15, pp. 65-97.

The proximity of the granite, and the presence of fluorite and tourmaline in the deposit, at once suggest that tin may occur in appreciable quantities: none has so far been located, and even if some is found to be present in the narrow fluorite-tourmaline veins, the prospects of its occurrence in payable quantities in this type of deposit are not very bright.

Thus there is little to encourage further developmental work being carried out on this deposit.

(25)—*Agnew Creek Alluvial.*

In the vicinity of the Agnew Creek, 1½ mile south-east of Mt. Agnew, the Zeehan-Trial Harbour Road crosses a fairly extensive flat on which some work has been done. This flat is partly included in Sections 1499M, 1869M, 1501M, 3470M, 3718M, and 3717M. The granite-slate contact traverses several of these sections, but there are no surface outcrops, as the rock is covered with a deposit of alluvial material derived from the higher ground, and this deposit was found to be tin-bearing.

Work in the locality has been very intermittent, and at the time of the writer's visit, two men were employed.

In his "Report on the Progress of the Mineral Industry of Tasmania for the quarter ending 30th September, 1900," the Secretary for Mines states (page 8): "The Mount Agnew Alluvial Tin Mining Company, holding about 60 acres near Mt. Agnew, has begun hydraulic sluicing. During the quarter a dam capable of holding 70,000 gallons of water has been constructed, and water-races of 37 and 18 chains cut, also a tail-race 10 chains. The fall from the dam to sluicing ground is 110 feet, and the length of piping 1200 feet. A paddock 50 feet by 33 feet has been stripped showing wash of an average depth of 3½ feet. Only one nozzle has been started, but preparations are being made for two more."

No further reference can be found to the operations of this company, which do not appear to have been successful. The writer was not able to locate definitely the site of the company's workings, as various patches have been worked at different points on the flat. The plant referred to has long since been removed.

The depth of the alluvial material exposed varies somewhat, but averages about 3 feet: it consists essentially of quartz-tourmaline stone from various veins on the slopes above, and occasional boulders of granite. The stones are

mainly sub-angular to rounded. The amount of overburden is slight, varying from a few inches to about 2 feet. Where exposed, the bottom is mainly granite, with slate to the east.

The deposit appears to be partly a recent accumulation of detrital material derived from the weathering of veins outcropping on the higher ground, but the rounded nature of some of the material suggests that it has been subjected to more grinding and pounding than such material would be likely to have received. It is not unlikely that it may represent older alluvial material which has been redistributed. In the discussion of the geological history of the field elsewhere, it has been shown that part of the old land surface was worn down by the long-continued action of weathering agencies, almost to base-level, the gradient of the streams becoming so flat that the burden of rock-debris could not be carried to the sea, and was deposited. Probably some such deposits were formed in this locality, and the recent uplift of the surface rejuvenated the streams, allowing these older deposits to be cut through and redistributed.

Some good patches of tin ore have been worked from time to time, but these have all been small, and the main troubles appear to have been (*a*) the patchy distribution of values in the ground, (*b*) the difficulty of getting an adequate supply of water on to the ground. It is doubtful whether any expensive scheme for getting water on to the ground is justifiable in view of past experience of the nature of the wash.

Thus while it is unlikely that any large number of men will be employed, these deposits will probably be worked intermittently by single men and small working parties when water is available.

(26)—*Section* 6667M, 80 *Acres*—*H. D. Marsh.*

This section is situated about 2 miles east of Mt. Agnew, and about 1 mile south-west of the Kynance (old Silver Stream) Mine, Comstock. It is on low-lying ground east of the foothills of Mt. Agnew, which rises steeply on this side. Portion of the section is occupied by a low marshy flat, through which gabbro-amphibolite outcrops at intervals. The whole of the section is very heavily timbered, and in most parts the scrub is so thick as to be impenetrable: consequently, no accurate mapping of the boundaries of formations was possible.

Access is given by the Zeehan-Trial Harbour Road, which approaches to within less than one-half mile of the property. From the road, a track led to the deposit about to be described: this, however, is completely overgrown in places, and in consequence the ore deposit is difficult to locate. At comparatively little expense, however, connection could be made with the road if occasion demanded, and the proximity of the road is a distinct advantage.

With regard to geological formations, no accurate mapping was carried out owing to the difficulties mentioned above. Attempts were made to locate corner pegs of the section without success. It appears, however, that the extreme north-western corner of the section is occupied by granite, the western half by contact metamorphic slates and lime-silicate hornstones, and the eastern half by gabbro-amphibolite.

The compass is so strongly affected at certain points as to suggest the presence of probably several magnetite bodies on the section. So far as the writer was able to find out, only one body has been definitely located, and the work done on the section has been confined to the partial exposure of this deposit: its position was not exactly located, but it appears to be about the centre of the section, or perhaps somewhat to the south-west of the centre. The outcrop was cut through by a small creek, and the amount of work carried out on it has been small, consisting of an open-cut into the creek bank. The length of the cut is 25 feet, width at entrance 15 feet, height of face 12 feet. This cut is taken on the strike of the formation, which appears to be about east and west, although where exposed in the vicinity the strike of the slates of the country-rock appears to be more nearly north and south. The full width of the deposit has not been exposed, as the cut is on the south side. The average width exposed in the face of the cut is about 10 feet: the deposit is narrowing somewhat in the face, measuring 12 feet in width in the upper part, and 8 feet in the lower part of the face: the width sampled was 10 feet.

The metalliferous minerals of the deposit are magnetite and blende, with a small quantity of pyrite in places: the gangue minerals are various silicates of lime and magnesia, the minerals noted being diopside, serpentine, chlorite, talc, and phlogopite. A description of these lime-silicate hornstones is given elsewhere, with the results of an examination of several thin sections of the rocks.([233]).

([233]) *Vide supra*, pp. 132–133.

The ore-body consists of irregular masses of magnetite and blende, with varying amounts of lime-silicates: frequently for several feet the ore is composed almost entirely of magnetite and blende, or it may be traversed by veinlets of diopside, or contain small amounts of greenish lime-silicates in the groundmass, indistinguishable in hand specimens. There is no defined banded structure in the ore-body as exposed; usually the magnetite and blende are very closely associated, although fairly pure masses of both minerals occur. Even in the purer magnetite, however, crystals and aggregates of blende are usually distinguishable in the groundmass. The ore is not uniform: in a few inches it may change from almost pure magnetite to almost pure blende. Sometimes masses of almost pure blende occur, bounded sharply by magnetite, but showing no walls. It is important to consider whether masses of blende occur which could be separated from the lower grade material, and which would be sufficiently pure to form a marketable product. The irregular masses of blende exposed in the present face are usually not more than a few inches across, but there is always the possibility of the masses widening. Where they do occur, the masses of blende are usually fairly pure, and it appears that some attempt has been made (successfully so far as the grade of ore is concerned) to hand-pick some of the high-grade blende.

A noteworthy feature of practically all specimens examined is the presence of small amounts of pyrite: this mineral is never present in large quantities. It sometimes occurs in minute veinlets traversing the magnetite and blende, more often in scattered crystal aggregates. The presence of pyrite in the magnetite is important when the latter is considered as a possible source of iron ore. A sulphur content is decidedly detrimental, and if it rise high enough, may nullify the value of the material as an ore of iron of economic value.

There is no well-defined wall to the formation exposed in the work done. Outside the boundaries of the main deposit are irregular masses (usually of small size) of magnetite and blende enclosed in the lime-silicate rock. Some of these masses of blende appear to be very pure.

No work other than this open-cut appears to have been done on the deposit. The exceptionally thick scrub at the time of the writer's visit rendered any attempt to trace the extent of the deposit futile.

An old tramway was constructed from the deposit for some distance, but is now in a state of disrepair, and there

are no signs that it crossed the boggy flat which lies between the property and the road, although some old timber suggests that a corded track was formed for at least part of the distance.

On the edge of the flat, between the road and the property, and about half a mile from the road, is a heap of from 4 to 5 tons of blende: this appears to have been hand-packed to its present position from the deposit described above. It evidently represents hand-picked ore, and an examination shows that it is remarkably free from magnetite. The inference is that purer blende occurred in the portion worked out than is exposed in the present face. A grab sample was taken from this heap and submitted to Mr. W. D. Reid, Government Assayer, for analysis. Mr. Reid reported:—

Zinc	40·81	per cent.
Iron	20·4	per cent.

A sample broken across the face of the open-cut, width 10 feet, was assayed by the same officer, who reported:—

Zinc	7·39	per cent.
Iron	23·4	per cent.

(27)—*Section* 892M, 80 *Acres (Nickel Reward.)*

This section is situated about 1½ mile east of Trial Harbour, and wholly within the area of Devonian serpentine, which has been previously described. A certain amount of work has been done to prospect an occurrence of nickel ore, but the section is vacant at the present time.

On the site of the old township of Remine there is a coastal strip, varying in width up to about ½ mile, of comparatively level ground, when the ground rises rapidly to the coastal peneplain. It is on the summit and slopes of this hill that the work has been carried out. The situation of the workings is well shown in Photo. 7.

No corner-pegs were available, and hence the exact position of the nickel ore on the section could not be determined.

The serpentine of the locality is very frequently covered by a crust of limonite,([234]) but outcrops of the rock are to be noticed in places. The presence of nickel was betrayed in an outcrop on the summit of the hill overlooking Trial Harbour, by the green stains in partially

([234]) *Vide supra*, pp. 215–217.

weathered specimens. A shaft was sunk here on the summit of the hill, about 200 feet above sea-level, for a depth of 26 feet, and an adit (called for sake of convenience No. 1 Adit) was driven in from the hillside to connect.

Lower down the hillslope, another adit (No. 2) has been driven. These workings are on the summit and western slopes of the hill. Some chains to the north, at about 80 feet below the summit, an adit (No. 3) has been driven south from the northern hillslope.

About the collar of the shaft on the hilltop, green nickel stains are noticeable in the serpentine in places, and it would appear that these stains have induced the work to be carried out. In the absence of ladders and a rope, no examination could be made of the shaft itself. At a depth of 26 feet, this shaft connects with the No. 1 Adit driven from the western slope of the hill. About 15 feet west of the shaft, on the brow of the hill, the serpentine carries an appreciable quantity of magnetite in streaks, irregular masses of magnetite slightly stained with manganese, and masses of radiating rosette-shaped aggregates of white brucite, associated with occasional tabular hexagonal crystals of the same mineral. These specimens are occasionally stained with bright apple-green garnierite.

The No. 1 Adit appears to have been of the nature of a prospecting drive, for it is too near the crest of the hill (26 feet below) to be of value as a working adit, as it would not open up sufficient backs. It has been commenced from the southern slope of the hill. The abundant magnetite in the vicinity affects the magnetic needle, and renders compass readings of little value. The adit is driven a little east of north for a total distance of 80 feet into the hill, the approach being 14 feet. At 47 feet from the entrance crosscuts extend west and east 21 feet and 17 feet 6 inches respectively. The shaft from the surface connects at 47 feet, and at this point a winze was sunk for 21 feet 6 inches.

The striking feature in this vicinity is the variety of secondary minerals met with in the serpentine. The rock is traversed by veins filled mainly with various lime and magnesia minerals. These minerals have been described more in detail elsewhere([235]), the principal being magnesite (carbonate of magnesia), arragonite and calcite (carbonates of lime), dolomite (carbonate of lime and mag-

([235]) *Vide supra*, pp. 41–47.

nesia), brucite (magnesium hydrate), deweylite (hydrous silicate of magnesia), pyrolusite (manganese dioxide), limonite (hydrated iron oxide), selenite (sulphate of lime), opal and chalcedony (silica).

The serpentine exposed in the No. 1 Adit is much fissured, and carries these minerals in abundance. No information was available as to the class of stone met during the progress of driving or with regard to the exact locality from which the ore on the dump-heaps was obtained. The examination of the walls of the drive was not very satisfactory owing to the length of time the adit had been open, but a partial cleaning down disclosed some interesting information. At about 20 feet in, nickel ore was noticeable *in situ* on the western side of the adit. The serpentine here is traversed by numerous veinlets of a greenish opaline mineral, which proves to be deweylite. There are smaller quantities of a darker-coloured mineral with similar characteristics, also in veins. Arragonite is also present in some veins in radiating masses, these veins being sometimes 3 inches in thickness. There is a main fissure of narrow width, nearly vertical, filled with greenish deweylite, and from this lateral branch veins extend on either side, some of these being about horizontal. The serpentine, which carries visible pentlandite, is surrounded by these veinlets of deweylite, the pentlandite being also included in the latter mineral, which has apparently impregnated the serpentine to some extent. The relation of this deweylite to the pentlandite is discussed in the chapter on Economic Geology.([236]) The nickel mineral is closely associated with magnetite. The serpentine in the vicinity is stained green, with garnierite derived from the weathering pentlandite, and from this point onwards along the course of the adit stains of garnierite are particularly noticeable along the more or less horizontal veins of deweylite which traverse the serpentine. The drive appears to have followed one well-defined horizontal vein, which shows green nickel stains almost continuously. At 47 feet in, the serpentine shows abundant stains of garnierite, various flat veins of deweylite and arragonite showing such stains to a marked degree. Pentlandite is visible occasionally in small quantity with magnetite, disseminated through the serpentine. At this point crosscuts have been driven, a winze sunk, and the shaft connected with the

([236]) *Vide supra*, p. 187.

surface. Apparently some at least of the high-grade ore on the heap at the mouth of the tunnel came from this portion of the workings, but no information was available, and the matter could not be definitely decided, as no similar rich ore was noticeable *in situ* at this point. The eastern crosscut extends 17 feet 6 inches through similar serpentine to that described carrying secondary lime and magnesia bearing minerals, and showing green nickel stains in places. The shaft from the surface, 26 feet, connecting in this eastern crosscut adjoining the main adit, is not available for inspection. In the roof of the crosscut at this point, however, there is seeen to be a vein striking about east and west, which is impregnated with limonite. This gossan band appears to be of very irregular width, varying from 6 to 18 inches. This gossan shows abundant nickel stains. It seems likely that the crosscuts may have been driven at this point to prove this vein, with the idea that it was a true vein of nickel ore.

The western crosscut has been driven for 21 feet through similar serpentine to that described above, still showing some stains of nickel. A winze was sunk from this crosscut, adjacent to the main adit, to a depth of 21 feet 6 inches. The upper portion only of this winze could be examined, but the serpentine appears to carry nickel here also. Veins of deweylite are noticeable, sometimes carrying garnierite, and a little scattered pentlandite is present in places.

In the face of the main adit, 33 feet beyond the crosscuts, no nickel ore was noticeable. The serpentine is seamed with veinlets of pale-green deweylite, intersecting at all angles. At times veins split and again coalesce, including areas of serpentine. Many of these veins of deweylite are traversed by veinlets of pyrolusite (manganese dioxide). A sample was broken from the face of the main adit, and submitted to Mr. W. D. Reid, Government Assayer, for analysis. He reports—

Nickel ... ... 1·9 per cent.

On the dump-heap at the mouth of the adit is a heap containing a few cwt., evidently, of hand-picked ore. This shows pentlandite freely in places, almost invariably associated with magnetite, the serpentine being light-green in colour, and sometimes slightly stained with garnierite. The writer was unable to find out from which part of the workings this ore was extracted. The pentlandite is always disseminated through the serpentine; no massive

sulphide was seen. A grab sample was taken from this heap and assayed by the Government Assayer (Mr. W. D. Reid), who reported—

Nickel ... ... 18·6 per cent.

An examination of the dump-heap showed that the ore had not been very carefully hand-picked, and a certain proportion of the serpentine on the heap also showed disseminated pentlandite. A rough sample was taken of this material, essentially to act as a check on that taken from the heap of ore, and as a result of his assay the Government Assayer reported—

Nickel ... ... 14·6 per cent.

About 1 chain north of the No. 1 Adit is a small open-cut extending for about 10 feet into the serpentine. On the outcrop at the brow of this cut is abundant white, radiating brucite, which includes granular aggregates of magnetite, a little recognisable pentlandite, and not uncommon splashes of bright-green garnierite. A narrow vein of fibrous chrysotile was noticed in one specimen, while deweylite and arragonite were also observed as fissure-fillings. Obviously, nickel is present in the serpentine at this point, but apparently not in such quantity, as it occurs a little further south.

About 40 feet below the No. 1 Adit a second adit (No. 2) has been driven about east into the hillside. The total length is 157 feet, with an approach of 11 feet. At 92 feet in, the drive bends a few degrees north, but no crosscutting has been done. The magnetite in the serpentine affects the compass, so that exact bearings could not be taken.

Although less nickel ore has been exposed in this adit than in No. 1, the nature of the serpentine passed through is very similar. About 5 feet from the entrance some green stains of garnierite were noticed, evidently derived from a small amount of nickel sulphide in the rock. No other ore was noticed *in situ* in the adit, although scattered pieces of oxidised ore are present on the dump-heap. These may have been derived from the surface outcrop. For 50 feet the serpentine is weathered, and numerous veins of secondary minerals are noticeable, frequently dipping west at a low angle. The minerals noted in these veins were deweylite, arragonite, calcite, dolomite, magnesite, and abundant stainings of pyrolusite. Towards the face of adit, the serpentine is fresher, bluish-grey in colour, and showing aggregates of magnetite. This serpentine is less

frequently traversed by similar veinlets of secondary minerals.

At about 50 feet from the entrance a fissure was intersected which dipped south at 20°, and which is noticeable in the drive for about 30 feet. This appears to be a fault-plane, for the serpentine on either side of it appears to be a good deal disturbed; secondary minerals are developed here also.

It is unfortunate that the work carried out at this point has not been successful in opening up a further supply of sulphide ore similar to that exposed by the No. 1 Adit. The adit has not been driven far enough to reach a point vertically below the ore in No. 1 Adit.

A few chains to the north of these workings, on the northern slope of the hill, and about 80 feet below the summit, No. 3 Adit has been driven in a southerly direction. This adit is not available for inspection, and its length could not be ascertained. The writer proceeded for about 50 feet, but found that the adit had been driven on a down grade, and water had accumulated. For this 50 feet decomposed serpentine is exposed, carrying veins of chalcedony, magnesite, calcite, and deweylite. Occasional slight stains of nickel are noticeable, but no sulphide ore was observed.

The mode of origin of the nickel deposits has been discussed elsewhere,[237] and from the explanation given it is clear that an accurate forecast of the future of the property is impossible. The ore, apparently, occurs in irregular masses, whose extent can only be determined by sampling. The veins of secondary minerals so abundant in the serpentine have no genetic connection with the sulphide ore, whose boundaries are ill-defined; in fact, the ore grades into serpentine, being merely a particular variety of that rock, in which the nickel-bearing minerals had become concentrated. Thus, systematic sampling is suggested as the only practicable method of determining the true extent of the ore.

Undoubtedly some rich ore does exist, but the work carried out up to the present indicates that the available quantity is not large, and its distribution uncertain. As described above, however, the amount of work done is small, and further prospecting might result in the discovery of larger bodies of ore. It is doubtful, however, whether such work is justified by present prospects,

[237] *Vide supra*, pp. 187–188.

although the writer considers that sampling of the serpentine exposed, particularly in No. 1 Adit, is justified, to determine actual values and extent of ore *in situ*. Should the results of this work be sufficiently encouraging to justify further work, this adit might well be extended a few feet, as nickel is present in the face, and then the lower (No. 2) adit might be continued for a short distance. There can be little doubt about ore being found at greater depths, but it is not possible from indications near the surface to predict what the behaviour of such a body of ore as that under consideration is likely to be, *i.e.*, whether it is likely to continue vertically, or whether it may extend laterally, beyond the limits indicated by exploratory work near the surface, or whether the actual shoots encountered may gradually merge into serpentine which does not carry payable nickel values.

Thus, while there are certain promising indications on the property, as shown by the high-grade ore on the dump-heaps, the future of the property is uncertain. While bodies of payable ore may be found, the nature of the ore deposit does not allow any definite forecast to be made.

The property is favourably situated for economically working by means of adits any deposit of ore which might be located. Such ore could be shipped from Trial Harbour, though the uncertain nature of this method of shipment caused by the exposed situation of the so-called "harbour" would add considerably to the freight charges.

(28)—*Little Henty River District.*

Several attempts were made to explore the country along the Little Henty River, but with only partial success, owing to the thick scrub, and the lack of tracks into this part of the district. Working along the northern bank up stream from the mouth, the scrub which has grown up in recent years since a fire went through is very thick, and without a track or another burning-off of the scrub progress is slow and painful. A track which had been cut out, and which is fast becoming overgrown, enters the scrub from the button-grass plain a short distance below Section 3555M (Connor's old section). This track appears to have been cut out to give access to a property locally known as "The Publican's Purse." The track cannot be followed right to the river; if previously cut out it has now become completely overgrown. It was found pos-

sible to break through to the river bank, and this was followed up and down stream for some distance. The country-rock through this area is composed of Pre-Silurian sedimentaries, slates predominating, usually a good deal hardened. No igneous rocks were seen. The track leads through dogwood for some distance, followed by open forest country with myrtle, sassafras, leatherwood, musk, &c., and "man" and "cathead" ferns. The country certainly is favourable for the occurrence of mineral deposits. Along the river bank a look-out was kept for alluvial flats which were worth prospecting for secondary tin ore. No deposits of any extent occur along this particular stretch of river, although in the bends of the stream there are several deposits of limited extent. It is probable that these would be found to carry tin, but the small size of the alluvial deposits and the presence of drift-wood, logs, &c., would probably render any attempt to work them unprofitable.

No examination was made of the southern bank of the river, which was not fordable at the points visited.

About ¾-mile from the mouth of the river is a bold gossanous outcrop on the northern bank, jutting out as a rocky point about half-way across stream. The surface crust, irregular patches in the body of the material, and the filling of fissures, is a soft limonite forming a true gossan. The material is very hard, and on freshly-broken surfaces is seen to be very dense and siliceous, though traversed by minute veinlets of chalcedony, and at times by crystalline quartz. Cavities frequently occur in the mass of the rock, lined with chalcedony, which, in turn, is sometimes encrusted with soft earthy limonite. Even on fresh faces, the rock is stained red with iron oxide. The strike is about N.N.W., and dip about vertical. The width varies considerably at different points, but would probably average 20 feet. The formation rises steeply to about 300 feet above the river, presenting a precipitous face to the west. It was traced for about ½-mile along the line of strike, until lost in the thick scrub near the belt of lime-silicate rocks which border the serpentine. Several specimens broken from different points on the outcrop were submitted as a sample to the Government Assayer, Mr. W. D. Reid, to be assayed for gold and silver, the result being—

Gold	Trace
Silver	1 oz. 4 dwt. 19 gr. per ton

While indicating that the precious metals are present in the formation, the results are scarcely such as to warrant prospecting work being carried out. It is possible that shoots may be located which will carry higher values, although the nature of the formation is not promising. Unless samples from other points show satisfactory values, no work is justified to open up the formation.

The Little Henty River was also reached from Mayne's Mine, by breaking through to the Burnt Bridge Creek, and following this creek down. The sequence of sedimentary rocks encountered here has been described elsewhere.[238] At the junction of this creek with another from the north there is a small deposit of alluvial material, and on the banks of the creek a little prospecting work has been carried out. A notice posted on a large gum tree about 1 chain to the north of these workings reads "Mines Department Prospecting, 640 acres. This notice is posted at north-west angle, date January 25, 1913: John Mitchell; witness, J. Redmond." This indicates that the work to be described was carried out comparatively recently, but no official record is available as to the objects or results of the work. On the western side of the creek is a short adit driven about west, 20 feet into the hill, which here rises steeply. This adit is in a state of collapse. In the approach are some specimens of green chlorite carrying abundant crystals of pyrite, showing dodecahedral, and occasionally cubical, forms. This material carries occasional geodes of quartz crystals, usually accompanied by soft micaceous aggregates. The structure is not clear in the present state of the workings, but the formation appears to be a narrow flat vein. At the entrance to the adit is a little gossan, the adit itself being driven on a slide, in soft white clay, showing no signs of mineralisation. On the hill to the south a little quartz-tourmaline wash was noticed. On the eastern bank of the creek is a trench which exposes only clayey wash. One-half chain east is a prospecting shaft 15 feet deep, now partly full of water. Solid country-rock does not appear to have been reached, the shaft passing through clay with angular detrital fragments of slates and sandstones. About ½-chain north of this shaft is a little pyritic material, now partly oxidised; there are segregations of pyrite in a decomposed clayey gossan. No work has been done here.

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(238) *Vide supra*, pp. 101–105.

Several specimens were picked up at the junction of the creeks of radiating aggregates of a very soft white mineral with a soapy feel and pearly lustre, apparently pyrophyllite.

A sample of the dense green pyritic material was submitted to the Government Assayer (Mr. W. D. Reid), who reported—

Tin ... ... 0·22 per cent.

While it is interesting to note that tin is present in the formation at a distance of over a mile from the exposed edge of the granite, the value is not promising, and it is doubtful if further work is justified in the locality.

The above result indicates, however, that the mineralising solutions have been active, and it is not improbable that richer deposits may be located in this part of the district.

No other mineral deposits appear to have been located in this part of the district, but it must be admitted that very little prospecting has been done owing to the inaccessibility of the country. Similar country has been reported from the opposite (southern) side of the Little Henty River, but this country is still less accessible, and is practically *terra incognita*. It is certainly favourable for the deposition of sulphide ores, and prospecting is strongly recommended. The occurrence of calcareous beds is worth noting, as these are liable to be replaced when mineralising solutions have had access to them, forming large bodies of ore.

As will be seen from the above notes, this part of the district was only broken into at a few points, and under the circumstances could not be examined in detail, but the hasty reconnaissance made left very favourable impressions as to the possibilities of the area.

VIII.—CONCLUSION

During his examination of the South Heemskirk Tinfield, the writer visited all properties on which he was aware that any work had been carried out, and although in many cases little is to be seen at the present time, the condition of the workings has been described, even though no definite opinion as to prospects can be formed. Little need be said at this stage of individual properties, which have already been described, but it seems advisable to review the present condition of mining on the field.

With only three properties being worked at all at the time of the writer's visit, with a total of a dozen men employed in lode tin mining, and about half that number working patches of alluvial ground, and acting as caretakers, it is clear that mining is not in a flourishing state in the district. This condition is certainly not the result of the mines being worked out. The total amount of mining work done is small, and out of all proportion to the amount of money which has been spent on the field, which must amount to several hundred thousand pounds since tin was discovered 40 year ago. The causes which have led to the present state of affairs have been traced as far as possible by the writer in dealing with the history of mining on the field, and it is not proposed to repeat what has there been set out. Briefly, the main causes seem to have been incomplete prospecting of certain short rich shoots of ore, and exaggerated reports of the results of prospecting work leading to a boom, when indiscriminate pegging of sections took place, and speculation was rife, and the premature erection of costly plants on undeveloped mines, leading inevitably to financial depression. Other causes, such as inaccessibility, the occurrence of pyritic ore, and (in a few cases, perhaps) mismanagement of properties, also contributed in a smaller degree. The main cause of the loss of confidence in the field was the extravagant and unwarranted expenditure on plant and surface works of money which should have been used in developing the ore-bodies. The writer is of opinion, however, that at at the present time the field is recovering from the setback it received at the period mentioned. Further prospecting has been carried out of late years, and has clearly indicated that some at least of the old properties were prematurely abandoned, and

that shoots of tin ore occur in some of the veins which should pay well for extraction and treatment under modern conditions.

As pointed out in the course of this report two of the smaller properties are working at a profit, and several others have excellent prospects. In the case of the main property on the field (the Federation Mine), the immediate cause of the present inactivity is want of capital for developmental work, several attempts to secure which have unfortunately failed recently. This property is commended to the careful attention of investors, as it certainly has sound prospects, and under efficient management should prove a steady tin producer. Although the report on such a property cannot be complete without systematically sampling the various ore-bodies exposed, after a study of the principles underlying the deposition of the ore, various suggestions and recommendations are made, which, it is hoped, will be of some value in planning future work.

A noticeable feature in the case of several of the properties examined was the lack of system displayed in carrying out work at different points. With a given amount of capital available for mining operations. it seems superfluous to say that this capital should be spent to best advantage, but the fact remains that this has not been done. As a result of the expenditure of numerous small amounts in spasmodic prospecting in widely separated localities, in some cases the position at the present time is that no useful object has been attained for the expenditure of a total amount of several thousands of pounds, an amount which would have sufficed to carry cut much useful and really permanent mining work, which could, moreover, have been utilised as a basis for further work, had the work been systematically planned. Future operations should be planned on definite lines, keeping in mind always the future development of the property, so that the maximum benefit may be derived from any given expenditure.

The practice followed in one or two instances of working out only the very richest portions of exposed ore-bodies, either leaving the seconds *in situ* or carelessly mixing them with country-rock on the dump-heaps, is to be strongly deprecated. While a temporary profit may be made by employing such methods, the result must necessarily be that the life of the property is shortened, and it has in some cases happened that mines have been abandoned when only a comparatively small proportion of the actual tonnage available has been extracted. Where this policy is being carried out, it usually means that the richest ore is being extracted without any corresponding developmental work being pushed ahead to provide for an uninterrupted supply of ore.

Another point to which attention should be drawn is the tendency to become somewhat careless as to treatment methods when rich ore is being treated, and to become satisfied with a good *aggregate* recovery, rather than to constantly aim at the very highest possible *percentage* recovery.

Mention should be made of the occurrence of pyritic ore on some of the properties, as noted in the text of this report. The question of the treatment of this ore will have to be faced in the near future. In the past the occurrence has caused trouble, and even led to the abandonment of good shoots of ore, because of the trouble in dressing, and the difficulty at the time of finding a market for pyritic tin concentrates. This treatment question should be honestly faced by the owners of those properties where stanniferous pyritic ore occurs, and after careful sampling, experiments made to determine the most suitable treatment process. The writer confidently believes that a successful method of treatment for these ores will be found with a minimum of experimental work, and the important aspect then becomes the actual tin content of the ore. The question indicated should not be postponed until the oxidised ores nearer the surface are exhausted, as there is a tendency to adopt this attitude in some cases. The future of these properties must depend on the pyritic ores, and as such ores are being successfully treated elsewhere, the matter should be confidently taken in hand without delay.

In mining operations the nature of the occurrence of the tin ore in the deposits should be carefully kept in mind. Past mining operations, though not extensive, have shown that it usually occurs in definite shoots, which, while very rich, may be of limited length and depth, although in some cases the dimensions of particular shoots are considerable. It is noteworthy that although in several instances mining operations at that particular point have ceased when the shoot being exploited has cut out, in cases where a reasonable amount of developmental work has been carried out, the presence of other shoots of ore has been demonstrated, both laterally and vertically. In

several instances rich shoots have been located accidentally in close proximity to worked-out bodies of ore. In the writer's opinion, such a general statement as has been made from time to time, that "on Heemskirk the tin does not live to depth" is quite unwarranted; certainly, insufficient deep mining has been carried out to justify such a statement, and the evidence provided by such mining work indicates clearly that tin ore does live to depth. This question has been dealt with in the course of the report, and the opinion expressed that conditions are favourable for a continuation to depths beyond the reach of economic mining of the tin ore. The noted occurrence of the tin ore in defined shoots, however, strongly emphasises the necessity for carrying out sufficient developmental work before erecting treatment plants, and for keeping such developmental work pushed ahead of actual ore-extraction operations, to ensure a constant supply of ore for the batteries. It is the neglect of these precautions which has directly caused the failure of some of the mining companies in the district during the past.

In working the ore-deposits it is important that the structural features should be understood, and it is hoped that some of the notes given will be useful as guides in the elucidation of some of the problems to be encountered by the mining managers, to whom are entrusted the working of the properties. The structural features are of especial importance in the case of the tin ore deposits in the sedimentary rocks, and these features have been explained as far as the present conditions of the properties allow of their interpretation.

Isolated cases of mixed metals in certain shoots are recorded, where the separation of the various sulphides and the cassiterite will be fraught with real difficulty: quantities and values of ore in such cases should first be determined to show how far experimental work should be carried. These cases are, however, the exception in the district.

In addition to tin ores, there are developed ores of bismuth, wolfram, and nickel in different parts of the area examined, which deserve further investigation than they have hitherto received. Molybdenite also occurs, but unfortunately in no case in sufficient abundance to become of economic importance, even with the high price obtaining at the present time: fresh discoveries are possible at any time.

The secondary tin ore deposits of the district have provided in the past, and will in the future continue to provide employment for a limited number of men, but the chief alluvial deposits have been worked out, and the future of the field must depend on the primary ore-deposits.

The district affords natural advantages for economic mining which must have an influence in bringing the field to its rightful position as a tin producer in the future. Mining to considerable depths from adit levels is possible in several cases, and the facilities offered for cheap power by the Cumberland Dam are exceptional. It is worthy of note in passing that in the North Heemskirk district falls occur on the Heemskirk River which could be harnessed to provide electrical power.

It is suggested that in a few cases an amalgamation of interests might have an advantageous effect on the successful operation of adjoining properties, if satisfactory arrangements could be made by the owners of the properties concerned.

Owing to the facilities offered by a large tract of comparatively level country free of timber along the sea-coast, surface prospecting has been carried out more or less carefully in one portion of the district, but the writer would unhesitatingly say that the whole district has not been thoroughly prospected, and that certain areas are very favourable for the occurrence of payable ore-deposits. The mountain country of the Heemskirk Range itself may be found to carry tin ore deposits, but the extremely inaccessible and forbidding nature of the country militates against the prospector, and although the writer is of opinion that denudation of the granite has not been so excessive as to have removed the tin veins, still it must be admitted that this area does not offer the same inducements to the prospector as the marginal portion of the granite.

The portion of the district which in the writer's opinion has not received the attention it deserves at the hands of the prospector is that including the sedimentary rocks forming the contact metamorphic zone round the immediate border of the granite. These rocks are favourable for the development of tin ore deposits. The accidental discovery of the rich ore at Mayne's Tin Mine within such a short distance of an established mine indicates that the sedimentaries near the granite contact were not prospected for tin in the earlier history of the field, and even that discovery did not result in the vigorous prospecting of the country in the neighbourhood which might have been expected. Other valuable ore-deposits may occur, and prospecting in the direction of the Little Henty River is recom-

mended. Although beyond the bounds of the South Heemskirk district, the country between the Little Henty and the Henty Rivers is earnestly commended to the attention of prospectors. Little is known of this area at the present time, owing to its inaccessibility, but conditions are favourable for the development of ore deposits, and this area occupies a corresponding position with regard to the Heemskirk granite *massif* as the Zeehan field to the east. In the course of this report the relation of the granite to the ore deposits not only of Heemskirk but also of Zeehan has been referred to, and this relationship indicates that the area mentioned must be regarded as favourable for the development of ore deposits of similar type to those known to occur in the Zeehan field. Whether ore-bearing solutions have been active in this area is for the prospector to determine, and the writer unhesitatingly recommends prospecting in the area. The country is mostly heavily timbered, and frequently carries thick undergrowth: the surface is irregular, being intersected by recent streams which have cut and are still cutting into an uplifted land surface which formerly had been worn down almost to sea-level.

The writer was unable from records available to determine the actual output of tin ore from the South Heemskirk Tinfield, but has estimated that at least 600 tons of tin oxide have been produced. This figure has been arrived at after a study of the annual and quarterly reports of the Secretary for Mines, official reports on particular mining properties, and from information supplied by individuals familiar with the mines in their earlier history. In some cases returns were quoted for the "West Coast," and an estimate has been arrived at by noting the mines known to be working other than those on the field itself, as well as those in the district, and crediting the latter with a fair proportion based on the proportion in years when full particulars were available.

Although the amount of 600 tons of tin oxide is only an estimate, it serves to give an idea that some good tin shoots must have been worked. After reading the chapter on the mining properties, in which is fully described the work which has been carried out, and noting the ore produced from this comparatively small amount of work, the writer would contend that a strong argument is presented for claiming further attention for this field.

As to resources of the district other than those of mining, it cannot be said that prospects are very bright. The bulk

of the granite area is covered by only a shallow layer of barren sandy soil and rubble from the weathering of the igneous rocks, which in the more exposed portions supports only button-grass. Clumps of timber occur in the more sheltered valleys of the Heemskirk Range, and will serve to satisfy mining requirements, but are not likely to prove of sufficient value, in their present inaccessible positions, to be exploited for sawmilling purposes. To the south and east of the granite, the area occupied by the basic igneous rocks and by the sedimentary rocks is usually fairly heavily timbered, and when this country towards the Little Henty River is opened up, it may be found that there is a certain amount of timber worth taking out. The soil here, especially that derived from the sedimentary rocks, is good, and some of this land, as for instance along Pyke's Creek, would be very suitable for grazing if cleared.

It is on mining, however, that the future of the district depends, and prospects are such as to warrant the hope that in the near future the South Heemskirk Tinfield will take its rightful place among the regular tin producers of the State.

In commenting on certain of the methods of mining and treatment in vogue at the time of his visit to the field the writer has not done so in any spirit of carping criticism, but rather in the hope that the suggestions offered may be adopted, confident that improvements on the lines indicated will help to restore public confidence in the field.

In conclusion, the writer would express his indebtedness to the reports of Messrs. G. A. Waller and L. K. Ward, which have been freely consulted in the preparation of this bulletin. He would also record his grateful appreciation of the kindness extended to him by all with whom he came into contact during his stay on the field: he would especially thank Mr. A. Yates for rendering valuable assistance in the field on many occasions, and for supplying much useful and reliable information concerning many of the mining properties which were deserted at the time of his visit.

Messrs. J. H. S. Munro and J. Barclay courteously placed their cottage on the Federation Mine at the writer's disposal during his examination of the district, and he has pleasure in thanking them for this hospitality.

L. LAWRY WATERHOUSE, B.E.,
Assistant Government Geologist.

Launceston, 15th October, 1915.

Appendix I.

NOTES ON PLATES.

Plate II.—*Geological Sketch-map of the South Heemskirk Tin-field.*

This map, as its title states, purports to be only a sketch-map. Topographical features are shown in a general way only, and the contours are only intended to give an idea of the general nature of the topography. As explained in the text of the bulletin, the surface of the coastal peneplain is very uneven, although the ridges are of approximately the same altitude; no attempt has been made to depict in detail the features of this coastal strip. The map is based on the mineral charts supplied by the Mines Department, Tasmania, and includes portions of the charts of Heemskirk, Zeehan, and Mallanna.

Plate III.—*Geological Sketch Section on the Line AB—Direction N. 55° E.;*

Plate IV.—*Geological Sketch Section on the Line CD—Direction N. 70° W.*

These sections are designed to illustrate the geological structure of the district as interpreted by the writer, and particularly the relationship of acid and basic igneous rocks to the intruded series of sedimentaries. The writer desires to emphasise that, although vertical scales are shown on the plates, and the surface profile has been made as accurate as possible by utilising this scale to indicate altitudes above sea-level, the scale does *not* apply to the underground contacts of the igneous rocks or to the contacts of the igneous rocks with the sedimentaries; this portion of the section is intended to be diagrammatic only. In other words, the section does not pretend to indicate the exact depth below the surface at which the igneous rocks would be encountered. Plate III. shows that, in the writer's opinion, the sedimentary rocks exposed in the country traversed by this particular line of section are resting on a foundation of basic rocks, which themselves are, in part at least, resting on acid rocks.

Plate V.—*Chart of Mineral Sections of the Heemskirk District.*

This plate includes the mineral chart of the district of Heemskirk and portions of the charts of Zeehan, North Heemskirk, and Mallanna, and is intended to show the numbers and names of the holders of the mineral sections in the area dealt with in the bulletin. The mineral charts referred to are those issued by the Mines Department, Tasmania.

Plate VI.—*Locality Sketch-map: The Federation Tin Mine;*

Plate VII.—*Locality Sketch-map: Kelvin and Mayne's Tin Mines.*

These plates are sketch-maps only, but illustrate the descriptions given in the text of the bulletin of particular mining properties. Plate VI. is based on the plate issued by G. A. Waller in his official report on the district in 1902, with additions by the writer, and also incorporates some information from a mine plan prepared by Mr. A. Yates, manager of the Federation Tin Mine.

Appendix II.

EXPLANATION OF PHOTOGRAPHS.

Photo. 1.—*Nodular Tourmaline Granite.*

The photo. shows a typical outcrop of "white" granite, with nodules of quartz-tourmaline, as described in the text. Being harder and more resistant to the attacks of weathering agencies than the surrounding granite, these nodules stand out in sharp relief. The scale (12 inches vertical, 12 inches horizontal) is shown. Just below the vertical edge of the rule is a narrow fissure filled with black tourmaline, standing out in slight relief, and cutting through one of the nodules, which obviously had previously consolidated. Similar narrow veins are shown on the left-hand boulder.

Photo. 2.—*Panoramic View of the Cumberland Dam.*

The photo. is taken looking in a south-easterly direction. The whole of the country shown is of granite. Typical rounded hills resulting from the weathering of this rock are seen.

E is the embankment across the gorge of the Cumberland Creek by which the whole of this magnificent body of water is stored. This embankment is only 1 chain in length, and is the only work which has been necessary to form this dam.

B, representing another creek, now forms the by-wash by which the overflow water escapes through the short race cut a few feet below the normal ground surface. The water is dammed back for some distance beyond the left-hand edge of the photo., and from this low ground the country rises steeply to the summit of Mt. Agnew. These slopes are heavily timbered. The country in the photo. is covered with button-grass, scrub occurring in the gullies. This plateau, another portion of which is illustrated in Photo. 19, is at an elevation of about 1500 feet above sea-level.

Photo. 3.—*Portion of Western Area of the Coastal Peneplain.*

This panoramic view was taken from the top of the haulage-line at the Federation Tin Mine, and includes a view from south-west to north-west. The whole of the country shown is of granite, and the photo. illustrates the manner in which the peneplain is dissected by short consequent streams. The area is covered with button-grass, scrub occurring in most of the creek-beds.

A The Pulpit Rock illustrated in Photo. 12.
B shows the position of the Cliff Tin Mine on the coast.
C shows the position of the Cornwall Tin Mine on the coast.
D is Gap Peak.

E shows the position of Granville Harbour.
F R. Clarke's Mine (old Prince George), on Packer's Creek
G Federation Cottage.
H Area stripped and worked for alluvial tin, small patches of which occur at intervals over the plain.
J The tip of the 570-feet level (No. 4 Adit).
K shows the position of the 500-feet level (No. 3 Adit).
L The Federation battery and concentrating plant.
O Outcrops of quartz-tourmaline lode-formations shedding large quantities of detrital material.
R The Trial Harbour-Corinna Road, winding over the peneplain.

Photo. 4.—*Panoramic View of the Southern Portion of the Coastal Peneplain.*

The view is taken from the spur of the Heemskirk Range overlooking Sweeney's Mine, and embraces the view from the south-east through south to south-west. The foreground of the photo. is granite, the contact with the Pre-Silurian slate being shown approximately by the edge of the belt of timber in the line KJJ.

A Cape Sorell.
B Mouth of the Henty River
CC Mouth of the Little Henty River, which here flows for about a mile in a meandering course across the sand before entering the ocean. The river sometimes cuts straight through the sand-bar, the conditions determining this change being discussed in the text of the report.
ABC represents the long stretch of sandy beach known as Ocean Beach, the entrance to Macquarie Harbour being a little to the left of A.
DD is a hill of supposed Silurian sandstone (shown also in Photos. 7 and 15), described in the text. Between D and E Pre-Silurian sediments, with some lime-silicate rocks intercalated, are exposed on the coast. Photo. 13 represents a view along this strip of coast.
E shows the hill of serpentine near Trial Harbour on which are situated the works of the Nickel Reward Mine. From E to F along the coast is serpentine.
F shows the position of Trial Harbour.
G is the turn-off of the Trial Harbour Road from the main road, Zeehan-Corinna.
GHHH shows the Zeehan-Trial Harbour Road following the coastal peneplain.
JJJCC shows approximately the course of the Little Henty River.

Photo. 5.—*Mouth of the Little Henty River.*

This photo. is taken from the northern end of Ocean Beach, looking about north. Instead of cutting through the beach in a direct course to the ocean the river, at the time this photo. was taken, was meandering along the

beach, as shown in Photo. 4. The prominent peak in the background is Mt. Agnew, with the Heemskirk Range on the left. In the middle foreground is the edge of the Little Henty peneplain, here very densely timbered.

PHOTO. 6.—*Typical Scene on the Sea-coast forming the Western Boundary of the Heemskirk Tinfield.*

The photo. was taken from the Cliff Tin Mine, looking north-west. The rugged coast is formed by granite cliffs from 300 to 400 feet in height. The more rapid slope of the coastal peneplain near the sea-coast, as described in the report, is illustrated by this photograph.

PHOTO. 7.—*Panoramic View of Trial Harbour and Vicinity, Looking South.*

The hills in the foreground on the left of the photo. are Pre-Silurian sedimentaries intensely metamorphosed; the country in the middle foreground represented by ABCREE is serpentine, while that in the background is Pre-Silurian slate and sandstone, with the exception of the hill G, which is probably Silurian.

ABC This hill shows the position of the Nickel Reward Mine described in the text.
A is the No. 3 Adit.
B the shaft.
C No. 2 Adit.
D represents the remains of the jetty on which was landed all the material for Remine, and, in their early history, everything for the Heemskirk tinfield and for Zeehan.
EE Long jutting reef of serpentine uncovered at low water, covered at high water, forming the southern boundary of the so-called harbour, which is represented by EEDF. It was necessary for steamers to anchor some distance out, and material had to be landed by boats and lighters.
G Hill of probably Silurian sandstone, grits, &c., shown also in Photos. 4 and 15.
H Mouth of the Little Henty River.
J Mouth of Henty River.
K Cape Sorell.
HJK Ocean Beach.
L Mouth of Montagu Creek.
R is the site of the old township of Remine, with not a building standing at the present time to indicate the exact position of the old township, the whole area being covered with dense scrub.

PHOTO. 8.—*Fissured Granite Cliffs.*

Photo. is taken from the Cliff Tin Mine, looking west, and shows well the parallel fissuring of the granite described in the text. The fissures are brought into prominence by weathering, largely assisted in this instance by salt water and moist sea air. The effect of this fissuring in determining the configuration of the coast-line is well

shown. Large flakes of rock break away, and the sea encroaches in narrow inlets along the line of strike of the fissures.

PHOTO. 9.—*Coarse-grained Pink Granite with Veins of Aplite.*

The veins of aplite traversing the granite shown are quite characteristic, and are very common throughout the district. The main vein of aplite shown has been faulted and displaced several feet. The scale is approximately shown by the geological hammer.

PHOTO. 10.—*Nodular Tourmaline Granite.*

The photo. shows a characteristic outcrop of the "white" granite of Devonian age on the high ground in the northern portion of the Federation lease. The quartz-tourmaline nodules frequently stand out several inches in relief, and, as weathering proceeds, collect on the hillslopes and in the creek-beds in great numbers. A thin plate of quartz and tourmaline is shown about the centre of the photo., and has resulted from the weathering away of the granite from a narrow fissure filled with the harder and more resistant quartz and tourmaline. The scale is shown in the centre of the photo. (12 inches vertical and 12 inches horizontal).

PHOTO. 11.—*Typical Granite Country of the Heemskirk Range.*

The photo. was taken from the old horse-tram of the Federation Tin Mine, looking about north. It shows the typical rounded granite peaks of the Heemskirk Range, and the parallel fissuring of the granite described in the text. Many of the hillslopes are covered with button-grass and low scrub, but in all sheltered gullies thick timber and very dense undergrowth flourish.

PHOTO. 12.—*Pulpit Rock.*

This rock (referred to in the text) represents a residual weathered boulder of coarse-grained pink granite of Devonian age. The photo. shows the effect of weathering and changes of temperature on such an exposed rock, thin plates flaking off from time to time. An idea of the size of the boulder is given by the camera bag at the foot of the boulder, measuring 12½ by 7½ inches, and the 5-feet stick alongside the bag. The rock stands on a ridge a short distance from the edge of the cliffs, and is said to be visible for many miles out to sea, and forms a landmark for the surrounding country. Its position is shown at A in Photo. 3. Elevation, 450 feet above sea-level.

PHOTO. 13.—*Differential Weathering of Calcareous Bands in Pre-Silurian Sediments.*

The exposure illustrated is on the sea-coast, about 1 mile south of Trial Harbour, and not far beyond the boundary of the serpentine. The Pre-Silurian sediments in this locality consist of slates and sandstones, usually indurated, with intercalated calcareous bands sometimes converted to lime-silicate rocks. The more rapid erosion of the cal-

careous bands at this spot gives the rock the honeycombed appearance which is well illustrated in this photo. The scale is indicated by the 2-feet rule bent at right angles.

PHOTO. 14.—*Foliated Pre-Silurian Slates.*

This exposure (in a side-cutting on the Zeehan-Trial Harbour Road) of Pre-Silurian slates illustrates well the anticlinal and synclinal folding which have been induced in the sediments; although at practically all points where exposed the sediments show signs of intense crushing, it is exceptional to find such a good example of folding as that illustrated.

PHOTO. 15.—*Coastal Exposure of Pre-Silurian Quartzites and Slates.*

The rocky point illustrated is about 1 mile north of the mouth of the Little Henty River. The sediments consist here of quartzites, with alternating bands of slate, the whole series showing signs of intense crushing. There is a tendency all along this coast, where the rocks are developed along the sea-board, for such hard rocks to form projecting points. The hill in the middle-foreground is just north of the Little Henty River, and is of sandstone and grits, which are probably of Silurian age (*vide* text of report).

PHOTO. 16.—*Coastal Cliffs showing Granite-Slate Contact.*

About 1 mile north-west of Trial Harbour. The granite (on the left of the photo.) is of Devonian age, and is the coarse-grained pink variety. The slate (showing as a black outcrop on the right of the photo.) is of Pre-Silurian age, and is intensely metamorphosed, abundant amphibole, biotite, quartz, &c., being developed. The cliffs at this point rise to a height of 400 feet above sea-level.

PHOTO. 17.—*Xenolith of Slate included in Granite.*

This interesting occurrence is situated at the base of the coastal cliffs, a few feet above sea-level, about 1 mile north-west of Trial Harbour. In the right-hand top corner of the photo. the actual contact of granite and slate is shown; the actual granite contact is about 20 yards to the right (south) of the xenolith. The block of slate shown in the centre of the photo. has become detached from the overlying rocks while the granite rock-mass was still molten, has sunk some distance in the molten mass, and been enclosed therein when the granite consolidated. The block is completely included in the granite, its size being shown by the scale (12 inches vertical, 12 inches horizontal) photographed. The rock is intensely metamorphosed, as described in the text of the report. The granite is the coarse-grained pink variety of Devonian age, and the slate is Pre-Silurian.

PHOTO. 18.—*Western Portion of the Federation Tin Mine.*

The photo. shows the gorge cut by a branch of Packer's Creek into the granite, and also the button-grass covered hillslopes with abundant granite outcrops. The freedom from timber is noticeable.

A The highest point on the Federation lease, about 1800 feet above sea-level, marking the position of Munro's shaft.
B shows the position of the Whip Shaft.
C the 500-feet (No. 3 Adit).
D 570-feet (No. 4 Adit).
E The top of the old haulage-line (the point from which Photo. 3 was taken) and the position of Yates' Level.
EJ The old haulage-line by which ore was removed to the battery, now in a state of disrepair.
F marks the position of the discovery of rich tin, which was afterwards worked by the tributers by an open-cut.
G is the tributers' tunnel driven to communicate with the pipe workings.
H Gray's lode.
J The Federation battery and concentrating plant.
KK Branch road connecting with the main road to Zeehan.
L Alluvial workings from which some tin and also some good wolfram were won, as described in the text.

The group of workings shown are known as the Western Workings. The photo. is taken looking east. The ridge in the background slopes eastwards to the Cumberland Dam.

PHOTO. 19.—*South-Eastern Portion of the Federation Tin Mine and Cumberland Dam Plateau.*

From the ridge in the left background of the photo. the slope is westward to the coastal peneplain, as shown in Photo. 18.

A The highest point on the Federation lease, marks the position of Munro's Shaft (compare Photo. 18).
B The Air Shaft workings.
C Talus heap, described in the report.
D The Long Tunnel.
E Site of residence of the manager of the old Cumberland Company.
FFFF The old tramway of the Cumberland T.M. Company by which ore was conveyed from the Long Tunnel to the battery for treatment.
G The Federation pack-track after crossing the embankment of the Cumberland Dam.
HHH The Heemskirk Range.
JJ Arms of the Cumberland Dam.
K Eastern workings of the Federation Tin Mine.

PHOTO. 20.—*Radiating Black Tourmaline.*

These specimens were collected from the old Cornwall Mine on the sea-coast, which provides magnificent cabinet specimens of the mineral. The radiating habit from a central nucleus is well illustrated. Scale of inches is shown.

PHOTO. 21.—*Mayne's Tin Mine Workings.*

The photo. gives an excellent idea of the way in which work was carried out at Mayne's Tin Mine. This photo. should be compared with Plate VI., upon which it throws a good deal of light. Rich tin was found to occur at different points on the hillslope, and was extracted without any systematic method of working and treated in sluice-boxes. Most of the dump-heaps shown in the photo. carry fair tin values. The photo. was taken from No. 5 Cut, looking north. The various open-cuts are numbered to correspond with those shown on Plate VI. The country-rock in the foreground is Pre-Silurian sandstone and slate; that of the Heemskirk Range, in the background. Devonian granite.

A No. 1 Open-cut.
B No. 2 Open-cut.
C No. 3 Open-cut.
D No. 4 Open-cut.
E Shaft.
F Entrance of tunnel driven through the hill.
G Workings on pyritic formation.
H Position of winze from No. 2 Cut.
J Side cut from No. 2 Open-cut.
K Camp.
L Dam of the old Orient Company.
M Mt. Agnew, with other peaks of the Heemskirk Range to the left.
NNNNN shows the approximate course taken by the pack-track constructed over a saddle of Mt. Agnew.
O Approximate position of Cumberland Dam.
PPP Pyke's Creek.
R Approximate position of Healey and McIvor's Mine.
S Approximate position of Sweeney's Mine.

PHOTO. 22.—*Kelvin (Williams') Tin Mine.*

The photo. shows the plant of the Kelvin Tin Mine; the light three-head battery is driven by a water-wheel (on the far side of the shed), the pulp being fed on to a Wilfley table and slimes over short canvas tables shown in the right of the photo. Quartz-tourmaline outcrops occur on the summit of the hill in the left-centre of the photograph.

APPENDIX III.

THE HEEMSKIRK MASSIF—ITS STRUCTURE AND RELATIONSHIPS.

By L. KEITH WARD, B.A., B.E.

(With Two Plates, Nos. XIII. and XIV.)

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I.—INTRODUCTION.

Most students of that branch of geological enquiry which is concerned with ore-deposits have within recent years come to believe that a large number of ore-deposits are genetically related to masses of igneous rock material which are to different degrees exposed in the immediate vicinity of the ore-bodies.

With the progress of systematic mapping it has become apparent that ore-deposits are distributed unevenly among the rocks of different ages, and that thus the periods of ore-deposition may be determined. For example, the majority of the ore-deposits in Tasmania are distributed through rocks of which the age ranges between the Pre-Cambrian and the Silurian. Looking at the matter in another way: those portions of Tasmania in which the Permo-Carboniferous, Mesozoic, and Cainozoic rocks are found at the surface (with the exception of one small region) (1) carry no primary metalliferous deposits of material importance.

By the comparison of the age of the ore-bodies and that of the associated igneous rocks it has been found that there is a definite time relationship between igneous invasion and ore deposition in many different parts of the world.

The statement of the historical aspects of ore deposition has been made for America by W. Lindgren,(2) for the British Isles by A. M. Finlayson,(3) for various regions in Europe, Africa, and Asia by L. de Launay,(4) and for Tasmania by W. H. Twelvetrees.(5)

In the discussion of this problem there are two rather different aspects which should for some reasons be kept distinct. The author would lay stress on the distinction between the "metallogenetic epoch" and the "metalliferous province"—the relation in time and the relation in space. This distinction must be borne constantly in mind when general problems concerning ore-deposition are under discussion; for in those cases in which ore-deposits have been formed in a single region at different periods a certain confusion may result.(6)

(1) The vicinity of Port Cygnet.
(2) "The Gold Production of North America" (Trans. A.I.M.E., Vol. XXXIII., 1903, pp. 790-845); also "Economic Geology," Vol. IV., No. 5, 1909.
(3) Q.J.G.S., Vol. 66, 1910, pp. 281-298.
(4) *Ibid.*, literature quoted in footnote on p. 281.
(5) Geol. Surv. Tas. Bulletin No. 9.
(6) A. M. Finlayson (*loc. cit. supra*) seeks to avoid such confusion by introducing such a term as a "metallogenetic inlier."

It is regarded by petrologists as an established fact that periods of igneous activity have been, throughout geological history, coincident with periods of crustal deformation, and that the sites of crustal movement have been the sites of co-ordinate igneous invasion.(7)

By a number of mining geologists a parallel claim is made, viz., that periods of ore-deposition have in like manner corresponded in time with the periods of igneous invasion.(8)

The coincidence of mineralised areas with areas marked by igneous invasions has already been referred to. Hence relationship in time must be considered with relationship in space. The igneous rocks which are found associated with ore-deposits are, in different places, products of different phases of igneous activity. In the present paper the author proposes to briefly discuss the form and relationships of certain products of the plutonic phase from the points of view indicated above.

The question is one requiring discussion in the light of data to be provided by many different metalliferous provinces. The present paper has been written in the light of the evidence presented by certain granite masses which play an important part in the geological history of Northern and Western Tasmania. Incidentally, the intrusive rocks which are to be referred beyond doubt to the same source as the plutonic rocks are mentioned, and all are shown together upon one of the sketch-maps which accompany this paper.

II.—The Proximate Source of Igneous Rocks and Metallic Ores.

Concerning the ultimate origin of igneous materials little can be said that is not based upon theories of cosmogony;(9) and since the primary source of all metallic ores must needs be igneous material,(10) the ultimate origin of the ores cannot be traced back with certitude through the more or less hypothetical stages of the early history of the earth.

We must be content for the present to accept only certain broad generalisations with regard to the composition of the earth as a whole. With respect to the distribution of heat and the physical conditions in the interior we are not, for the purposes of this paper, concerned. The author feels that we may safely accept the following statements as being substantially true:—

1. That the interior of the earth is largely composed of metallic ingredients—the "barysphere" of Posepny(11) or the "nife" of Suess.(12)
2. That these metallic ingredients are expelled from time to time into the outer portions of the earth's mass and thus come into place in the zones which are open to geological investigation.

(7) A. Harker: "The Natural History of Igneous Rocks," p. 13.
(8) This correspondence in time is in most cases really the most conclusive proof of the genetic relationship between the igneous bodies and the associated mineral deposits.
(9) *Vide* A. Harker: "The Natural History of Igneous Rocks," p. 13.
(10) *Vide* J. F. Kemp: "Genesis of Ore Deposits" (A.I.M.E., p. 684), and many other writers *passim*.
(11) "Genesis of Ore Deposits" (A.I.M.E., pp. 11, 73, 79).
(12) "The Face of the Earth," Vol. IV., p. 544.

Of the mechanical processes involved in the upward migration of the heavy metals but little can be inferred.

It is, in the opinion of the author, an indubitable fact that the metallic contents(13) of at least many ore-deposits have ascended in association with much larger masses of igneous material of different composition. From the ascending materials, in certain cases at least, three principal products are derived, viz.:—

1. The igneous rock masses (mainly non-metallic).
2. The metallic ores and many of their gangue minerals.
3. The juvenile or magmatic vapours and solutions.

Rather than state that the igneous rocks or vapours have served as carriers of the metallic ores, the author would affirm that all three groups together constitute the real essence of the magma.

The question of the relationship between the metallic ores and the igneous rock-masses demands a detailed discussion for each region in which the relationship may be declared to exist. A study of one such region(14) has been made by the author, and his conclusions stated elsewhere.

In some cases the metallic ores are disseminated through the igneous material with which they have ascended; in other cases they have been collected with the assistance of the magmatic vapours into certain foci, from which they are expelled during the final stages of consolidation.

In either case it is evident that the metallic ores and igneous rock materials have ascended together from the deeper portions of the earth's mass.

With regard to the separation of the metalliferous magma which ascended in the Heemskirk-Comstock-Zeehan district into its several component parts, the author has claimed that a very definite succession of events may be detected from the field evidence. In the evolution of the magma towards the solid state it appears perfectly certain that the granite is the earliest product and that the ore-deposits are the latest products of consolidation.

With the completion of the process of consolidation the period of igneous activity and the metallogenetic epoch closed. It is claimed by the author that *the period of complete solidification of the whole magma and the period of cessation of primary ore-deposition are coincident and co-ordinate for this region.*

It is highly probable that this statement, advanced with confidence for the region mentioned, is applicable also to the other occurrences shown on the maps, in which like igneous rocks are associated with like ore-bodies. With regard to the particular region mentioned the field evidence appears to be particularly conclusive.

III.—The Structure of the Heemskirk Massif.

(*a*) *The Visible Contours.*—From the progress of erosion in the region to which special reference is here made, we are enabled to form a reasonably complete mental picture of the

(13) With regard to the Tertiary andesitic goldfields, Dr. Malcolm MacLaren has put forward other hypotheses. *Vide* "Gold," 1908, p. 61
(14) The Heemskirk-Comstock-Zeehan region of Western Tasmania.

upper portion of the sum total of the consolidation products of the magma as they would have appeared before erosion—with all the intruded rock-masses stripped from them—in the district immediately adjacent to the Heemskirk Range.

The granite *massif* of Heemskirk appears to have possessed an arched or dome-like surface, from which certain tongues or narrow ridges (of granite porphyry) extended upwards.

Traversing the smooth surface of the granite, and even cutting across the apophyses of granite porphyry, the tabular dykes and veins of later date have formed ribs or flanges standing out far in relief above the granite boundaries. This much we may deduce from the study of the present features of the granite *massif*, its borders, and the immediately adjacent country.

(*b*) *The Invisible Contours.*—(i) In a horizontal direction.—When the immediate vicinity of the exposed *massif* is left, the mental construction of the form is to be made only by the application of inferences to be drawn from observation. The upper boundary of the granite dips below the intruded rocks and has not been encountered in mining operations. But the subterranean extension of the granitic portion of the magma beyond the limits of the exposed *massif* of Heemskirk may be, from field evidence, regarded as certain.

Dykes of granite porphyry are found at several points in the Zeehan district, and must of necessity imply an underground extension of the magma in that direction. No less significant, in the opinion of the author, is the distribution of the mineral veins, which are, according to his view, also derivatives from the same mother magma.

The horizontal contours of the invisible extensions of the granite *massif* may thus be to some degree determined by the observation of the distribution of the dykes and veins at the surface, if the hypothesis of the author with regard to the genetic relationship between the ore-bodies and the igneous rocks is true. The limitations of such a method of mapping the underground extensions are obvious. The amount of erosion subsequent to consolidation, the depth of the granite below the present surface, the vertical extent of the dykes and veins, and the ease or difficulty with which surface phenomena may be examined, all influence the degree of success which any such attempt may attain.

(ii) In a vertical direction.—With regard to the vertical extensions of the concealed portions of the granite *massif*, still greater difficulties are involved. Here we are confronted with the great problem of the structural features of a great plutonic intrusion—a problem to which more than one solution has been offered. One of the objects of this paper is to offer a brief discussion of one aspect of the question from the point of view of the student of one genesis.

The granite *massif* of the Heemskirk Range would, in all probability, be classified by different geologists under different names, according to individual taste and usage.

An admirable compendium of existing nomenclature has been given by Professor R. A. Daly, in his paper on the "Classification of Igneous Intrusive Bodies,"(15) to which reference is here made on several occasions.

(15) Journ. Geol., Vol XIII., 1905, pp. 485-508.

The igneous *massif* under discussion is one of which the outcrop occupies a considerable area (approximately 37 square miles), and which appears to descend with steeply sloping sides below the surrounding rocks. Such a mass would probably be termed by different geologists a stock,(16) boss,(17) or batholite,(18) and being thus named, one most important structural hypothesis would be implied, viz.: that with increasing depth, the area occupied by the igneous mass is ever increasing, and that the upper portion of the igneous material rests only upon the more deeply-seated part of its own mass.(19)

It is to this view that the author would demur from the consideration of the field relationships of the ore-bodies which are believed by him to be genetically related to the granite, as has been discussed elsewhere.

The grounds for the author's objections are largely hypothetical, but are based upon a hypothesis constructed from the evidence of actual occurrences.

The points upon which stress is here laid are four in number:—

(1) The ore-bodies of the region appear to constitute a genetically related series, of which the several types are on the whole distinct, but connected by "passage-types."

(2) The ore-bodies of one type are not known to intersect those of another type.

(3) The roots of the vein series appear to be, beyond all shadow of doubt, direct products of differentiation.

(4) The period of primary ore-deposition appears to have terminated abruptly.

While the cooling of the magma as a whole may well have extended over a long period, the metallogenetic epoch has been, according to the views of the author, of relatively short duration—beginning when consolidation was already far advanced, and itself marking the utter termination of consolidation.

If the batholitic structure exists, it is difficult to believe that existing facts of occurrence could have resulted. For then it appears probable that consolidation would have extended over a much longer period, and that from time to time the derivatives of successively deeper portions of the magma would have been extruded. The result would undoubtedly be a marked intersection of the older veins characteristic of one zone by younger veins characteristic of a higher zone, as the source of the vein-matter became deeper and deeper, through consolidation of the magma.

It appears to the author impossible, in view of the field evidence, to admit the alternative view of a batholitic mass in which the mineralisers and metallic ingredients have floated to the top and there collected in a reservoir, so that the metallogenetic epoch closed, not with the complete consolidation of the magma, but with the exhaustion of the reservoir of mineralisers and metals The observed facts point to a general, if

(16) *Ibid.*, p. 502.
(17) *Ibid.*, pp. 501, 502.
(18) *Ibid.*, pp. 503-505. Note: The English usage of a termination in '-ite' rather than '-ith' is here followed for all such words.
(19) *Ibid.*, p. 506. See also J. Barrell: "Geology of the Marysville Mining District, Montana"; Prof. Paper No. 57, U.S.A. Geol. Surv. 1907, p. 168; and E. Suess: "The Face of the Earth," Vol. IV., p. 551.

irregular, distribution of metallic ingredients and mineralisers throughout the whole mass of the magma, or at least through portions which have always possessed very different altitudes since they reached their *mise en place*.

We therefore appear compelled to adopt the view that the mass of the magma is limited. The substructure of the Heemskirk Range is not an ever-expanding mass of granite which is connected with the deeper portions of the earth. When once the limited mass of igneous material has passed into the completely solid state, all connection with the abyssal region has been effectively sealed up. This view implies the necessity for a very definite *bottom* to the greater part of Heemskirk *massif*, above which lie the magmatic foci whence the ore-deposits have been expelled.

What, then, are we to call the Heemskirk *massif*? The only term applicable appears to be that invented by Professor Daly—chonolite. The definition of a chonolite, according to the creator of the term, is[20]:—

"An igneous body (*a*) injected into dislocated rock of any kind stratified or not; (*b*) of shape and relations irregular in the sense that they are not those of a true dyke, vein, sheet, laccolite, bysmalite, or neck; and (*c*) composed of magma either passively squeezed into a subterranean or orogenic chamber or actively forcing apart the country-rocks."

The form of the particular mass under consideration is probably extremely complex. The visible outcrop resembles that of a batholite or stock; but as has been indicated above, it is highly probable that this particular outcrop is that of a mass possessing some of the features of an irregular transgressive laccolite.[21] It remains still to investigate the relationships of this chonolite to the other neighbouring outcrops of similar material, and to those masses which have not been revealed by erosion, but the existence of which we surmise from the observation of dykes and veins identical in character with those found in association with known outcrops.

IV.—The Relation of the Heemskirk Massif to Neighbouring Massifs of Similar Composition.

If the contention of the author with regard to the nature of the Heemskirk *massif* is sound, certain difficulties attend the discussion of its relationship to the other developments of granite at the North Pieman and the Meredith Range. These difficulties are not met with if the batholitic hypothesis with regard to the substructure of the Heemskirk *massif is* supported; for the outcrops mentioned (together with several others lying to the northward, and shown also upon one of the maps) may be regarded as the surface exposures of one great granite mass which underlies an extremely large proportion of Tasmania. All geological evidence supports the view that all these granites are derived from the same source, and that they attained their *mise en place* synchronously.

Yet if a chonolitic form be assigned to each *massif*, a continuous subterranean connection between all of them cannot

(20) *Loc. cit. supra*, p. 499.
(21) *Vide* A. Harker: "The Natural History of Igneous Rocks," p. 68, Fig. 11.

be assumed (except, of course, at an extreme depth below the surface).

An alternative hypothesis, which the author offers for consideration, as being of possible application to the region under discussion, is as follows: —

> The present visible outcrops of granite are the exposures of chonolites of limited extent, though possibly all of greater areal dimensions at some depth below the present surface than at this level. These chonolites extend in a horizontal direction below certain regions, and may in certain cases unite with others. The distribution of the several chonolites is determined by crustal or subcrustal stresses and their results. Hence the distribution tends to be more nearly lineal than that of the more symmetrical bodies (laccolites) which have been injected into unfolded or unfractured regions in other parts of the world. Chonolites, between which connections exist, are arranged along lines or zones of crustal weakness.

This hypothesis, since it states that any connections that may exist between neighbouring chonolites are distributed in accordance with zones of crustal weakness and even dislocation, demands some treatment of the question of the distribution of the igneous rocks and ore-bodies in space.

Without wishing to enter upon a full discussion of the metalliferous provinces of the region to which reference has been made, the author would draw attention to certain already ascertained facts which appear to have some bearing upon the question of the subterranean continuity of the granitic magma.[22]

Unfortunately, the study of the structural geology of the whole region is not yet sufficiently far advanced to permit of the discussion of the relation between structure and the distribution of the igneous rocks in detail. However, the distribution of the igneous rocks and the ore-bodies has been to some extent ascertained, and to this matter of distribution some reference should be made.

When the attempt is made on the assumption of the essential intimate consanguinity of the acidic igneous rocks and the ore-deposits,[23] to follow the course of the Devonian intrusions of the ore-bearing magma, according to the method indicated above, certain striking facts concerning the distribution of mining fields, granite *massifs* and granite porphyry intrusions arrange themselves before us with singular simplicity.

Taking the Heemskirk *massif* as our starting point, and following the mining fields, we pass along a zone which is absolutely continuous in one direction. From Heemskirk we pass to the Comstock, thence to Zeehan, and on through the Five-mile, North Dundas, Colebrook, Rosebery, and Mt. Farrell to Granite Tor. (Perhaps also the Barn Bluff field belongs to this mineralised zone.) Beyond Granite Tor the Dove River and Mt. Claude mineral fields carry on the line, which perhaps extends much further still.

(22) The words "granitic magma" are used to imply the magma from which the granite, *inter alia*, is derived, and has been explained above.
(23) The consanguinity of the ore deposits cannot be doubted. A specimen of typical first-class galena ore, with its characteristic blebs of chalcopyrite, is of constant habit, whether it be obtained from Mt. Zeehan, the Five-mile, Mt. Farrell, or Mt. Claude.

The continuity is as remarkable as are the features of similarity between different ore-bodies in the mining fields mentioned. From point to point structural features vary in detail. These variations are, for the most part at least, introduced by local conditions, and have no genetic significance.

On the other hand, restricting our attention to the distribution of the acidic igneous rocks of Devonian age, we find, on following the same course from the Heemskirk *massif*, that dykes of granite porphyry occur at Zeehan and North Dundas (24), and that granite itself outcrops massively at Granite Tor. Beyond these, and in general line with them, lie the granite porphyry at the foot of Bond's Peak, near the western boundary of the V.D.L. Company's Middlesex block, and the granite mass north of the Dove River and west of Mt. Claude. Then, after a great interval, but still in line, comes the aplitic and pegmatitic granite of Anderson's Creek, near Beaconsfield. This coincident lineal extension of the acidic igneous rocks and mining fields appears to the author to be of the greatest significance, and to imply the existence of some lineal direction of weakness in the crust.

Some confirmation of this view is afforded by the general parallelism of distribution of the consolidation products of an earlier igneous invasion—that of Cambro-Ordovician time. The keratophyric tuffs and the spilite of Zeehan,(25) the keratophyric tuffs and breccias of North Dundas,(26), the schistose keratophyres or porphyroids and porphyrites of North Dundas, North-East Dundas, Rosebery, and Mt. Farrell are on this belt. The granite porphyry which extends from the north-west of Granite Tor to the Dove River, the schistose porphyry of Mt. Roland, and possibly even the epidote porphyrite of Beaconsfield, are to be taken into consideration with these others. The distribution of these related rocks is, at least, significant in support of this hypothesis. Along this line, or rather zone, are situated some of the most important mining fields of Western Tasmania.

The relation of other mining fields and igneous rocks to those which have been mentioned demands passing notice.(27)

A prominent feature in the geology of the West Coast region is the distribution of certain old igneous rocks—schistose tuffs, porphyries, porphyrites, syenites, and granites, some of which occur along a meridional zone which extends from Mt. Darwin to the north of Mt. Black. Plutonic, intrusive, and effusive phases are all represented in this group (that of Cambro-Ordovician age already mentioned), the present distribution of which is clearly axial, even if the lineal arrangement has been accentuated by orogenic disturbances subsequent to consolidation.

The distribution of the Mt. Darwin, Mt. Jukes, Mt. Huxley, Mt. Lyell, Mt. Read, and Chester mineral fields, is, in general, coincident with that of this belt, but in the opinion of the author the ore-bodies belong to the Devonian metallogenetic epoch. The reasons for this statement cannot be here fully discussed. It suffices to state that the author believes that the

(24) Aplite has been also recorded in Zeehan, Geol. Surv. Tas. Bulletin No. 8, pp. 27-28. A doubtful case of the occurrence of pegmatic has been observed to the south of Mt. Farrell. Annual Report Sec. Mines, Tas., 1909, p. 83.
(25) Geol. Surv. Tas. Bulletin No. 8, pp. 15-19.
(26) Geol. Surv. Tas. Bulletin No. 6, pp. 16-18.
(27) For they, too, extend along restricted zones. Between the zones of intrusion by igneous materials there are no known mineral fields.

mineralogical character of the ores of this belt of orogenic disturbance points most strongly to the necessity for classifying them with the Devonian ore-bodies. Hitherto there have not been found any igneous rocks along this belt which may be assigned to the Devonian intrusion. The author anticipates that these will yet be recognised, but he believes that the characters of the ore-bodies themselves are sufficient evidence of the existence of the Devonian granitic magma along this zone below the surface.

The two zones already mentioned appear to unite in the neighbourhood of Rosebery, not far from Mt. Black. These two zones do not include within their limits a number of the important outcrops of granite and granite porphyry of Tasmania, nor do they embrace some well-known mining fields. Of these other mining fields the author has no detailed knowledge.

Having, however, indicated that there is one very well defined zone of intrusion and mineralisation between Heemskirk and Middlesex, it is interesting to observe that the outcrop of granite at the Meredith Range and Heazlewood, the granite porphyry at Mt. Bischoff, the outcrop of granite on the Blyth River to the east of the V.D.L. Company's Hampshire Hills block, and again that of the Dial Range, are disposed in a zone which is approximately parallel to the former. The further investigation of this zone cannot at present be made.

There remains the North Pieman *massif*, which is not a prominent one, its surface being barely exposed by the total effect of successive cycles of denudation. With it are to be grouped the dykes on the coast-line to the south of the Pieman Heads. The relationship of this *massif* to that of Heemskirk and that of the Meredith Range cannot be said to have been definitely recognised in any particular.

Whether the Meredith Range *massif* has any connection with the Heemskirk-Middlesex zone remains to be proved. Should the hypothesis here put forward be sound in principle, it will be of interest to investigate in the future the already recognised zone of intrusion, marked by the basic rocks which extend from the Colebrook Hill towards the Parson's Hood, for signs of the acidic magma.

V.—Conclusion.

From the several considerations discussed, the author would affirm that the relationships of the Heemskirk *massif* to its immediately surrounding rocks, to the associated dykes and ore-bodies, to certain other similar *massifs* and other ore-bodies, and to certain of the main structural features of Tasmania are approximately known. These relationships may be briefly summed up as follows:—

(1) *The Relationship to the Surrounding Rocks.*—The granite outcrop is that of a massive transgressive intrusion of irregular form, but limited mass—that is to say, of a "chonolite" or irregular transgressive laccolite.

(2) *The Relationship to Associated Dykes and Ore-bodies.*—The granite is one of the products of the consolidation of a magma which gave birth, during its passage into the solid state, to a definite succession of fractional parts, all of which, taken together, constituted the essence of the magma at the time of irruption. Of these fractional parts the granite is the greatest

in mass. The ore-bodies formed within the limits or in the immediate neighbourhood of the *massif* are the latest-born products of the parent magma, and are zonally disposed with regard to the granite. The temperature of the granite at the period of ore-deposition has exerted a potent controlling influence upon this zonal distribution of metallic ores.

(3) *The Relationship to Other Similar Massifs and Other Ore-bodies.*—The Heemskirk *massif*, with its apophyses and cognate dykes and veins, is genetically related to the similar invading materials which made their irruption into many parts of Tasmania shortly after the close of the Silurian period. They are most directly related with the igneous dykes and ore-bodies arranged along a zone extending from Heemskirk through Middlesex (perhaps even to Beaconsfield). Along this zone the granite itself outcrops at several points, the granitic apophyses at intermediate points, while the ore-bodies are distributed along a practically continuous belt of mineral fields. At some depth below the surface there is possibly complete continuity of the granite along the zone.

(4) *The Relationship to Certain of the Structural Features of Tasmania.*—While the actual form assumed by the Heemskirk *massif*, its apophyses, and its associated dykes and veins are all to be ascribed very largely to local structural conditions, the general distribution of these derivatives of the ascending magma has been decided by the existence of an old zone of crustal weakness. For no less remarkable than the lineal definition of this zone is its geological persistence. The granite of Heemskirk lies upon an axis of at least two igneous invasions, viz., those of Cambro-Ordovician and Devonian time. Still another invasion (of gabbro, norite, and serpentine) affected some portions of this zone at a period which is of Post-Silurian but pre-granitic age.

With the acceptance of this statement of the structure and relationships of the granite of the Heemskirk Range, many problems of interest and of economic importance suggest themselves. The author cannot here undertake the discussion of such problems, but desires to lay stress upon the necessity for regarding the granite *massifs* of Western Tasmania as being themselves of limited extent in a vertical direction, and extending horizontally along lines of crustal weakness which are axes of igneous invasion.

The author desires to acknowledge the receipt of no small amount of information with regard to the distribution of the rocks here mentioned from Mr. W. H. Twelvetrees, from whom he has obtained permission to publish the accompanying maps.

PLATE II

GEOLOGICAL SKETCH MAP OF THE SOUTH HEEMSKIRK TIN FIELD

5 cm

SCALE
10 5 0 10 20 30 40 50 60 70 80 CHAINS
0 ¼ ½ ¾ 1 MILE

KEY TO NUMBERS OF MINERAL SECTIONS

Number of Section	Acres	Lessee
3577-M	368	W. H. S. Munro
6765-M	40	
10 a M	18	
3915-M	2	
6860-M	20	E. Mulcahy & M. Bollen
1141-M	20	D. Sweeney
1142-M	20	
1187-M	71	D. B. Sweeney
1188-M	15	
3276-M	2	R. Clarke
6206-M	60	J. Campbell
4653-M	5	J. Campbell & H. Castle
6922-M	60	Liscombe & Hutchinson
6086-M	40	H. V. Williams, C. O'Brien, & T. Buckley
6240-M	60	R. W. Horsburgh
6742-M	60	C. Brumby
6667-M	60	H. D. Marsh
6715-M	60	
463 D.C.		R. Clarke

LEGEND

SEDIMENTARY

RECENT — Unconsolidated Sand and Alluvium
SILURIAN ? — Grit Sandstone and Conglomerate
PRE-SILURIAN — Slate Sandstone and Tuff

IGNEOUS

DEVONIAN — Granite and Granite Porphyry — G G
DEVONIAN — Gabbro and Gabbro – Amphibolite — G G
DEVONIAN — Serpentine — S S

Lode Contents: Tin-Sn Iron-Fe Wolfram-W Bismuth-Bi Molybdenum-Mo Lead-Pb Zinc-Zn Nickel-Ni

Geological Boundaries
Boundaries of Mineral Sections
Boundaries of Town and Forest Reserves
Altitudes above sea-level in feet — o 2000 ft.
Surface Workings
Adits — Shafts
Tracks — Roads
Trainways — Water Races
Line of Geological Sections
Lode Formations

PACIFIC OCEAN

SOUTH HEEMSKIRK LINE

ZEEHAN

Mt. Heemskirk

Mt. Lyell

Mt. Darwin

Mt. Owen

Mt. Farrell

Mt. Sophia

Mt. Black

Mt. Murchison

Mt. Read

Mt. Huxley

Mt. Jukes

Mt. Dundas

Mt. Zeehan

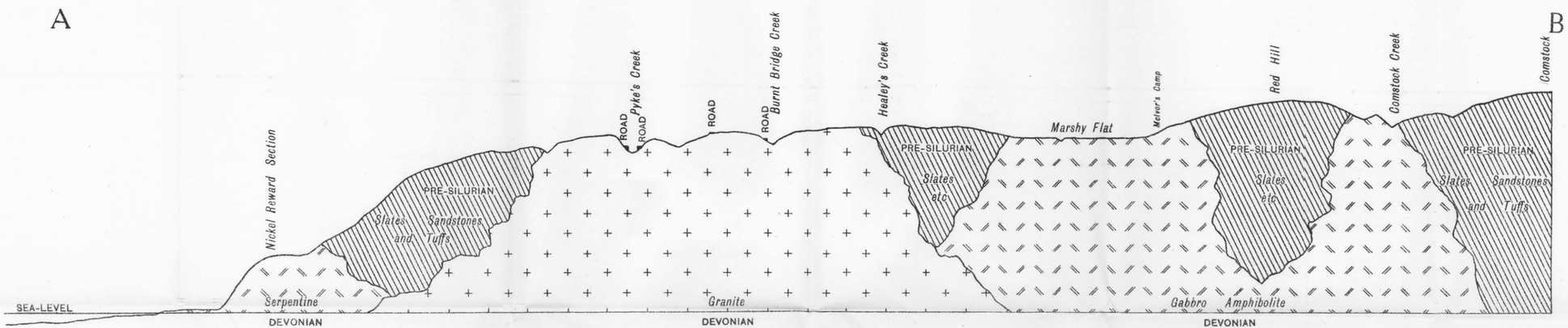
Mt. Sedgwick

Mt. Selwyn

Mt. Donaldson

PLATE III

GEOLOGICAL SKETCH SECTION ON THE LINE A B



HORIZONTAL SCALE

10 0 20 40 60 80 CHAINS

VERTICAL SCALE

100 0 200 400 600 800 FEET

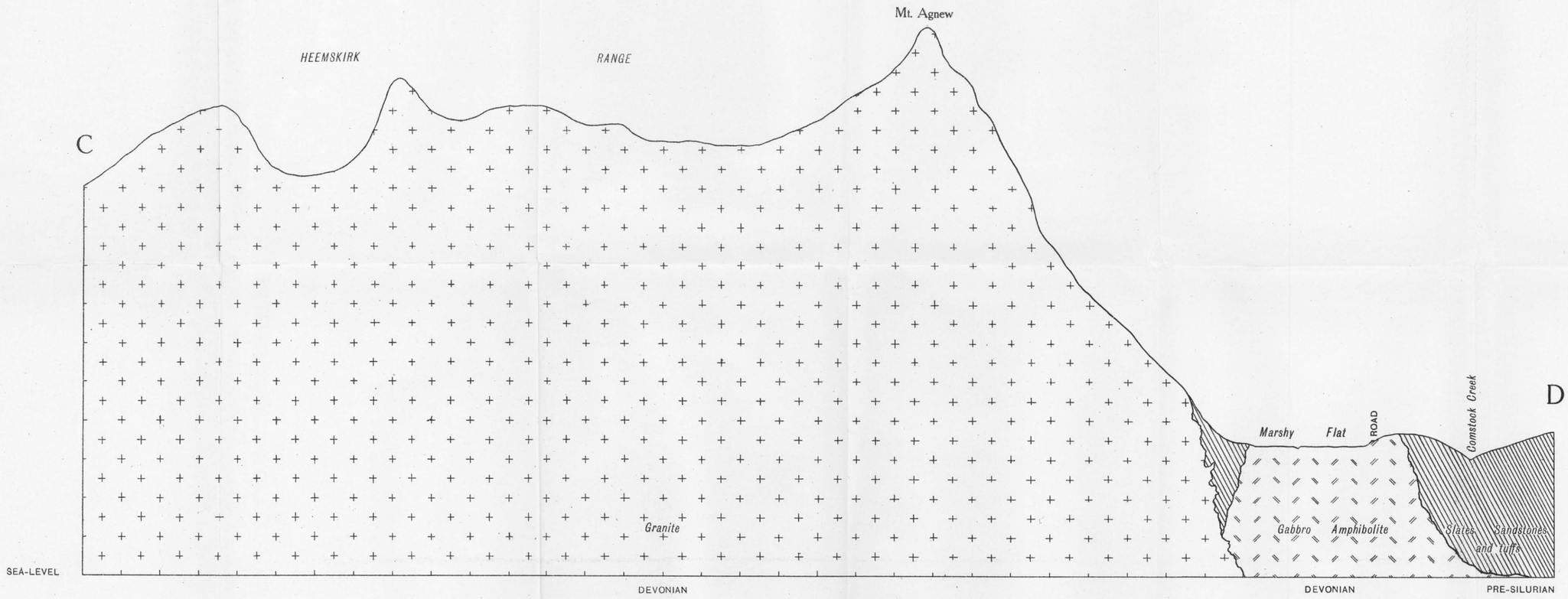
L. Leury Waterhouse B.E.
Assistant Government Geologist
15th October 1915.

5 cm

Photo. Lithographed by John Vail Government Printer Hobart Tasmania.

PLATE IV

GEOLOGICAL SKETCH SECTION ON THE LINE C D



HORIZONTAL SCALE

10 0 20 40 60 80 CHAINS

VERTICAL SCALE

200 100 0 200 400 600 800 1000 FEET

5 cm

L. Laurie Waterhouse B.E.
Assistant Government Geologist
15th October 1915.

Photo Lithographed by John Vail Government Printer Hobart Tasmania.

PLATE V

MINERAL CHART
OF
THE HEEMSKIRK TIN FIELD

L. L. Leary Waterhouse B.E.
Assistant Government Geologist
15th October 1915.

SCALE

5 cm

FOREST RESERVE

FOREST RESERVE

REMINE

ZEEHAN

Photo Micrographed by John Vail Government Printer Hobart Tasmania

PLATE VI

SKETCH LOCALITY MAP OF THE FEDERATION TIN MINE.



SCALE

100 0 100 200 300 400 500 600 700 800 900 1000 FEET

1 0 2 4 6 8 10 12 14 15 CHAINS

5 cm

LEGEND

Boundaries of Mineral Sections

Approximate Contour Lines Sketched

Outcrops of Quartz-tourmaline and Lode Formations

Water Races

Open Cuts — Adits

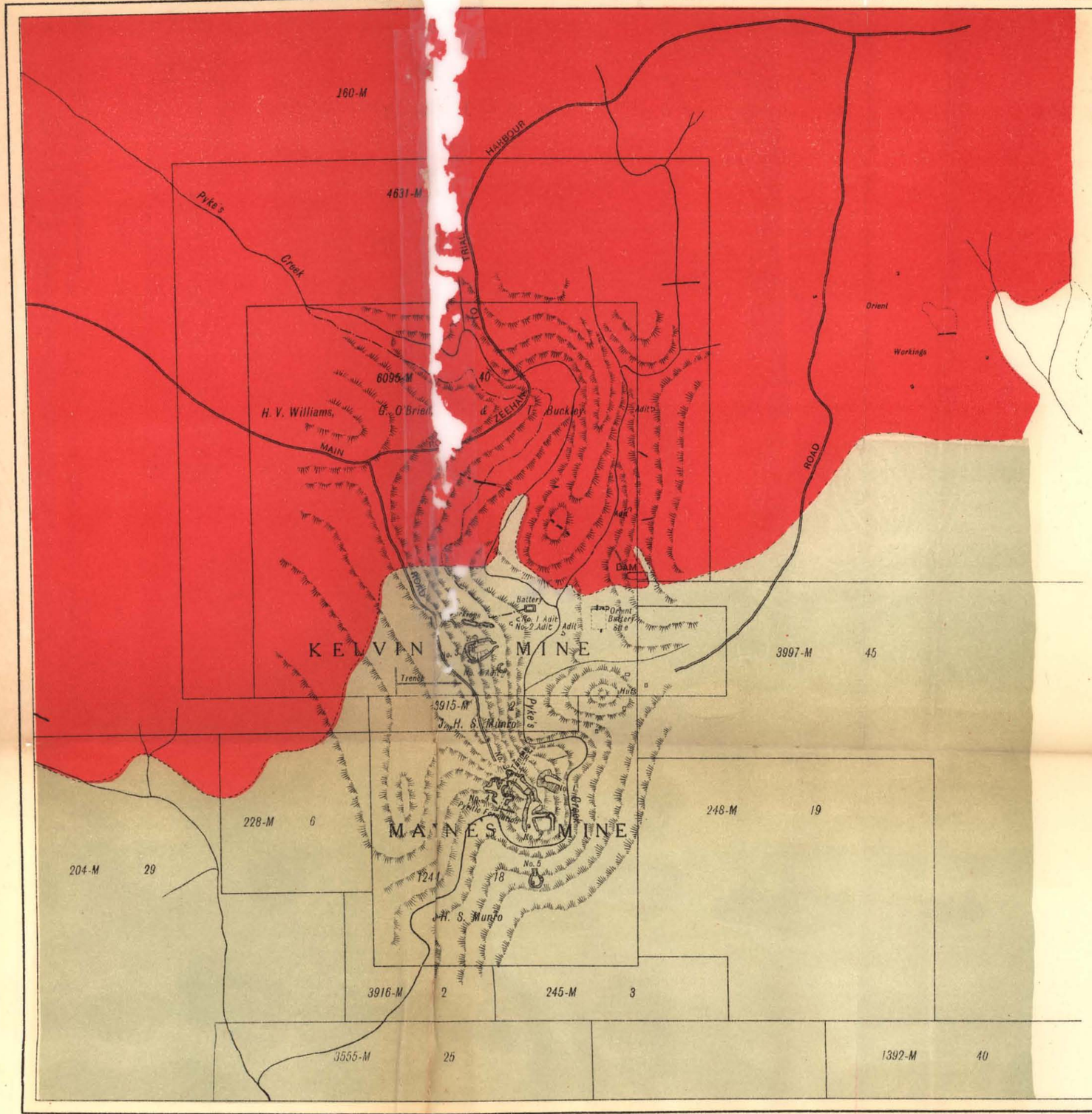
Shafts — Trenches

L. Leury Waterhouse B.E.
Assistant Government Geologist
15th October 1915.

Photo Lithographed by John Vail Government Printer Hobart Tasmania.

PLATE VII

LOCALITY SKETCH MAP OF KELVIN AND MAYNE'S MINES





5 cm

SCALE

0 1 2 3 4 5 6 7 8 9 10 CHAINS

LEGEND

DEVONIAN _ _ _ _ Granite _ _ _ _ _ _ _

PRE-SILURIAN _ _ _ _ Slates and Sandstones _ _

Geological Boundaries _ _ _ _ _ _ _ _ _

Shafts _ _ _ _ _ _ _ _ Water Races _ _ _

Open Cuts _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _

Outcrops of Lode Formations _ _ _ _ _ _ _ _ _ _

L. Laurey Waterhouse B.Sc.
Assistant Government Geologist
15th October 1915.

Photo Mgraphed by John Vail Government Printer Hobart Tasmania.