Tasmania

DEPARTMENT OF MINES

GEOLOGICAL SURVEY BULLETIN

No. 16

The Jukes-Darwin Mining Field

BY

LOFTUS HILLS, M.Sc., Assistant Government Geologist

Issued under the authority of
The Honourable EDWARD MULCAHY, Minister for Mines

Tasmania:
JOHN VAIL, GOVERNMENT PRINTER, HOBART

B52976

1914

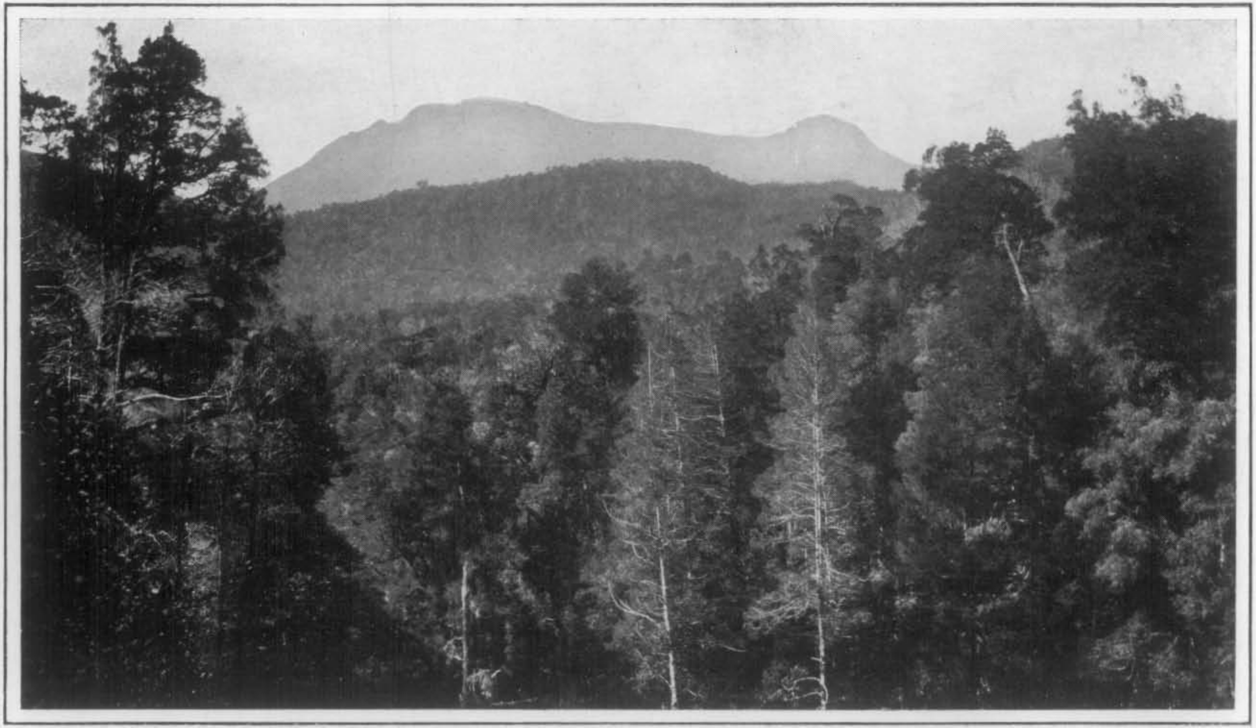


PLATE I.—Mt. Jukes, from the Lynchford Road. [Beattie, Hobart, Copyright.

TABLE OF CONTENTS.

THE JUKES-DARWIN MINING FIELD.

PLATES.

At the back of the report

5 cm

LOCALITY MAP

Photo Algraphed by John Vail Government Printer Hobart Tasmania

The Jukes-Darwin Mining Field.

I.—INTRODUCTION.

(1) Geographical Position.

The area with which this bulletin deals is situated on the West Coast of Tasmania, and is bounded on the south by the shores of Macquarie Harbour. The greater portion of this region consists of mountain masses, which constitute the southernmost portion of the West Coast Range. This range of mountains follows a meridional course from Mt. Murchison on the north to Mt. Sorell on the south, the intervening peaks from north to south being Mts. Geikie, Tyndall, Sedgwick, Lyell, Owen, Huxley, Jukes, and Darwin. The two latter mountain ranges embrace practically the whole of the mineral sections in the mining field under discussion, as although Mt. Sorell was included in the area traversed during this geological examination, no mining sections have yet been surveyed thereon.

The West Coast Range is, roughly, 20 to 25 miles distant from the western coast of Tasmania, the foothills of the most southerly part of the range running to the shores of Macquarie Harbour, in the neighbourhood of Kelly Basin and Farm Cove. The area under examination, therefore, is situated nearer to the sea-coast than the remainder of the range.

The Mt. Lyell mining field is situated to the north of this area, being distant about 8 miles from the King River, which forms the northern boundary of the Jukes-Darwin mining field.

It will thus be seen that natural boundaries delimit the area both on the north and south. The North Mt. Lyell railway from Kelly Basin to Linda was chosen as the eastern boundary of the area to be examined, as the whole of the surveyed mining leases are situated to the west of this line. This railway practically follows the course of the relatively low-lying region included in the valley which separates the eastern foothills of these mountains from the Engineer Range. The latter, running in a meridional direction, separates the southern portion of the West Coast

Range from the mountain masses situated to the eastward, of which the Frenchman's Cap forms the culminating peak.

The western boundary of the area examined is an indefinite line running from the junction of the Newall and King Rivers on the north to Kelly Basin on the south. The adoption of this purely artificial line is convenient in so far as the whole of the surveyed mineral leases and the mountains of Jukes, Darwin, and Sorell down to their western foothills are thus included in the examination. Mt. Strahan, situated somewhat further to the west, was not included in the examination, the approach thereto being absolutely impossible without the cutting of a track.

The area examined measures approximately 70 square miles.

(2)—General.

The geological survey of this region was carried out with the assistance of the charts of mineral sections supplied by the Mines Department. These are (1) the Huxley and Jukes chart, and (2) the Kelly Basin chart. The former includes those sections which have been surveyed on Mt. Huxley, which lies immediately to the north of the King River, but only that portion of the chart was used which lies to the south of that river. This mineral chart also includes a great number of the sections situated on Mt. Darwin, the remainder of the sections on that mountain being shown on the Kelly Basin chart. In the maps accompanying this bulletin these two charts have been combined as one, and the whole designated by the title of the Jukes-Darwin mining field.

The topographical features have been plotted with reference to the surveyed mineral sections, care being taken to complete the courses of streams which are only partially shown on the abovementioned charts. These have been sketched with as great accuracy as was possible under the circumstances, and may be taken as substantially correct. In this connection there is a correction which must be noted. In the Kelly Basin chart a river is shown as flowing in a southerly direction between Mts. Darwin and Sorell, and is there called the Clark River. This river is not charted as entering Macquarie Harbour, but there is a river named Fysh River which is shown flowing in a southerly direction into Kelly Basin, through the township reserve of Pillinger. As a matter of fact, these two streams are one and the same, and the so-called Fysh River is not in the position shown in the chart, but is situated more to the west, although the position of mouth is correctly charted. The writer, therefore, assumes the responsibility of combining these two streams under the one name of the Clark River, the approximate course of which is shown in the accompanying maps.

An alteration has been necessary in the marking of the mile-posts on the North Lyell railway. In the Huxley and Jukes chart, the miles are marked as from a point 2 miles from the Linda station. In the Kelly Basin chart, they are shown as from Kelly Basin as the starting-point. The usage on the railway itself and by the residents generally is to take the measurements as from Kelly Basin. Consequently, in the maps accompanying this bulletin the mile-posts in the Huxley and Jukes chart have been altered to conform with this usage.

Other minor details have been rectified, which do not deserve special mention.

In a region such as this, which has been very little visited or examined, there must necessarily be river courses and mountain peaks which are not known by any definite or descriptive names. This is especially notable in this field, and the writer, in order to make the following descriptive matter perfectly intelligible with reference to the accompanying maps, has been compelled to give names to streams and mountain peaks which were previously unnamed.

The geological features have been plotted with reference to the side-lines of the mineral leases where such have been surveyed. Where no such surveys have been made, the geological data have been sketched with reference to points fixed by triangulation.

The heights above sea-level have been calculated from aneroid readings with reference to three separate points on the North Lyell railway as bases. The writer is indebted to the officials of the Mt. Lyell railway for these heights. The heights of the three places, namely, Crotty, Darwin, and the 10-mile, are the respective heights of the rails at these points above mean sea-level at Kelly Basin.

On this journey, the writer left Launceston on 20th February, 1913, and returned to that city on 1st May, 1913—a total of two and a half months.

Active work was being carried on only on one property on the field (Section 6012-M), and this necessitated the carriage of food supplies, &c., from one base of operations to the next. Altogether, six such bases were used. These do not include Crotty and Kelly Basin, where good accommodation is obtainable.

The writer was accompanied throughout practically the whole of the survey by Mr. J. Cocking, as field assistant, whose thorough knowledge of the district, together with his energy and enthusiasm, rendered it possible to cover such a large area of extremely rugged and mountainous country in so short a time. The writer wishes here to express his appreciation of this assistance, and at the same time to place on record his thanks for the hospitality tendered by those in the field, particularly to Messrs. J. Souter and J. Nourse, of the Mt. Jukes Proprietary, and Messrs. H. Thompson and Vincent Bruscoe, two prospectors under Mr. Hartwell Conder, M.A., State Mining Engineer. Acknowledgment and thanks must also be made to Mr. E. Carus Driffield, Engineer-in-Charge, Mt. Lyell Railway, for valuable information concerning heights of certain points on the North Lyell Railway, as also to the officials on the North Lyell railway for repeated kindnesses.

II.—THE HISTORY OF THE FIELD AND PREVIOUS LITERATURE.

The history of the Jukes-Darwin field is closely associated with that of the adjoining field of Mt. Lyell. In the year 1881 Conrad Lynch landed at Farm Cove, at the head of a party instructed to prospect for gold. Thomas Currie was his first lieutenant. Lynch, with one section of the party, started northwards from Farm Cove, skirted the foothills of Mt. Sorell, and travelled up the Clark Valley, crossing over the Slate Spur into the valley of the Garfield, ultimately succeeding in finding gold in the Queen River, at a point which has been named Lynchford, in memory of his name. His subsequent movements only concern the discovery of the Mt. Lyell ore-body. Suffice it to say that he was the first prospector to enter the district. The section of the party under Currie travelled north-easterly along the southern foothills of Mt. Darwin towards Frenchman's Cap, but apparently failed to observe the outcropping ore-bodies which are so numerous on the southern portion of Darwin.

These two men were apparently the first to enter this field, as although there was, many years before, a convict settlement on Macquarie Harbour (established in 1822), the dense forest growth and the general inhospitable character of the country was instrumental in preventing any exploration by the authorities.*

After the discovery of the Mt. Lyell Mine no prospecting was attempted in the Jukes-Darwin field until the great excitement incidental to the birth and youth of the former field had somewhat subsided and allowed attention to be paid by prospectors to the neighbouring fields.

The first section taken up on the field was Harris' Reward, near the junction of the Newall River with the King, which reward was granted for gold. This was followed by the pegging of many sections in the immediate neighbourhood of the parent property.

The main deposits of the field were not located until the year 1897. The first registered application for a min-

* In spite of the wild and repelling nature of the country, some of the convicts preferred the chance of death in it to enduring life in the settlement, and many escaped to the bush. One of these apparently reached the summit of Mt. Darwin, as is evidenced by the discovery of a leg-iron on what is now Findon's section.

ing lease on Mt. Jukes was dated the 23rd February, 1897. and the applicant's name was Richard Camm. The location of the section was on the northern slope of Jukes, and this, in fact, is one of the sections which now are included in the consolidated lease, 6012-M. A few days after the original application by R. Camm, the section was transferred to J. P. Lonergan, and, together with the adjoining section, was worked as the Mt. Jukes Proprietary Copper Mine.

There immediately followed an excited pegging of sections over the whole area, and this continued for the next 12 months. The first sections taken up on Mt. Darwin were applied for in the latter part of 1897.

After the first excitement, matters calmed down somewhat, and it was only when the North Lyell Company built their railway from Kelly Basin to Linda, and erected their smelters at Crotty, that renewed activity was displayed in exploratory work.

In April, 1900, Mr. W. H. Twelvetrees, Government Geologist, visited the field, and his report, entitled "Report on the Mineral Districts of Mts. Huxley, Jukes, and Darwin," is dated the Government Geologist's Office, 30th November, 1900.

The closing down of the smelters at Crotty gave the field a distinct set-back, from which it has not yet recovered. Immediately following the cessation of smelting operations at Crotty practically all mining work was suspended in the Jukes-Darwin field.

The deposits of alluvial gold on Mt. Darwin were discovered by the Hudson Bros. about this time, and the working of these deposits has kept a few men occupied at intervals up to the present time.

In September, 1903, Mr. G. A. Waller, then Assistant Government Geologist, visited Findon's section on Mt. Darwin, and his report, entitled "Report on Findon's Copper Section, Mt. Darwin," is dated at Zeehan, October 10, 1903.

Subsequent to Mr. Waller's report the field has been almost wholly neglected. A few sections were taken up from time to time and small syndicates formed in Queenstown to work them, but these without exception ended in failure, either through the non-existence of the imagined ore-body or the inability or unwillingness of the shareholders to subscribe sufficient capital to continue operations.

A number of the properties were taken up by the companies operating in the Lyell district, and especially by the North Lyell Company, who hoped to thus secure supplies of ore adjacent to their smelting works. Thorough surface prospecting of the field was also brought about by the vital necessity which arose in connection with the working of the smelters of procuring oxide of iron for fluxing purposes. Practically the whole of the field was scoured in the search for this desirable material.

The North Lyell Company utilised the limestone deposits at Darwin for fluxing purposes, and the quarry is situated a few chains east of the Darwin township reserve.

In more recent years a small syndicate, of which Mr. W. H. Taylour, formerly of the Mt. Lyell Company, is one of the principals, have persevered in carrying out exploratory work on several sections. It is this syndicate which now holds the greater number of the occupied sections in this field, and their tenacity of purpose and great faith in the potentialities of the field are deserving of the fruition of their hopes.

III.—PHYSIOGRAPHY.

(1)—Topography.

(a)—*The Mountains.*

The district is one of extremely high relief, and may be briefly described as excessively rugged and precipitous.

The West Coast Range in this area consists of three large distinct mountain masses, all connected by well-defined spurs. The most northerly of these is known as Mt. Jukes, which is separated from Mt. Huxley (lying immediately to the north) by the deep canyon of the King River. This mountain mass rises abruptly from the King River, which here is only 160 feet above sea-level, to a height of 3250 feet at the Proprietary Peak. From this peak the mountain range extends southwards for a total distance of 2¼ miles, rising to its maximum height at the Main Peak, which is 3790 feet above sea-level. From the Main Peak southwards this mountain consists of a long narrow plateau with several prominent peaks rising from its undulating surface, which has an average elevation of 3100 feet. The width of this plateau is approximately 50 chains, but varies from point to point.

From the edges of the plateau the surface falls steeply away in every direction. The eastern face of the mountain is very precipitous, there being generally a practically vertical drop from the summit to the more gently sloping foothills. The height of this vertical cliff varies, the most striking portion being in the neighbourhood of Main Peak, where the cliff drops 2000 feet vertically into the valley of the Traveller River. Another striking cliff is that at the foot of which lies Upper Lake Jukes. The height of this vertical cliff, from the surface of the lake to the summit of Central Peak, is 600 feet. At other points the cliffs are not as high, but are nevertheless sufficiently marked as to give to the whole eastern face of Mt. Jukes the effect of an almost unbroken line of cliffs. The places at which this line of cliff faces becomes broken or less continuous are the points where spurs run south-eastwards down to the comparatively level country, which has an elevation of 500 feet, and which is traversed by the North Lyell railway.

One of these spurs runs from the South Jukes Peak in a south-easterly direction down to the 14-mile, but throws

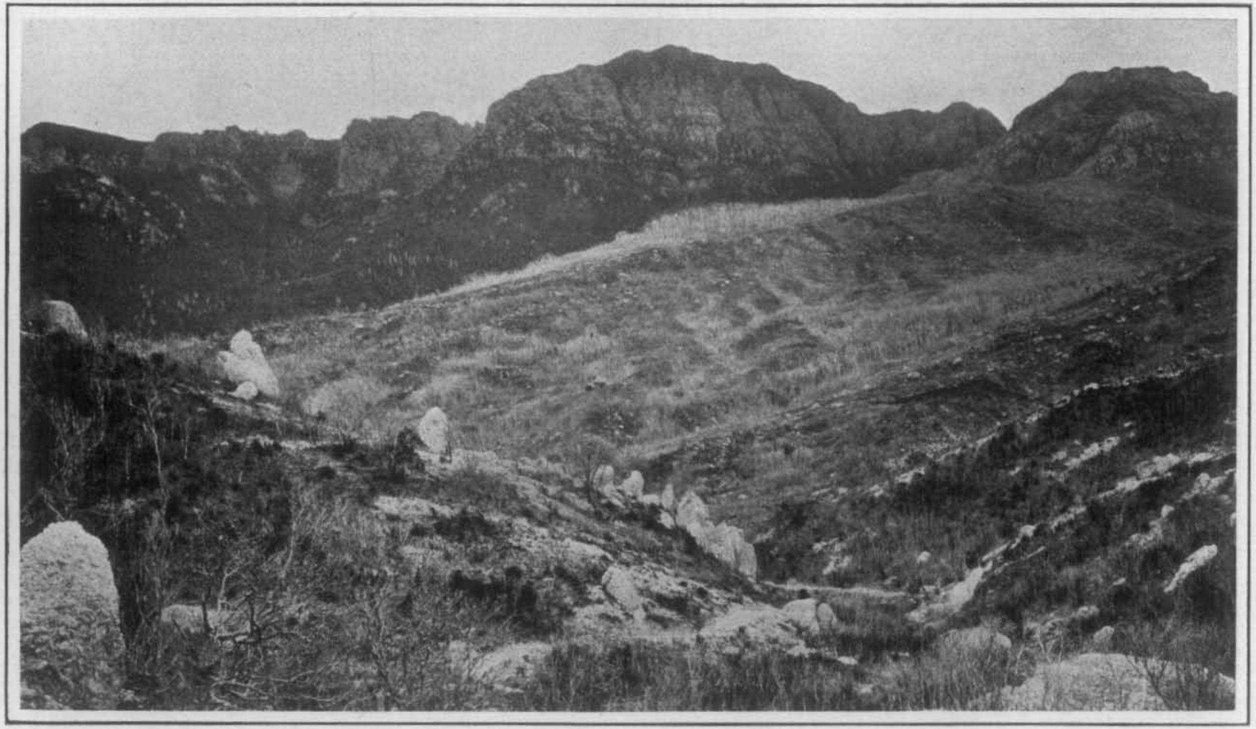


PLATE III.—View of Eastern Face of Mt. Jukes, taken from the Track to Crotty. [*Beattie, Hobart, Copyright.*

off branches towards the north-east which, approaching closely to the south-eastern termination of the Yellow Knob Spur, form a deep gorge through which flows Fish Creek. This latter spur, which has been named the Yellow Knob Spur, runs from the Central Peak, in a south-easterly direction, to the point where the smelter branch of the North Lyell railway crosses Fish Creek. It is a typical razor-back spur, the descent on either side being very steep. This spur also throws off a north-eastern branch from near its south-eastern termination, which, by approaching the southern termination of the East Jukes Spur, forms a deep gorge for the passage of the waters of the Traveller River.

From the Proprietary Peak the country descends north-easterly to the saddle in which lie the Jukes Proprietary sections, and which is 1850 feet above sea-level. From this saddle, the country rises rapidly to the north-east to the East Jukes Peak, which is 2290 feet above sea-level. From this peak, the surface slopes precipitously to the King River 2130 feet below. A main spur, called the East Jukes Spur, runs from the peak in a general south-south-east direction, and comes to a termination at the smelter site at Crotty. This spur is much steeper on its eastern than on its western face.

The western side of Mt. Jukes is also very precipitous, but not to such a marked degree as the eastern side. Three spurs slope westwards from the western edge of the Jukes Plateau, namely the Crown Spur, Newall Spur, and Cliff Spur. The northern face of the former is practically vertical; between this and Newall Spur is the deep precipitous gorge of the Little Newall River, and between the latter spur and Cliff Spur is the gorge of the Big Newall River. The southern side of Cliff Spur presents a vertical cliff face, that portion immediately west of West Peak actually overhanging.

From South Jukes Peak, which is 3140 feet above sea-level, the country slopes down to the Intercolonial Spur, which forms a connecting saddle between Mt. Jukes and Mt. Darwin. This spur has an elevation of 2050 feet, and is about 1 mile long by a quarter of a mile wide; the surface is slightly undulating, but viewed from South Jukes Peak it presents the appearance of a small narrow plateau.

Mt. Darwin may be regarded as consisting of the two units—(1) the main mountain mass or ridge, and (2) the southern plateau. The former in generalised shape is conical, the summit being 3340 feet above sea-level. The surface of this cone-shaped mass is deeply dissected and corroded. The eastern face is very steep, but does not present the line of vertical cliffs which characterises the eastern face of Jukes. There are two points, however, where the eastern face is almost vertical, the first of which is at the head of Tunnel Cirque, which is occupied by a prominent waterfall; the other is the head of the East Darwin Cirque.

The northern end of Mt. Darwin consists of two peaks, with spurs running from these in a north-westerly direction. The more northerly of these is known as Conglomerate Peak, and the spur as the Conglomerate Spur, which runs to the junction of Conglomerate Creek with Tony's Creek. The other peak is known as Snake Peak, and the spur as Snake Spur, which runs north-westerly to the junction of Tony's Creek with the Currie River. Both these spurs have steep slopes, and may be called razor-back ridges.

The eastern face of the mountain is very steep, especially the walls of the Garfield Cirque. The approach along the slope of the conical mass of Darwin towards the South Darwin Plateau is only practicable by traversing the comb of the most exceptionally acute-angled ridge known as the Razor-back, which separates the deep gorge of the Canyon Creek from the eastern slope of Darwin.

The South Darwin Plateau has a general elevation of 2000 feet above sea-level, and possesses a gently undulating surface. The length of this plateau is roughly 2 miles, and the width is half a mile. From the eastern and western edges of the plateau the surface falls rapidly downwards. At its southern extremity the plateau rises into the South Darwin Peak, which is 2450 feet above sea-level. From this point southwards to Kelly Basin the country consists of a succession of hills and deep youthful valleys, gradually diminishing in height until Kelly Basin is reached.

Mt. Sorell is connected with Mt. Darwin by a narrow saddle (the Slate Spur) which leaves the main mass of the latter mountain immediately west of and below the northern end of the Razor-Back, and, running south-westwards, joins Mt. Sorell near the northern termination of the main ridge. Mt. Sorell consists of a long ridge approximately 2 miles long, running in a meridional direction. For this distance the ridge has an approximately uniform height, the highest point, which is 3730 feet high, being not more than

PLATE IV.—View of Mt. Darwin, taken from the North-east.

[*Beattie, Hobart, Copyright.*

one or two hundred feet higher than the lowest point in this length. From the southern end of this ridge the land slopes steeply down to the flat country in the neighbourhood of Pillinger. From the northern end a long continuous spur slopes away to the northwards between the two branches of the Garfield River; another spur runs north-westerly towards Mt. Strahan. To the east and west this narrow ridge slopes steeply downwards, the slope on the eastern side being very steep, while that on the western side, while not quite so steep, yet is decidedly precipitous.

(*b*) *The Rivers and Valleys.*

The river systems of this region are somewhat complicated. There are five main systems of drainage, two of which have an outlet into the King River, and thus constitute a part of the larger system of that stream; two of the other three river systems flow into Macquarie Harbour at different points in Kelly Basin, while the fifth flows into the Franklin River, which is a tributary of the Gordon.

The first river system is that of the Traveller, Governor, and Baxter Rivers. These streams drain the eastern side of Mt. Jukes as far south as the South Jukes Spur and the western slopes of the Engineer Range. The Traveller River has three main branches which junction, and the main stream flows through a narrow gorge on to the flat plain at Crotty, and, turning northwards, flows into the King River. The Governor River rises in the northern portion of the Engineer Range, but the Baxter River rises further south in this range. These two streams junction about 10 chains east of the point of the debouchure of the united streams into the King River, which is situate about 60 chains eastwards of the point of junction of the Traveller and King Rivers.

The second river system is that of the Newall, Currie, and Garfield. The Newall River rises in two main branches on the Jukes Plateau, which is completely drained by this river. These branches flow through their respective deep gorges and junction with the main stream at the foot of the western cliffs of Jukes, whence it flows in a north-westerly direction to the King River, which it joins about 20 chains east of the confluence of the latter with the Queen River. The Currie River drains the south-western end of Jukes, the Intercolonial Spur, and the northern portion of Mt. Darwin, occupied by Conglomerate and

Snake Spurs. These three main branches junction near the north-western end of Snake Spur and the combined stream flows north-westerly from this point. The Garfield River drains the western slopes of Mt. Darwin as far south as Slate Spur, the northern portion of Mt. Sorell, and the eastern slope of Mt. Strahan. After the junction of these feeders, the Garfield flows in a direction a little west of north, until it junctions with the Currie, whence it flows in a general north-westerly direction to the King River, which it enters some distance west of the point of confluence of the King and Queen Rivers.

The King River itself rises in the Eldon Range and flows in a southerly direction at the base of the eastern slope of the West Coast Range, until it reaches the north-eastern corner of the region under discussion, where it takes a sudden turn to the west, and flowing through the flat Crotty Plain at the foot of the Thureau Hills, enters the tremendous gorge between Mts. Huxley and Jukes. This gorge retains its profound depth for about 2 miles, and for this distance is a most striking and impressive-looking canyon. The total depth from the summit of the East Jukes Peak to the river below is 2130 feet, and the fall from the summit of Huxley is about 3000 feet. The distance between these two peaks is 1¼ mile, which gives the sides of the gorge an average slope of 37°. The fall from the Proprietary Peak to the river below is 3090 feet, and the horizontal distance is 60 chains, which gives an average slope of 35°, or 1 in 1½.

The third river system is that of the Clark River, which, rising on the south side of the Slate Spur, drains the eastern side of Mt. Sorell and the western fall of South Darwin, and flows in a general southerly direction into Kelly Basin, a little to the east of the township reserve of Pillinger. The portion of this river near Kelly Basin has been known as the Fysh River, but as explained previously, it is necessary to discard this name.

The fourth system of drainage is the Bird River system, which drains the extreme southern end of Darwin and the eastern fall of South Darwin as far north as a line drawn west from the 10-mile. The two main branches of this stream unite at the 4½-mile, and from this point it flows beside the railway-line and almost parallel thereto, until Kelly Basin is reached, which it enters about three-quarters of a mile east-south-east of the mouth of the Clark River.

The fifth drainage system is that of the Andrew River, which drains the south side of South Jukes Spur, the eastern fall of the Intercolonial Spur, and the whole of the eastern side of Mt. Darwin as far south as the 10-mile. The Andrew River flows in an easterly to south-easterly direction, and joins the Franklin River, thus reaching Macquarie Harbour per medium of the Gordon River.

The whole of the river valleys of this region present those features which are characteristic of topographic youth. The river courses for the most part are successions of rapids and waterfalls, running in valleys with very steep walls, and in many cases constitute pronounced and impressive gorges. On the eastern side of Mt. Darwin, south-west of the Darwin township reserve, is a prominent waterfall, formed by the waters of Allan's Creek flowing over the vertical cliff which forms the head of the Tunnel Cirque. There are really two waterfalls here, the upper one not being visible from the township. After heavy rain these falls present an impressive sight when viewed from the plain below. The valley above the falls is a typical "hanging valley," which is a type quite common in this district.(1)

The Clark Valley between Mts. Darwin and Sorell is a tremendous depression which deserves special mention. The centre of this valley is occupied by the Clark River, which follows a somewhat meandering course through it for the first 3 miles, after which it plunges into the deep precipitous gorge which constitutes the southern portion of the Clark Valley. It is the northern 3 miles of this valley, however, to which special reference is made here. This portion of the valley extends from the foot of the southern slope of Slate Spur to a point about due west of South Darwin Peak.(2) For this distance (about 3 miles) the cross section is in the shape of a U, the western limb being higher than the eastern. The top of the eastern limb is the general level of the South Darwin plateau, which has an elevation of 2000 feet; the western limb terminates in the summit of Mt. Sorell, which is 3730 feet above sea-level. The bottom portion of the U has an elevation of approximately 800 feet, and the generally flat country is roughly half a mile wide; the distance between the tops of the two limbs is $1\frac{3}{4}$ miles. The general slope of each side is not very far from vertical. This is undoubt-

(1) See p. 18.

(2) This valley is known amongst those who are conversant with the field as the "Golden Valley" or the "Sheep Run," because of its sheltered position from prevailing storms.

edly a typical U-shaped glacial valley (3) Other evidences of this glaciation are afforded by the abundant erratics strewn over the floor of the valley.

The only development of flat country of any extent in this region is the area in the neighbourhood of Crotty and Smelter Junction. The township site of old Crotty is situated on a button-grass plain, which has an elevation of, roughly, 500 feet, and through which flow the Baxter and Governor Rivers. This plain is bounded on the north by the King River, which flows at about 20 feet below its surface. To the south, near the Crotty station, this plain is succeeded by undulating hills, which rise to a height of about 700 or 800 feet above sea-level. The old North Lyell smelters occupy a site on a flat-surfaced terminal moraine,(4) about 140 feet above the lower Crotty Plain. This Smelter Plain runs southwards to the Smelter Junction, whence it continues to the 14½ mile; its maximum width is half a mile. The township site of Darwin is situated on a small area of flat country having an elevation of 560 feet.

(*c*) *The Lakes.*

There are two lakes in this region, both of which are situated on the eastern side of Jukes, and are within half a mile of each other. They are both situate high up on the mountain side at the foot of the eastern cliff face of Mt. Jukes.(5) The higher or Upper Lake Jukes is about 2660 feet above sea-level, and occupies an area of approximately 8 acres. This lake is situated directly below the Central Peak, and one can look down from that pinnacle into the dark waters of the lake 600 feet below.(6) The second or Lower Lake Jukes is situate at the foot of the cliff between Pyramid Peak and South Jukes Peak. It is approximately 2350 feet above sea-level, and occupies an area of about 10 acres. No data are available as to the depth of these lakes, as no measurements have been made up to the present.(7)

(3) See "Characteristics of Existing Glaciers," by W. H. Hobbs, p. 63.

(4) See p. 57.

(5) See p. 8.

(6) A noticeable feature of the waters of these lakes is the deep brownish-black colour when observed in any thickness. This is probably due to the organic compounds derived from the abundant vegetation.

(7) There exists on the field the belief that these lakes are practically bottomless. This is absolutely improbable.

The lakes are of glacial origin, occupying, in fact, the rock basins scooped out by the glacier, which was instrumental in developing the Lake Jukes Cirque, of which they form a part.

(*d*) *The Glacial Cirques.*

The mountain ranges of this field have all been subjected to glaciation, and some of their distinctive features have been developed by the effect of this geological agent. Chief among these topographical features, due to the action of glaciers, are the notable amphitheatres or cirques which have been excavated in the mountain masses.

The meaning of this term "cirque" is explained in the following passage by R. D. Salisbury (8):—"There is often a steep descent of a mountain glacier near its head. This steep slope, and especially its lower part, is the site of great erosion, which carries the head of the valley back farther and farther into the mountain, and at the same time gives it steep slopes at sides and head. The big, blunt, steep-sided heads of valleys developed by the erosion of valley glaciers are known as *cirques.*"

W. B. Scott (9) explains this topographical feature as follows:—"Glaciers flowing from high mountains had usually large amphitheatres or 'cirques,' caused by the lateral plucking of the rocky walls by the fields of ice and snow. Each cirque slowly retreats upward, thus often reducing the divides between them to extremely sharp 'knife-edges.'"

There are seven of these cirques on this field, each of which forms a prominent feature of the topography. On the east side of Mt. Jukes there are two—the Main Jukes Cirque and the Lake Jukes Cirque. The former is included between the southern slope from the Proprietary Peak and the East Jukes Spur on the north, and the Yellow Knob Spur on the south, its western or head-wall being the main cliff of Jukes beneath the Main Jukes Peak, which, as mentioned above, is 2000 feet in vertical height. It is really composite, and thus consists of two cirques of lesser magnitude. These are respectively situated at the northern and southern ends of the main cirque, and are now the deep steep-sided

(8) "Physiography," by R. D. Salisbury, p. 248. For a complete discussion of "cirques," the reader is referred to "Characteristics of Existing Glaciers," by W. H. Hobbs (Macmillan & Co.).

(9) "An introduction to Geology," by W. B. Scott, p. 164.

heads of the gorges of the middle and south branches of the Traveller River respectively.

The Lake Jukes Cirque is situated in the depression between the Yellow Knob Spur on the north, and the South Jukes Spur on the south, the western or head wall being the steep eastern cliff face of the mountain. This again consists of two subsidiary cirques, one of which is that portion occupied by Upper Lake Jukes, and the other by Lower Lake Jukes. These lakes occupy depressions in in the floor of the cirque which have been scooped out by the action of the glacier.

The third is much smaller in size, and is situated at the head of the gorge of Allan's Creek. The waterfall described above flows over its head. It is shown on the charts accompanying this bulletin as the Tunnel Cirque.

The next cirque, travelling southwards along the eastern face of the range, is the East Darwin Cirque, which occupies the heads of the gorges of the two branches of 11-Mile Creek. This cirque forms a striking feature of the eastern face of Mt. Darwin, the main outline being semicircular and the walls practically vertical.

The South Darwin Cirque is situated to the south of this latter cirque, between the steep slope southwards from the summit of Darwin and the Razor-back Spur. It has the appearance of a deep gash in the side of the mountain, and actually represents the youthful stage of the development of a cirque.

The Clark Cirque is at the head of the main branch of the Clark River, the head being situated to the west of the head of the South Darwin Cirque. The heads of these two cirques approach to within a few yards of each other, and the top of the Razorback forms the divide between them.

The seventh cirque forms the head of the eastern branch of the Garfield River, and is roughly semi-circular, and forms a prominent feature of the western side of Mt. Darwin.

It will be at once apparent to the reader that it is within these cirques that the prominent cliff faces occur. As a matter of fact the formation of these cliff faces has been the direct result of the cirque-cutting action of the glacier; the recession of the cliff wall into the mountain mass being an accompaniment of their development and recession.

These give interesting illustrations of the different stages in the life-history of cirques. The general process of their development is indicated by the following passage by W. H. Hobbs (10):—

"In this stage (the youthful stage) the cirque will be but little, if any, wider than the deepened and widened valley below. Later, with the continuation of the sapping process, the cirque becomes enlarged to such an extent that its sides form recesses in the walls of the valley. Thus, in the plan, the glacial valley of this stage bears some resemblance to that of a nail with a large rounded head. As the upland is still further dissected, the cirque becomes more irregular in outline, and widens into a roughly elliptical form, not infrequently allowing it to be seen that it is in reality composite or made up of several cirques of a lower order of magnitude."

The South Darwin and Clark Cirques are both examples of an early stage of development; the East Darwin and Garfield Cirques have advanced a stage further, and may be likened as above to a nail with a large rounded head. The Main Jukes and the Lake Jukes Cirques are both of mature age, and, as explained above, are in reality composite in character.

(*e*) *The Evolution of the Topography.*

As will be seen subsequently in this bulletin,(11), the conclusion is arrived at that this region occupies part of a former central high-level plateau, the drainage from which, flowing westwards, fed the stream or streams, the base-levelling of which developed the generally level plain of degradation known as the Henty Peneplain. By a subsequent uplift of the whole region the streams of this peneplain became rejuvenated, and have carved deep steep-sided gorges; while the central upland region has entered upon a period of renewed erosional activity, following upon, and in continuation of, that great cycle of erosion which, in its previous stage, was able to make only very small progress towards the establishment of a base-level.(12)

---

(10) *Cited previously*, p. 29.

(11) See p. 25.

(12) The time necessary for the development of a base-level throughout a drainage basin is known as a *cycle of erosion*.

The present stage of this prolonged cycle of erosion has only advanced far enough to produce the appearance of high relief and extreme youth, which characterises the topography of the Jukes-Darwin field. This present topography is certainly the result of the atmospheric and aqueous agencies of erosion accompanied and accentuated by the action of an epoch of glaciation.

The evidences of this glaciation are frequent throughout the field. The cirques described above—the presence of terminal moraines and large erratics in the Crotty and Smelter Plains and Clark Valley, the well-defined lateral moraines in the Main Jukes Cirque, the hanging valleys and mountain tarns and the rounded rock-masses or "roches moutonnés" at Lake Jukes—all these are unmistakable indicators of the former presence of mountain glaciers. Nowhere, however, could the writer observe undoubted examples of ice-grooving or scratching. The absence of this general accompaniment of glaciation is explained, in the first place, by the unsuitability of the conglomerate for the registration of these scratches, and, in the second place, to the fact that those rocks (felsites, &c.), which were liable to receive scratches, are subject to rapid weathering, which would be quite sufficient to eradicate any grooves that had been formed.

The whole of the evidence gathered during the survey of this field goes conclusively to show that this glaciation was in the form of mountain glaciers, and not of the type known as continental. These mountain glaciers were generally most probably of the horseshoe type,([13]), and flowed from the mountains into the valleys below. In the case of the Clark Valley they seem to have coalesced and flowed down the valley for some distance, thereby excavating its present U-shaped outline. On the eastern side of Jukes and Darwin, however, the "horseshoe glaciers" appear to have reached the piedmont plain, and there deposited their lodes of morainal matter; the melting seems to have taken place as soon as the plain was reached.

The evidences of glaciation do not extend to sea-level. Such evidence terminates in the Clark Valley at 700 feet above sea-level, while on the eastern side of the mountain range the lowest point at which glacial action has left its imprint is 420 feet above the sea.

There is one small portion of the area which has apparently been reduced to base-level. This is the Crotty Plain,

([13]) W. H. Hobbs, cited previously.

situated in the north-eastern corner of the field. The streams which flow through this plain are sluggish, and possess all the characteristics of mature rivers. The King River itself is about 20 feet below the level of this plain. This base-level is purely a temporary one, and has been caused by the check to the corrosion of the King River Valley, which has been brought about by the passage of that river over the extremely hard band of conglomerate which extends from the top of Mt. Huxley to the present bed of the river in the canyon between that mountain and Mt. Jukes. On the western side of this mountain range the outlet has been towards the sea, and consequently the effect of the progress of the erosion is shown chiefly in the deepening of the valleys, which has taken place at such a rate as to markedly exceed the process of widening. On the eastern side of the King River canyon, however, the rate of deepening of the river valley is dependent on the rate at which the hard rock bar at the head of this canyon is cut down. This has been a slow process compared with the erosion of the relatively softer rocks (sandstones, slate, &c.) which lie to the eastwards. The resultant effect of this has been that the King River, east of the mountain range, has had its valley made broad in relation to its depth to such an extent as to present the characteristics of a mature valley. The processes which are instrumental in base-levelling any region have had sufficient time and opportunity to bring this valley into a state of maturity, while the river itself has been carving its deep canyon through a belt of hard resistant rock.

(2)—The Relation of Topography to Geology.

The general topographic features having been brought about by the action of the agents of denudation, the character of the rock types will determine, to some considerable extent, the development of topographic forms, while the geological structure will only have an effect on the development of details. This statement must, however, be taken as applicable strictly only to the particular stage of the cycle of erosion which is at present in operation, for, as will be seen later,[14] the geological structure has been instrumental in predetermining the existence of this mountain range.

[14] See below p. 65.

In general, it may be stated that the more resistant conglomerate, quartzites, and porphyroids occupy the higher portions of the region, while the softer rocks, such as the Silurian sandstones, slates, and limestones, constitute the country of less high relief, but nevertheless deeply dissected, which bounds the mountain range on the east and west.

Coming to the investigation of details, we observe that the greater part of Mt. Jukes is covered with conglomerate, as also is the whole of the long ridge of Sorell, whereas Mt. Darwin is wholly composed of members of the porphyroid series, with a very small development of conglomerate on the peaks which occur on either end of the mountain. The reddish colour which characterises the weathered surface of the felsite on Mt. Darwin is the most striking feature of that mountain when viewed from a distance, as compared with the uniformly white capping of Sorell and the variegated aspect of Jukes.[15] All the most prominent spurs of Mt. Jukes are capped by conglomerate as well as all the prominent peaks, but this is not solely the result of the greater resistance of the rock in these neighbourhoods, as the whole of these mountains was undoubtedly at one time completely covered with this conglomerate series, and these residual patches are simply the pinnacles and comb-like ridges, developed by the "fretting" of an original upland surface; this fretting having, within the area of the cirques, &c., taken place to such an extent as to remove the overlying conglomerate, and also to some extent the underlying porphyroids.[16]

The different members of the porphyroid series affect the development of topographic details to some extent. The softer schistose varieties, being more subject to the denudational agencies, are eroded comparatively quickly, leaving the more resistant felsite standing in relatively high relief. The granite, which is developed on South Darwin Plateau, is a rock which is disintegrated at a much faster rate than the surrounding felsite, and the existence of this generally level upland surface is due to this comparatively speedy denudation. This is very clearly

---

[15] This red colour was instrumental in giving to Mt. Darwin its original name "The Red Mountain."

[16] W. D. Johnson, in "Maturity in Alpine Glacial Erosion," *Journ. Geol.*, Vol. 12, 1904, likened this "fretted upland" due to cirque recession, "to the irregular remants of a sheet of dough on the biscuit board after the biscuit tin had done its work."

brought into evidence by the included elongated mass of felsite within the granite itself. The superior resistant character of this inclusion has been instrumental in causing the development of the long narrow ridge which runs in a meridional direction for practically the whole length of the granite plateau. Its width is about 2 chains, and it is wholly composed of the felsitic variety of the porphyroids. This ridge forms a notable feature of the plateau.

The occurrence of mineral deposits in the porphyroids has affected the topography in only small details. The only noteworthy effect is that of the masses of red hematite in the felsite at Sections 5241-93M, 3868-M, and 4414-93M. The markedly resistant character of the red hematite has been instrumental in developing the serrated crags which are prominent characteristics of these localities. The ore-body at the Jukes Proprietary is seen at the surface as a well-defined ridge with a conspicuously red surface, caused by the weathering of the pyrite into limonite.

In considering the deeply dissected regions to the east and west of the mountain masses, we are at once struck by the remarkable regularity with which the limestone is seen at low levels (either outcropping in the alluvial flats or in the beds of the streams) as compared with the occupancy of the more elevated portions, by sandstones or slates. This fact has been repeatedly remarked in western Tasmania, and has always been to some extent a very puzzling feature. All the occurrences in this region, however, are capable of explanation by the readiness with which limestone yields to the action of the agents of erosion, as compared with the rate of erosion of sandstone, taken in conjunction with the geological structure in the form of anticlines and synclines. In the northern portion of the eastern section of this region, the limestone invariably occurs in the beds of the streams or outcropping in the flats. In the southern portion, however, where the limestone forms the predominating rock type, the limestone actually constitutes hills of high relief. It is noticeable, nevertheless, that wherever the beds of limestone are of the purer variety their outcrops occur in flat country. It is the impure siliceous or argillaceous limestones which constitute the higher land. We see in this, therefore, the direct result of the unequal resistance to erosion of the rock types.

It will be seen subsequently in this bulletin that the limestone forms a lower horizon in the Silurian system than the sandstones, and that these beds have been thrown into a series of anticlinal and synclinal folds. Along the axes of the synclines, the limestone is protected by the overlying sandstone. In the neighbourhood of the anticlines, however, the limestone has been quickly exposed by the removal, by erosion, of the anticlinal crest of sandstone.(17) Erosion has subsequently proceeded in this limestone at such a rapid rate as to bring the surface at these points to a base-level, and the sandstone has been left as hills and ridges. Consequently any outcrops of limestone must necessarily occupy a position in the low-lying portion of the surface. This applies to the northern half of the east ern division of the area, but in the southern half the erosion has taken place to such an extent as to everywhere cut through the upper sandstones into the underlying limestone series, and the effect described above of the variation of the extent of erosion according to the purity of the limestone is apparent.

The generally flat surface of the Crotty and Smelter Plains, as well as the flat at Darwin, are covered for the most part by glacial or glacio-fluviatile deposits of recent date.

The structural geological features have influenced the topography in some particulars. The East Jukes Spur owes its sharp outlines to the band of conglomerate which in that locality strikes in the direction of the ridge and dips at a high angle of about 80° to the south-west. This hard conglomerate, practically standing on end, has to some extent determined the existence of this ridge. This same band of conglomerate, with the same dip and strike, runs along nearly the whole of the eastern side of the mountains, and is repeatedly responsible for the development of pronounced ridges, *e.g.*, the 10-Mile Hill, &c.

The whole area is cut by many faults, and these have had some influence on the development of the details of the topography. The Central Jukes Fault has thrown up the hard white conglomerate beds to the level of the upper and softer beds, and as a consequence the white conglomerate stands out as a conspicuous ridge on the Jukes Plateau. Other faults have also been responsible for the position of this hard, white conglomerate on the top of the mountain, and whenever this happens, the result is the development of prominent white knobs or crags.

(17) This principle of the proneness of the crests of the anticlines to be eroded more quickly than the synclines is a well established one, and is discussed in the following works, *inter alia*: "Geology," by Chamberlin and Salisbury, pp. 158-161, "An Introduction to Geology," by W. B. Scott, pp. 456-457.

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

The present state of our knowledge with regard to the topography of the country north and east of this region is somewhat meagre. The country to the west and north-west, however, is better known, and general conclusions regarding the topography of that portion of the country have been arrived at. The country to the south, south-west, and south-east, is almost totally unknown.

It is important to correlate as far as is possible the topographical details of this field with those of the areas which surround it, and any general deductions as to the evolution of this topography should be made with due regard to facts already established in regard to these adjacent regions. Accordingly, an attempt is here made to decide whether the general facts deduced for this field harmonise with those made for neighbouring districts.

L. K. Ward (18) and Prof. J. W. Gregory (19) have both recognised the existence of an extensive peneplain, which extends from the western foot of the West Coast Range to the coast-line. This peneplain has been called the Henty peneplain by Gregory and the Little Henty peneplain by Ward, the latter being the northern continuation of the former. The mountain masses of Zeehan, Agnew, and Heemskirk represent residual "monadnocks," which rise above the general level of this plain. A magnificent view of this peneplain can be obtained from the summit of Mt. Jukes or Mt. Sorell, preferably the latter. From this point, the general level of the plain can be seen extending from the foot of the range westwards, northwards, and southwards; the southern portion extending south of Macquarie Harbour to beyond Point Hibbs, and apparently to the foot of the Junction Range. The general elevation of this peneplain is given as approximately 700 feet. The western part of the area included in this bulletin embraces the extreme eastern portion of the peneplain, and it is this portion which is mentioned above as being composed of the series of sandstones, slates, and limestones, and being consequently more eroded than the mountain range.

(18) See Geol. Surv. Tas. Bull, No. 8, pp. 11-12.

(19) See "Some Features in the Geography of North-Western Tasmania." Proc. Roy. Soc., Vic., 1903, pp. 177, *et seq.*

Mr. L. K. Ward ([20]) has correlated this Henty peneplain with the peneplaned surfaces at North Dundas, in the neighbourhood of Parson's Hood, and at Balfour, and has come to the conclusion that they constitute one physiographical unit. Mr. L. L. Waterhouse ([21]) has recognised the same peneplain in the Stanley River district near Parson's Hood, and from his observations confirms Ward's correlation as regards the northern portion.

The development of such an extensive peneplaned surface must have taken place during a prolonged period of relative stability of land and sea. The master streams flowed westwards from higher land situated to the east. It is the western portion of this central highland or plateau that claims our attention as supplying the parental mass of the present West Coast Range.

It is quite apparent that the uplift, which has rejuvenated the streams of the coastal peneplain and caused its dissection, has had no effect on the general outline of the western slope of the West Coast Range, for this general outline must have existed at the close of the period during which the process of peneplanation was in progress, the details of the present surface, of course, having been determined by the amount of the erosion since that uplift. This western steeply-sloping face of the mountain mass is continued northwards along the whole of the length of the range.

This range, which has a general meridional trend, consists of an almost unbroken series of mountain peaks, joined by relatively lower spurs. These undoubtedly constitute one physiographical unit, the causes which were instrumental in forming that part of the range, which is included in this field, being precisely the same as those which determined the contour and existence of the remaining portion. The depression which separates Mts. Jukes and Darwin from the western outliers of the central plateau is continued northwards along the whole eastern side of the West Coast Range. That portion of the valley south of Mt. Sedgwick is occupied by the King River, and may be regarded as having been caused by the erosional activity of this stream, which for the whole of this length has reached a mature stage.([22])

([20]) See Geol. Surv. Tas. Bull. No. 10, pp. 14-15.

([21]) See Geol. Surv. Tas. Bull No. 15.

([22]) See L. K. Ward's report on the Overland Track in "Report of Secretary for Mines," 1907-8, p. 34.

This, therefore, corresponds with the mature development of that river at Crotty. The northern portion of the dividing depression is the valley of the Murchison River, which has excavated a path across the mountain range in a similar manner to the King.

When we consider the course of the King River from its northern portion to the point where it enters its deep canyon between Huxley and Jukes, we are at once struck by the remarkable fact that the river, flowing through an alluvial flat, suddenly takes a turn at a right angle while still running in its flood plain, and then flows through a tremendous gorge. The ordinary explanation by laymen, in cases of this kind, is that the gorge is really the site of an enormous open fracture. In this case, however, there is no evidence whatsoever of any fracture where the gorge now exists, and this explanation is certainly not applicable here. In the writer's opinion, the whole effect is due to the action of erosion. The King River orginally occupied its present course, but at a much higher level; this level being as high as, and most probably somewhat higher, than the present summit of the West Coast Range. Its present course across the mountain range was then determined as an ordinary feature with no accompanying gorge. At this period the central plateau of Tasmania was practically continuous with the West Coast Range, which did not then exist as a separate mountain range. By the erosional activity of the King River, the present valley and canyon have been developed, the stream persisting in retaining its course even in spite of the uplift which succeeded the formation of the Henty peneplain. The King River is in fact an "antecedent stream."(23)

By the excavation of this main valley of the King, the West Coast Range was separated from its parent mass, the Central Plateau; and it may be regarded as the western outlier of this central mountain region of Tasmania.(24)

The evidences of glaciation, established in this field, correspond with observations made in the other portions of the West Coast Range. This question of glaciation in Tasmania has been weighed and discussed by Prof. J. W. Gregory, D.Sc., who quotes the opinions and observations of all writers on the subject up to 1904. No discussion can be attempted here on the general question as to the

(23) See below p. 67.

(24) "The Glacial Geol. of Tas.," by J. W. Gregory (Quart. Journ. Geol Soc., pp. 37-53.

extent, &c., of these glaciers, but from the writer's observations in the Jukes-Darwin field, and in the Linda Valley, he is of the opinion that there is nothing to contradict the assertion that these glaciers were "Mountain Glaciers," and that "Continental Glaciers" played no part in the phenomena. Consequently there was not a glacial epoch in Tasmania, but merely a glacier stage.

(4)—The Relation of Topography to Mining.

(*a*) *Transportation Facilities.*

The Jukes-Darwin mining field may be reached by two main routes, both of which involve the utilisation of the North Lyell railway.

The port of Strahan (Regatta Point), situate on Macquarie Harbour, is in communication by rail with the Tasmanian railway system, and can be reached by boats of a maximum draught of 13 feet.

The first route from Strahan is *via* Queenstown, which is reached by means of the Mt. Lyell railway, 22 miles in length. From Queenstown it is necessary to travel by road to Linda, which is on the other side of the mountain range. This road is about 4 miles in length, and passes over the Gormanston Gap, which is a low saddle connecting Mts. Owen and Lyell. The grade is good, considering the rugged country passed over, but to obtain this grade the route has had to be made somewhat tortuous. From Linda the North Lyell railway is available at present on two days per week. This railway is 28 miles long, and follows the valley of the King River as far as the point where the latter turns westwards. From this point the railway continues in a general southerly direction to Kelly Basin.

The second route by which this field can be reached from Strahan is by means of boat, *via* Kelly Basin, where extensive wharf facilities exist. From this point the North Lyell railway is available.

From this railway the approach to the mining properties may be made by steep mountain tracks. There are three main points on the line whence these tracks start. These are Crotty (17 miles from Kelly Basin), Darwin (13 miles), and the 10-Mile (10 miles).

From Crotty there is a track cut to the Mt. Jukes Proprietary Mine. This track is 3½ miles in length, measured from the Crotty station. The first mile to the Crotty smelters only rises 160 feet, but for the remaining 2½ miles the rise is 1200 feet, or an average grade of 1 in 11. This track is well graded, the steepest portion being not far from the above grade, but at present it is in a somewhat rough state owing to the action of the rains in washing away the lighter material and leaving the track covered with boulders up to a foot in diameter. In these places the walking is difficult. It badly wants attention. There is another track starting from Crotty. This leads to Lake Jukes. This track also was well cut in the first instance, but has been allowed to become overgrown and washed out in several places. This track is about $2\frac{3}{4}$ miles in length from the Smelters, and the rise in this distance is 1630 feet. The average grade is 1 in 9.

From Darwin station a track has been cut up the steep eastern face of the mountain for a total distance of $2\frac{1}{4}$ miles, the average grade being 1 in $8\frac{1}{2}$. This track is in good order. It gives communication with the Darwin Proprietary and surrounding sections.

All three of these tracks were cut to a maximum width of 6 feet, and are designed for the use of pack-horses. They are the main lines of access to the mining properties, but other tracks have been more or less completely cut out to other mining sections from these as starting points. Some of these latter have been cleared sufficiently to allow a man to carry a pack without undue hindrance. These tracks are marked on the maps as foot-tracks. Others are merely blazed tracks, and these are suitable only for travelling without a load.

From the 10-Mile a track leads to the South Darwin plateau, and thence to the Clark Valley. This is a narrow foot-track, and rises 500 feet in the first 20 chains, corresponding to a slope of 1 in $2\frac{1}{2}$. This pinch is known as the 10-Mile Hill.

Besides the two main approaches to the field mentioned above, there is another route available from the Mt. Lyell railway. This route starts at Lynchford, and after crossing the King River near its point of confluence with the Newall, climbs in a zig-zag fashion up the northern end of Jukes. This is a 6-feet track, and was originally well cut and of good grade (1 in 12), but has been allowed to get into bad order, until at present it is unsafe to take a horse over it. It could, however, be very easily put in good order.

It will be seen, therefore, that the final approach to the mining properties, after leaving the railway, is attended by those difficulties which are inseparable from such a mountainous country as this. This field is, however, one to which the system of transportation by means of aerial ropeways is especially applicable, and in no cases are great difficulties presented as regards the erection and working of these aerial ropeways. These will convey the products from the mines to the valley below. Once the mines have reached the productive stage, this conveyance by aerial ropeway will undoubtedly be the means by which the main part of the transportation between the mines and the flat country below will be effected.

Such disabilities in the way of communication are directly the result of the topographical features, and the present inactivity on the field is to some extent the result of this resultant great expense of transportation.

(*b*) *Prospecting and Exploitation.*

Since the ore-deposits have had no marked effect on the topography of this region, there has been no material aid to prospecting from this source. The special prominence of the red hematite crags at the Crown Jukes, &c., caused attention to be paid to these occurrences, which was ultimately proved to be unwarranted. The brown-coloured ridge which represents the outcrop of the mineralised zone at the Jukes Proprietary, &c., has been certainly instrumental in drawing attention thereto.

The deeply dissected and rugged nature of the surface has undoubtedly been instrumental in making the field one which is ideally suited for mining by the adit system. In the case of no deposit observed up to the present time will there be any necessity for sinking shafts—at any rate, until the development of the mine is well advanced.

(5)—Rainfall and Water-supply.

The rainfall in the Jukes-Darwin field is undoubtedly very heavy, but as no meteorological station exists thereon, no accurate statement can be made as to the precise amount of water that annually is precipitated. The nearest recording station is at Kelly Basin (Pillinger), but the rainfall at that place is much lower than that in the mountain region, as there is frequently a heavy fall of rain on the mountains while it is quite fine at sea-level. The whole of the West Coast mountain region is characterised by a remarkably high annual rainfall, and the best means of gaining any idea of the amount of water that falls on this particular area is by comparison with the observed data at Mt. Lyell. The amount of rainfall varies with the height of the station on the range, the higher the station the greater being the rainfall. This is illustrated by the fact, shown in the following table, that the rainfall at Mt. Lyell is much heavier than that at Queenstown; and also by the observations of the writer while in the field that it is often raining heavily near the summit of the mountains, while it is quite fine half-way down the mountain side.

The following table gives the amount of the rainfall for the last five years at Pillinger, Queenstown, and Mt. Lyell.

The Rainfall from 1st October to 30th September (in inches).

	1907-8.	1908-9.	1909-10.	1910-11.	1911-12.
Pillinger	...	69·44	84·45	72·51	72·23
Queenstown	100·10	88·48	103·70	90·9	99·78
Mt. Lyell	110·24	...	121·66	105·06	115·94

August, September, and October are generally the wettest months, but there is no general rule in this regard, the distribution of the rainfall being very variable.

Snow falls during the winter months, and the region in that season is decidedly a cold one. Strong winds and violent storms from the south, varying to the north-west, also make the conditions of living on the exposed mountain ranges somewhat unpleasant.

The region being one of extremely high relief, there is a quick return of the water to the sea. The result is a scarcity of water on the higher parts of the ridges even after a few days' fine weather. In fact, a few weeks' fine weather brings about a wonderful diminution of the amount of water flowing in all the streams, while a heavy fall of rain converts them into raging torrents.

Such being the general character of the drainage, no reliance could be placed on the water-supply for generating power. There are only two localities at which natural facilities exist for the storage of water to any extent. These are the Lower Lake Jukes and the valley above the East Darwin waterfall. At the former locality the building of a dam across the steep-sided gorge, which constitutes the only outlet of the lake, would enable a considerable amount of water to be stored. In fact some small attempt at controlling the waters of this lake was made by the North Lyell Company in connection with the supplying of their smelters with water, but this could be vastly improved upon. By the building of a dam across the valley at the top of the East Darwin waterfall some considerable quantity of water could also be stored, if desired, at a point 1340 feet above the plain directly below.

The old North Lyell Company, in connection with the working of the smelters at Crotty, built several dams and races, including one of considerable size in the Traveller River. The water thus obtained was utilised for general purposes at the smelters and concentrating plant.

The Lake Jukes Company utilised the water from the Upper Lake Jukes in generating power to drive a five-head battery, and the quantity was quite sufficient for that purpose. .

The water-supply has also been availed of in the working of the alluvial gold deposits, and has been found to be sufficient for these requirements.

The opinion is expressed in the concluding chapter of this bulletin that it is possible for this field to repay any outlay, only by being worked on a large scale, and in a comprehensive manner, and it is therefore evident that it is impossible to generate sufficient power for these works by the utilisation of the water-supply of the field. There will, however, be ample for all general purposes of mining and concentrating, as well as for the development of power on a moderate scale.

(6) Vegetation and Timber.

Originally, the whole area was covered with dense forest with the exception, of course, of the highest mountain crags. This dense vegetation has been to some considerable extent removed by bush fires, &c., but in some cases the time which has elapsed since the fire, has been sufficient to allow a fresh mass of tangled scrub to cover the surface.

The character of this forest growth is similar to that occurring elsewhere on the West Coast, and notable for its impenetrability. The commonest trees are the myrtle, King William pine, Huon or white pine, celery-top pine, gum, manuka, blackwood, leather-wood, fagus (the only native deciduous tree in Tasmania), and waratah. With these grows the well-known horizontal scrub, which, together with the smaller trees and scrubs (*e.g.*, bauera and numerous ferns and climbing plants) forms a tangled mass, to traverse which it is necessary to cut out a path with the aid of the axe.

The best timbers are the Huon or white pine, King William pine, gum, blackwood, celery-top, and myrtle, whilst manuka makes the best firewood. The exposed parts of the hills and ridges, north of the South Darwin Peak, have been practically denuded of their timber, but some good mining timber still remains in the gullies and gorges. In the southern part of the field, however, there is everywhere an abundance of good mining timber and firewood.

The timber industry was responsible for the first settlement of this region by man. In the early days "piners" cut tracks in many directions. Some of these still can be followed in places. Thus, a track was cut from Farm Cove, which traversed the Clark Valley to the south end of Darwin, up the western slope of which it rose, crossed the South Darwin Plateau, and then descended to the south branch of the Andrew River, where considerable quantities of Huon pine were obtained. Similarly in other parts of the field as in the Clark Valley, King River Valley, &c., the timber industry has been an important factor in the general history of the region.

The higher parts of the mountain ranges are covered with mosses and stunted varieties of Huon and King William pine, &c.

The surface is generally covered with a thick layer of peaty soil.

The climate and soil of the piedmont plain are suitable for the cultivation of flowers and vegetables, and there are several gardens at Crotty and Darwin.

IV.—GENERAL GEOLOGY.

(1)—The Rock Types Represented on the Field and Their Mode of Occurrence.

A.—IGNEOUS ROCKS.

(1)—*The Porphyroid Group.*

There is an abundant development of rocks of igneous origin in this district. With the single exception of the acid glass, which is quite a rare and unique occurrence, and which may be regarded as having no connection with the other igneous rock types of the field,([25]) these igneous rocks all belong to one great geological group representing a prolonged period of igneous activity.

These rocks may clearly be regarded as consanguineous, belonging, as they all do, to the important family of rocks known as the porphyroids, which are here represented as a most interesting series of rock types. These types range from typical granitic rocks, through quartz porphyry, granophyre, felsite, keratophyre, &c., to fragmental types of all varieties, including volcanic breccias and tuffs. The original structures have in most cases been greatly altered by the action of dynamic stresses, the metamorphism having sometimes advanced to such a stage as to render the original structure practically unrecognisable. The original character of the rock-mass has been an important factor in the development of the schistose structure, and it is this variation of the resultant effect of the metamorphic action, according to the difference in the original rock type, that explains the remarkable transition from the schistose rocks to rocks which megascopically show but slight schistosity—a phenomenon which is to be repeatedly observed in the Jukes-Darwin field.

Applying such a term as "consanguineous" to such a series of rocks which now possess widely different characters, might at first sight appear to have no justification, but the microscopical characters of the rocks, combined with their structural relationships to be hereinafter described, force us to the conclusion that we have here a prolific development of varied consolidation products of one parent rock-magma. The varying rock facies depend

([25]) See below p. 40.

on the conditions which governed their consolidation from the original liquid condition, for their distinctive characters. The conditions of such consolidation may vary from those which produce normal or eugranitic structure to those under which the original magma was ejected from a volcanic vent in the form of fine ashes and collected as a volcanic tuff. It is in such a sense, therefore, that the term consanguineous has been used here.

The term "porphyroid" is one that has been adopted by the Geological Survey as indicating a suite of ancient igneous rocks occurring in Tasmania. They are typically developed on the west and north-west portions of Tasmania, being altogether absent from the eastern and southern portions of the island, excepting a small development near Beaconsfield. In previous publications of the Geological Survey their occurrence has been described from Mt. Farrell,(26) at Gunn's Plains in the Leven Basin,(27) North Dundas,(28) Zeehan,(29) Mt. Balfour,(30) and Middlesex,(31). A summary of the general characters of this series of rocks is given by Mr. Twelvetrees in the latter bulletin, and the reader is referred thereto for such information. The same igneous series is developed in the Mt. Lyell field, and are there the repositories of the copper ores. The Mt. Lyell schist belongs to this series.(32)

The rock-types belonging to this series will now be described under the respective headings of the more important general types.

The Darwin Granite.—This rock is developed on the south end of Mt. Darwin and constitutes the greater portion of the Darwin Plateau. The granite outcrop is in shape an elongated belt measuring 3 miles long by half a mile wide. There is a separate occurrence south of this plateau which measures approximately 25 chains by 10 chains. As mentioned previously, the existence of this plateau is due to the influence of the granite on the rate of denudation.(33)

(26) See Geol Surv. Tas. Bull. No. 3, pp. 9-19.
(27) See Geol. Surv. Tas. Bull. No. 5, pp. 11-15.
(28) See Geol. Surv. Tas. Bull. No. 6, pp. 15-18.
(29) See Geol. Surv. Tas. Bull. No. 8, pp. 15 *et seq.*
(30) See Geol. Surv. Tas. Bull. No. 10, pp. 21 *et seq.*
(31) See Geol. Surv. Tas. Bull. No. 14, pp. 23 *et seq.*
(32) See "The Mount Lyell Mining Field," by J. W. Gregory, D.Sc., Aust. Inst. Mining Eng., Melb., 1905, pp. 34 *et seq.*
(33) See above p. 20.

The granite has the coarsely holocrystalline appearance characteristic of that rock species. The felspars are of two colours, pink and white. The latter are generally stained green by secondary chlorite. Black mica is present in relatively small amount, and quartz is abundant in clear glassy masses. The whole appearance is particularly handsome, the mottled pink, green, white, and black colouring giving the granite quite a distinctive character. This is the normal megascopic character of the rock, but occasionally, as in the neighbourhood of Section 1203-M, there is a marked variation therefrom. At this point the pink felspar is wholly missing, and the mica only occurs exceedingly sparsely. The result is a white coarse-grained admixture of quartz and felspar, and there is no greenish chloritic discolouration of the felspar.

Microscopic examination shows the rock to possess typical granitic structure. The quartz shows marked "wavy" or "shadowy" extinction, indicative of the rock having been considerably affected by dynamic strain. The felspars are mainly orthoclase, but some plagioclastic varieties do occur. These latter are considerably affected by the development of secondary minerals, and extinction angles are difficult to measure. What measurements could be obtained, however, indicate an approach to oligoclase. These felspars show alteration to an aggregate of kaolin and chlorite, thus explaining their greenish hue. The mica is wholly biotite, no muscovite being present.

The rock is therefore one which has undergone some alteration, and has been subjected to considerable pressure. It is a rock which clearly is distinct from the ordinary granite of Tasmania, which is of Devonian age. The nearest development of Devonian granite is that constituting the mountain mass of Heemskirk. This Darwin granite may be classed as the geological analogue of the Dove River granite.(34)

The boundary-line between the granite and the felsites which it has intruded is sharp and well defined. This line of contact has been opened up in several places by trenching, and the granite can there be seen in contact with the felsite, being quite as coarse-grained as in the interior of the mass, no transition into finer-grained varieties being observable at the margins.

Felsitic and Porphyritic Types.—There is a great variety of rocks in this field which may be included under these

(34) See Bull. No. 14 referred to above, p. 23.

general types. They vary from fine-grained homogeneous rocks to distinctly porphyritic types; the phenocrysts may be either quartz or felspar, or both. All these types alternate with each other and with the schists and fragmental types to be described subsequently, the strike of the various belts varying in different parts of the field from North and South to N. 20° W., S. 20° E.

The most characteristic structural feature is the occurrence in practically vertical bands having an approximately meridional strike, and the gradual transition which takes place from one band to the other in a horizontal direction at right angles to this trend line. This gradual mergance takes place from a fine-grained felsitic to a porphyritic type, and also from either of these to the schistose varieties. No sharp line of demarcation between the various types can be observed at any part of the field, excepting at the contact of grey schist with felsite at East Darwin.

The inference to be drawn from this is that none of these porphyritic types represent intrusive dykes, but that they are really extruded lava flows. This is not contradicted by a microscopic examination of the many types.

Excellent exposures of these rocks occur on the track from the Jukes Proprietary to Lynchford, and also on the track from Crotty to Lake Jukes. Both of these tracks are sideling cuttings, and the comparatively freshly-broken rocks offer great facilities for the study of their petrological characters, as well as of their interrelations. On other parts of the mountain range there are good exposures, particularly on Mt. Darwin, where the predominating rock-type is of this general character.

In general the mineralogical constituents are quartz, plagioclase (albite or the more acid varieties), orthoclase, chlorite, sericite, and some epidote, and magnetite. The relative amounts of these minerals in any one rock vary within wide limits.

A rock-type occurring on the Lynchford track consists macroscopically of a dense, compact, light green groundmass, through which are scattered abundant phenocrysts of pink felspar. The weathered surface of the rock is yellowish white. Microscopically this type is seen to consist of a groundmass composed of ragged aggregates of chlorite, which are arranged in streaky lines and patches, through an allotriomorphic granular matrix of felspar (the exact character of which is undeterminable, but is probably albite) and quartz. In this groundmass are scattered idiomorphic phenocrysts of felspar, which is generally remarkably clear, but is sometimes slightly clouded. This felspar shows albite twinning, and the extinction angles, where measurable, indicate a variety approaching albite. This rock is evidently one which has undergone great alteration, the original structure being quite masked by a reconstitution of the mineral constituents. The present ground mass is obviously a secondary structure, as are also the idiomorphic felspar phenocrysts. The rock is most probably a keratophyre, but here the necessity is felt of a chemical analysis, which would finally determine this point.

The rock at Lake Jukes in which the bornite veins occur is, in the hand specimen, seen to consist of a homogeneous pinkish-red groundmass, through which are distributed dark-green phenocrysts of felspar. Under the microscope this rock-type is seen to have a typical granophyric groundmass, and the phenocrysts show intense alteration to kaolin, chlorite, and sericite. Its petrological designation would be granophyric quartz-porphyry, or simply granophyre.

Another typical rock-type is that which forms the greater part of Mt. Darwin, with the exception of the southern end. This is a bright, pinkish-red rock, with phenocrysts of felspar, which have been altered to a light-green colour. In thin section this rock seems to show at first sight a granophyric intergrowth of clear, glassy quartz and cloudy felspar, with some alteration to chlorite and sericite. On closer examination, however, this groundmass resolves itself into an aggregate of felspar crystals, which have been broken down into secondary quartz with remnants of the original felspar still recognisable in the cloudy aggregates containing chlorite and sericite. The original groundmass is unrecognisable. The phenocrysts are also seen to have been partly converted to sericite and chlorite, the latter giving the greenish tinge. The nature of the felspar is unrecognisable. Scattered grains of magnetite occur in the groundmass. Variants of this type occur, characterised by a more abundant development of magnetite and chlorite, which impart to the rock a darker hue.

Still another common type which occurs at the Jukes Proprietary is a dense red rock having the appearance of a red quartzite in a hand specimen. No porphyritic crystals are visible. Examined in thin section the original structure is again masked by secondary alteration and reconstitution. Clouded felspars, partly altered to sericite, are seen to have been broken down in places to clear glassy quartz in allotriomorphic aggregates, which appear in the groundmass of kaolinised and sericitised felspar. The groundmass here was probably originally felsitic, and the rock would be called a felsite, or by some petrologists a felsophyr; if the chemical analysis shows predominant soda, the rock is a keratophyre. Its field designation is felsite.

Numerous other varieties occur throughout the field. Some of these show abundant quartz phenocrysts, and some both quartz and felspar phenocrysts. In thin section some of these quartz phenocrysts are seen to have their outlines rounded and occasionally deeply embayed; in other cases they possess idiomorphic outlines, and are undoubtedly secondary. The absence of undulatory extinction in the corroded quartz phenocrysts is due to the protective action of the more yielding groundmass. The felspars are generally difficult to identify, as they are almost invariably altered. They seem, however, to be in most cases the more acid varieties of the plagioclases.

Most of these rocks show signs of mechanical deformation, and the whole character of the rock types point unerringly to the action of intensive dynamo or regional metamorphism.

The weathered surfaces vary in colour. Generally it may be stated that those rocks of a white or greenish hue weather to a white argillaceous product, while the reddish varieties retain that red tinge in the decomposition product, which is intensified by the presence of pyrite in the rock.

Fragmental Types and Schists.—As stated previously, these fragmental types and schists are continuous by insensible gradations with the felsites, quartz-porphyries, &c. It is, in fact, very difficult at times to decide whether a certain rock-type was originally a fragmental or a massive variety. Some indication, however, is afforded by the character of the weathered surface, as the unequal resistance to denudation of the included fragments results in the development of a markedly variegated surface resembling a brecciated structure. The fresh fracture of the rock, however, in this case gives not the slightest indication of its fragmental character.

There are a great number of varieties of these fragmental types, varying from coarse volcanic breccia, which even on a fresh fracture shows the true brecciated character, to fine-grained tuff. These grade into true schists.

Examined under the microscope they show distinct evidence of their fragmental character, but the original form of the rock is completely masked by the effect of the subsequent metamorphic action. It is here that we must apply the evidence obtained from the study of the structural features and field relationships of the collective types in order to arrive at some idea of the original character of those rocks which are now of a distinctly schistose character.

It will be seen at a later stage of this bulletin,[35] that the means by which the present structure of parallel vertically-disposed beds of the porphyroids in this field has been brought about, has been by the development of isoclinal folds, since truncated. The deformative forces, therefore, acted in a direction approximately east and west, and *the whole of the beds were subjected to this compressive and metamorphic action.* At East Darwin we find the occurrence of grey schist in contact with hard, red, felsite rock, the dividing-line between them being very sharply defined. As both rocks were under the same conditions of dynamic stress during the process of metamorphism, it logically follows that the original characters of the rocks must have been markedly different, in order that their present distinctive features may be explained. We may accept without hesitation that the red felsite was originally in the form of a lava sheet not markedly dissimilar in character to that which now obtains. We are therefore forced to the conclusion that the original character of the rock-type, from which the schist has been derived, was some fragmental or loosely aggregated deposit, which was especially suited to the permeation and circulation of those solutions which, acting in conjunction with the compressive forces, have brought about the present schistose condition. It thus follows that the original rock was either a pyroclastic product such as a tuff or a truly sedimentary rock. The general character of the schist, however, would indicate the former as its progenitor. This tuff was either spread out on the surface of the felsite lava sheet, or the latter was outspread over the former.

In those cases in which the change from one rock-type to another is gradual, we must assume that the nature

[35] See below, p. 64.

of the original rock-type likewise gradually varied from point to point. Thus on the Lake Jukes track we have a dark-red quartzite-like rock, which weathers to the appearance of an almost white fissile sandstone, and which horizontally gradually merges, by the growth of quartz phenocrysts, into what megascopically would be called a quartz-porphyry. It is very probable that both of these types, together with all intermediate variations, are fragmentary in their origin.

Microscopically the East Darwin grey schist consists of a quartz mosaic and quartz grains in a ground of sericite disposed in wavy lines. Occasional embayed phenocrysts are seen, which are now composed of a quartz mosaic. The rock shows distinct foliation. This type is very similar to the schist of the North Lyell Mine.

A schist occurring on the Lake Jukes Track has a deep purple colour, and is clearly derived from a fragmental product, as inclusions of varying character are visible in the hand specimen. In thin section it is seen to consist, in part, of a quartz mosaic associated with quartz phenocrysts, some of which show distinct undulatory extinction, while others show none, and are obviously secondary. Felspars are seen, but they are so much altered to quartz-sericite or kaolin sericite aggregates that their character is undeterminable. The groundmass of these felspars seems to be in places a fine quartz-felspar aggregate. The rock is plainly an altered fragmental product, and shows marked foliation in places.

The green chlorite schist of the Jukes Proprietary is seen in thin section to consist of a fine obscure groundmass, through which are scattered shreds, patches, and streaky masses of green chlorite. At times idiomorphic phenocrysts of quartz are present, which are plainly secondary. This rock shows marked schistosity, and is generally soft. The original character is not quite clear.

There is an almost endless variety of these schistose and fragmental types, and complete descriptions of them are unnecessary: suffice it to say that they are all metamorphosed conditions of pyroclastic deposits varying in texture from fine-grained tuff to quite coarse-grained products.

The coarseness of some of these fragmental types becomes at times so pronounced that the weathered surface presents a coarse brecciated appearance. This is well seen on the Lake Jukes track, west of Hanlon's Creek and Snake Peak, and on the Prince Darwin section. The occurrence on the Lake Jukes track shows on a fresh fracture no signs of this brecciated structure, the component fragments having been completely welded together as the result of the reconstitution of the rock. The breccias at the two other localities mentioned, however, generally show, even on a fresh fracture, the angular fragments disposed in a paste of finer grain. Associated with this coarse breccia west of Snake Peak, is a rock of finer grain, which in the hand specimen resembles grauwacké, but microscopic examination shows it to be a true tuffaceous product. These breccias and tuffs are clearly a distinct series from the brecciated conglomerate at the base of the West Coast Range conglomerate series.(36)

All these fragmental products may be included under the term "clastoporphyroid," which embraces all those members of the porphyroid series which are fragmental in origin. The schists, therefore, are in reality clastoporphyroids, but must retain their designation as schists on account of their distinctive lithological characters.

In all these varieties of the porphyroids, including the fragmental types, schists and felsites, &c., a series of chemical analyses is badly needed, as such is absolutely necessary before a complete understanding can be arrived at as to their original nature. It may be confidently accepted, however, that the whole of the series now described are of igneous origin, as explained in the opening remarks of this chapter.

(2)—*The Darwin Glass.*

This glass occurs on the eastern side of the Jukes-Darwin mountain range, as irregularly-shaped fragments lying on the surface and disseminated in the upper 9 inches of the surface detrital accumulations. Its most plentiful development is on the Ten-Mile Hill, where it can be picked up in quantity. Its occurrence has also been reported from 3 miles west of Mt. Sorell and from Flannagan's Flat, west of Mt. Darwin. It does not occur on the higher portion of the mountains.

The glass is vesicular and very acid, containing roughly 85 per cent. silica. Its mode of occurrence has been investigated by the writer, and being of great scientific interest, opinions as to its nature and origin have been obtained from eminent men of science of Europe and

(36) See below, p. 41.

United States. Being, however, of a purely scientific interest and of no direct economic importance, its description, history of discovery, and origin are treated in a separate publication, which will be issued as a Geological Survey Record, to immediately follow the issue of this bulletin. Suffice it to say, in this place, that the writer has been able to prove the impossibility of any derivation other than from a cosmic source, which conclusion confirms the opinion of Professor F. E. Suess, of Vienna, that they are to be classed among the tektites.

The reader is referred to Geological Survey Record No. 3, to be published shortly, for a complete description, &c., of this most interesting substance.

B.—THE SEDIMENTARY ROCKS.

(1)—*The Slates associated with the Porphyroids.*

Occurring interbedded with the members of the porphyroid series are bands of a dark-coloured slate, black to bluish-black in colour. They are only developed to a relatively small amount on the track from Harris' Reward to the Jukes Proprietary, but occur somewhat more extensively in the eastern portion of the Clark Valley and the eastern end of Slate Spur. In these latter localities there is a development of some accompanying coarse-grained felspathic sandstones, and the strike can be there seen to be north and south and the dip to the east at 42°

This slate in microscopic section is seen to be a normal type with no development of secondary minerals.

(2)—*The West Coast Range Conglomerate Series.*

This series, in the Jukes-Darwin district, consists of two divisions, which are mainly differentiated by distinct lithological characters, but also are to some extent unconformable to each other. They are—(*a*) brecciated conglomerate, and (*b*) the normal conglomerate. These constitute the only development of sedimentary rock on the mountain ranges in this field.

(*a*) *Brecciated Conglomerate.*—This actually forms the base of the whole West Coast Range conglomerate series in this district, being almost invariably found underlying the normal conglomerate, and by virtue of the marked difference in lithological character, it may be conveniently considered as a separate series.

This rock series consists of a varying thickness of beds composed of angular, sub-angular to partially-rounded fragments of those members of the porphyroid series which are developed in this field, including, *inter alia*, fragments of the Darwin granite. Some fragments of quartz and quartzite are also present, but in the brecciated conglomerate proper these are present only in a very subordinate amount, the predominant constituents being the porphyroids. These fragments are cemented together by a paste of the finer particles of the same rocks. The size of the constituent fragments varies from masses approximately 4 feet in diameter down to the finest material forming the cementing paste. The arrangement of the fragments is generally tumultuous, but occasionally a distinct stratification is present. This is specially developed where layers of fine-grained material occur, as at South Darwin, but a rudely-stratified structure is developed in places by the occurrence of alternate light and dark coloured layers. Although the varying character of the beds is thus instrumental in developing a rudely-stratified arrangement, the disposition of the fragments in the beds themselves is always devoid of any stratiform character.

These breccias are seen on the northern end of Mt. Jukes, above the Lynchford track, at an elevation of, roughly, 2300 feet. They are here seen to be resting unconformably on the upturned edges of the porphyroids and show a distinctly stratified arrangement *en masse*. The lower beds are composed of very large masses, the largest being 4 feet in length. These coarse-grained beds are overlain by beds of finer material, which are again succeeded by the normal conglomerate beds, which are here conformable to the brecciated conglomerate. The strike is north-west, south-east, and the dip is at a low angle (from 5° to 10°) to the south-west. The constituent fragments are those members of the porphyroid series which are developed in the northern portion of Mt. Jukes; granite could not be observed as a constituent. The thickness of the brecciated conglomerate here is roughly 300 feet.

This series is again seen at the head of the gorge of the south branch of the Traveller River, and also along the foot of the Main Jukes cliff. In the former locality the beds form a vertical cliff, and their connection with the overlying conglomerate is again clearly seen, although this is an area of local crumpling. At the foot of the Main Jukes cliff the beds are seen to be the basal members of the conglomerate series, and are roughly 300 feet thick at this point.

The largest development of these breccias, however, occurs in the southern portion of the field at the South Darwin Peak and on Mt. Sorell. At both of these localities the thickness of the series is greater than elsewhere in the field, and the sections exposed give interesting information as to the connection with the associated normal conglomerate.

The development of the series on South Darwin occurs on the western and south-western sides of the South Darwin Peak, and the beds here form a prominent cliff face. Starting from the northern end of the valley at the western foot of the peak, these beds occur in alternating light and dark bands of very coarse texture, until towards the top of the series exposed on this cliff there are developed several fine-grained beds of the nature of felspathic grits or grauwacke. The strike is thus seen to be north-east, south-west., and the dip is to the south-east at 50°. Above these finer beds, there again recur the alternating bands of light and dark-coloured breccia composed of large fragments of porphyroids. When these upper brecciated conglomerate beds are traced in a southerly direction along their line of outcrop, they are seen to gradually merge into beds of the normal conglomerate series. This is accomplished by the incorporation of large and small boulders up to 8 inches in diameter, which are more or less rounded, of white quartz or quartzite. This inclusion of the white quartzites gives to the rock a lithological character which at once distinguishes it from the brecciated conglomerate. When traced still further southwards in the direction of the strike of the beds, the lithological character changes completely to the normal conglomerate by the gradual elimination of the porphyroid pebbles.

This change in a horizontal direction from the generally dull-coloured aspect of the breccia to the white or pinkish-white colour of the normal conglomerate, is very marked, and is quite a notable feature of the upper portion of this cliff face. The lowest bed of breccia which shows this longitudinal transition into normal conglomerate is overlain by a bed of coarse breccia, which, as far as can be seen, does not merge into conglomerate: the change to conglomerate in any case does not take place directly above the point of change of the underlying bed. The next succeeding bed does show a horizontal change to white normal conglomerate, but the point at which the prominent white pebbles first occur is situated about 15 feet north of the corresponding point in the lower transition bed. The next succeeding bed of brecciated conglomerate shows no transition to normal conglomerate, but the portion of this bed to the southwards is covered with debris so that it is impossible to see whether this change does take place in this direction. The overlying breccia bed, however, again shows the transition at a point about a chain north of the point of change of the first transition bed. There is another bed of breccia overlying this, but it is impossible to see where any change takes place, owing to the occurrence of large boulders shed from the higher portions of the peak, covering the greater portion of this bed. Immediately overlying this last bed of breccia are the beds of normal conglomerate which form the capping on the peak, the two series being here quite conformable.

The fragments of this breccia are composed of all varieties of the porphyroids, including the schists and the Darwin granite, together with some pebbles of hematite and magnetite. These are in shape angular to sub-angular, and are cemented together by a paste of finer material of the same character.

The greatest development of this brecciated conglomerate series occurs on Mt. Sorell. Standing on the Darwin plateau and looking westwards towards Mt. Sorell that mountain is seen to consist of two portions, the upper portion which occupies about one-half of the total rise from the Clark Valley being white in colour; while the lower half of the mountain is a uniform yellow colour. The upper white portion is the normal quartz conglomerate, while the lower yellow portion consists wholly of brecciated conglomerate. The latter is here generally massive in character, and at the best only shows a rudely-stratified arrangement. In one place, however, there is a bed of grey micaceous and markedly fissile slate intercalated between the coarser beds, and the general strike is seen to be N. 20° W., with a dip of 75°, to S. 70° W. The lithological character is the same as that of the other occurrences described, and if there is any outstanding feature, it is the relative abundance of blocks of granite among the constituent angular fragments. The total thickness of this brecciated conglomerate series on Mt. Sorell is, roughly, 1500 feet. The overlying conglomerate has the same strike as this breccia series, but the angle of dip being 45° is less, showing that there is a slight unconformity between the two series. These brecciated conglomerates occur throughout the whole length of the eastern face of Mt. Sorell, from its southern end to beyond the Slate Spur.

At the outset of any discussion as to the origin of this brecciated conglomerate, it must be stated that it constitutes a series quite distinct from the igneous breccias which occur associated with the porphyroid series as intercalated bands. The occurrence of the brecciated conglomerate beds lying almost horizontally on the upturned edges of the felsites, &c., clearly establishes this fact. This latter relation is best seen on the north end of Mt. Jukes.

A further interesting and important point is the occurrence of granite fragments as part of the masses constituting this rock-type. As granite is a rock which owes its distinctive characters to having consolidated at some distance from the surface, we must assume, in order to explain the presence of this rock in the brecciated conglomerate, that a period of denudation ensued subsequent to the granitic intrusion. The amount of this denudation must have been sufficient to lay bare the underlying granite, before even the bottom layers of the brecciated conglomerate could have been laid down. This series, therefore, must necessarily be of younger age than the porphyroids. This occurrence of granite fragments also serves to differentiate this rock type from the breccias associated with the porphyroids, as the latter have never yet been observed to carry such fragments.

As regards the mode of origin of this brecciated conglomerate series, three distinct processes suggest themselves.

The first process to be considered is that of the formation of fault or crush-breccia along a plane of faulting. In this case the structural conditions are such that, in the writer's opinion, this view as to the mode of origin is untenable.

The second mode of formation that might account for the origin of this series is the process by which volcanic breccias in general are formed. This process consists in the ejection from a volcanic vent, of masses of lava of all shapes and sizes, which collect on the surface in the neighbourhood as a rudely-stratified deposit. In the case under discussion, however, the occurrence of granite as a constituent of the breccia at once throws this process out of consideration. As a matter of fact, this supposition would necessitate the assumption that subsequently to the uplifting of the porphyroid series, a renewed volcanic activity ensued, but we have no evidence whatsoever to lead us to adopt such a view, and considering the presence of granite fragments, we need not further take this mode of origin into account.

The third process to which this rock type may owe its origin consists of a combination of those agencies by which conglomerates and breccias in general may be formed. This process is caused by atmospheric disintegration of rocks acting in conjunction with the more or less complete effect of the action of water either in motiŏn or stagnant; conglomerate being the result of the completed rounding and smoothing action of running water or wave-action, while breccia is composed of the angular fragments on which the effect of running water has been inappreciable; brecciated conglomerate then being composed of a mixture of sub-angular to angular fragments, must be the result of that stage of the process which is intermediate between the above two extremes. Normal breccia may be regarded as cemented cliff talus or scree; while normal conglomerate is the result of the collection of more or less rounded and smoothed pebbles on a sea beach or river bed, subsequently firmly consolidated by cementing material. Brecciated conglomerate would, therefore, be the consolidated and cemented product of the materials which were washed down from mountain ranges on to the piedmont plain under conditions which may roughly be described as characterised by high relief and comparatively arid climate.([37]) This latter process may, in the writer's opinion, be regarded as explaining the mode of origin of the brecciated conglomerate occurring in this field.

The transition from brecciated conglomerate to normal conglomerate along the line of strike, described above as taking place at South Darwin, can be explained by the

---

([37]) Since writing the above a paper has been received, written by Andrew C. Lawson of the University of California, entitled "The Petrographical Designation of Alluvial Fan Formations," and dated 12th June, 1913. In this paper Lawson describes the occurrence of alluvial fan formations in Nevada, Utah, New Mexico, Arizona, California, and Mexico, which are now in process of accumulation under conditions of high relief and comparatively arid climate. Such deposits and conditions are the exact parallel of those which have been indicated above as explaining the origin of the brecciated conglomerate. He further describes an occurrence of an ancient alluvial fan formation at Battle Mountain, Nevada, which is exactly analagous in character to those which occur on the Jukes-Darwin field. He further remarks the rarity of these occurrences in geological formations throughout the world, and thus this Tasmanian occurrence is of peculiar interest. He discusses the nomenclature of this class of deposit, and proposes the term "fanglomerate" as a suitable designation.

change laterally from the conditions governing the formation of brecciated conglomerate to those instrumental in developing conglomerate beds. The former conditions have been characterised by very little translation of material, but the formation of the conglomerate has been accompanied by considerable transportation of its constituent pebbles. The normal conglomerate in this case has been formed as a typical littoral deposit, while the brecciated conglomerate has been formed inland from the shore-line. We can therefore clearly understand the overlapping which occurs at South Darwin, for this will evidently occur when a positive or negative movement of the strand line caused a recession from or an advance towards the sea of the brecciated conglomerate—normal conglomerate transition zone. The repetition of this overlap has been brought about by the alternation of the changes of the relative positions of land and sea.

(*b*) *West Coast Range Conglomerate.*—This rock series has been referred to previously in this bulletin as the normal conglomerate, but in addition to this typical rock type it consists of associated beds of sandstones, quartzites, grits, and shales of various colours. These rocks all belong to one great period of sedimentation, and therefore must be treated as a whole.

This series occurs on the greater part of Jukes, and caps the whole of the long ridge of Mt. Sorell, but is absent from Mt. Darwin, with the exception of two small isolated patches on the extreme northern and southern ends of that mountain. The most complete development, however, as regards the thickness and variety of beds occurs on Mt. Jukes, where the total thickness is seen to be approximately 1600 feet. The series, as developed on this mountain, is divisible into four clearly-marked étages, each having a thickness of about 400 feet.

The lowest étage consists of conglomerates of varying degrees of coarseness and colouring. Generally it may be stated that the colour is a dark red or brown, although some of the layers in certain parts of the mountain are pinkish-white in colour. In places the constituent pebbles of the conglomerate are very coarse, the rock being more of the nature of a "puddingstone." The size of the pebbles varies from this size down to that of peas. The reddish varieties owe their colour to the presence of much hematite as the cementing material.

This lower generally dark-coloured conglomerate is succeeded by a thick bed of red or pinkish quartzite which constitutes the second étage. This quartzite is fine-grained and very hard, and its pronounced colour is a notable feature of the mountain colouring. In places it is characterised by a network of gash veins filled with white quartz.

Above this red quartzite is the third étage, which consists of a uniform unstratified deposit of white to pinkish-white conglomerate, which represents the more typical rock type of the whole series as developed in this field. The constituents are white or pink quartz, quartzite, or quartz-mica schist pebbles, which are always worn smooth and generally well rounded. The cementing material is small in amount compared with the number of pebbles, and consists of quartz grit cemented by silica into a hard resistant rock mass. The size of the pebbles varies from about 2 inches in diameter to not less than 1 inch.

The uppermost étage consists of alternating thin beds of conglomerates, quartzites, grits, sandstones, and shales, varying in colour from almost white to a deep chocolate-brown. The shales are generally greenish-grey in colour. These beds, being of a more yielding character than the other members of the series, have been in many places affected by the local squeezing, and at these places they are thrown into folds and fine puckerings.

The whole of these four étages, together with the underlying brecciated conglomerate, can be seen as one conformable series in the Main Jukes cliff, which, as stated above, is approximately 2000 feet high. Standing on the Proprietary Peak, and looking southwards towards this cliff, a magnificent view of the whole series can be obtained. The different beds are there clearly exposed on the vertical cliff face without any interference from the vegetation or soil, and the gradation in colour from one bed to another gives a most striking scenic effect. The strike is seen to be approximately north-west, south-east, and the dip is to the south-west at a comparatively low angle. Coming to the development of the conglomerate on Mt. Sorell, we see that on that mountain the series consists of only one rock type which corresponds to the third étage on Mt. Jukes. The thickness of this white or pinkish-white conglomerate is approximately 1500 feet, and the same rock type persists from the top to the bottom for this distance. In the distance no trace of stratification can be seen, but on a closer view a division into thick beds can be traced, and the dip is seen to be towards the S. 70° W:, at an angle of 45°, and the strike is N. 20° W. These beds continue on their line of dip to the western foot of the mountain.

The conglomerate occurrences on Mt. Darwin are isolated patches, and generally consist of members of the lower étages.

The marked change in the relative proportions of the two étages present on Mt. Sorell, as compared with those prevailing on Mt. Jukes, is not a surprising feature, for breccias and conglomerates in general are recognised as being characteristically subject to this rapid change in lithological character in a short longitudinal distance.[38]

Coming now to a consideration of the structural features affecting the West Coast Range conglomerate series, we observe that although a generally uniform strike characterises the whole series, there is an infinite variation in the amount of dip. The general trend of the series is about N. 25° W., and the dip varies from horizontal to vertical, with an inclination either to the west or east, but is more often in the former direction. This variation in the amount of dip is the result of a combination of folding on a large scale and repeated block faulting. It is obvious that this series was laid down as an approximately horizontal series, and, therefore, that the tilting and fracturing are both subsequent.

These faults can be best studied on Mt. Jukes, the whole of the conglomerate series on this mountain being split up into blocks with varying dips, by intersecting fault planes.

We will first consider the main mass of conglomerate constituting the Jukes plateau. There are two principal strike faults here, which are responsible for much of the complexity of the structural features. One of these is situated on the eastern side of the plateau, and runs in a direction of N. 20° W. from near Lower Lake Jukes to a point about 1 chain west of the adit on Section 5241-93M. It is thus traceable for 2 miles. This is the most pronounced fracture line in the district, and will be called the Central Jukes Fault. The other strike is of lesser extent. This occurs on the south-western side of the plateau near West Jukes Peak, but its effect on the surface is masked by repeated dip faults towards the north-

(38) For a discussion and explanation of this character refer to: "Text Book of Geology," by Sir A. Geikie, Vol. I., pp. 651-652.

west. The effect of the Central Jukes Fault has been to tilt the conglomerate beds at an angle of 50° to S. 70° W., and at the same time to throw the white conglomerate beds up to the same level as the chocolate-brown sandstones of the uppermost étage. The resulting comb of white conglomerate, which dips at a greater angle than the sandstones to the east, is seen at the surface extending from the northern foot of Central Peak to Section 5241-93M, on the extreme northern end of the Jukes plateau. The effect of the other strike fault has similarly been to raise the white conglomerate beds, but the tilting in this case has been towards the east, so that the dip is to north-east at 45°. The line of meeting of these two mutually inclined blocks is represented, in the southern portion of the Jukes plateau by an area of crumpling, the conglomerate beds which on the surface are the dark sandstones, occupying indiscriminate vertical, horizontal and inclined positions.

This Central Jukes Fault has also been instrumental in raising the felsite at Upper Lake Jukes to a position which has led many to regard that occurrence as evidence of the intrusive character of the porphyroid series. The conglomerate there is seen to be abutting against a mass of felsite, as if the latter were an intrusive dyke. This structure is, however, the direct result of the upthrust along the Central Jukes Fault of the conglomerate, together with the underlying felsite, the tilted conglomerate beds, which were originally overlying the Yellow Knob and the Lake Jukes Hog-Back, having been subsequently removed by denudation. This is well seen from the western end of the Yellow-Knob Spur, where a magnificent view can be obtained of the succession of dip faults which occur in addition to the abovementioned strike faults, and complicate the structure resulting therefrom.

These dip faults are extremely numerous, and the amount of throw varies greatly, but at most is not more than about 100 feet as far as can be observed in the face of the East Jukes cliffs. A succession of these dip faults can be seen at Lake Jukes as the cliff face is traced from the northern foot of Pyramid Peak to the north of Central Peak. They are all upthrows on the northern side, whereby the red quartzite étage and the next succeeding étage of white conglomerate are brought at successively higher levels in this direction. Four such fault planes can be seen in this locality, the ultimate effect of which is a throw of approximately 300 feet. A continuation of the most northerly of these faults has been instrumental in developing by tilting or pivotal faulting, the abnormal direction of dip which characterises the conglomerate on the western end of the Yellow-Knob Spur, namely, N. 30° E., at an angle of 50°.

Several dip faults can be seen at the head of the gorge of the central branch of the Traveller River. Here there are two downthrows on the northern side of the fault planes. The result has been the squeezing of these downthrown blocks, with the accompanying production of the synclinal and anticlinal folds which characterise the beds at the head of this gorge, and which can be well seen on the other side of the mountain to the north-west of this point.

There are numerous minor faults (dips, strike, and oblique faults being represented) on the western side of the mountain and west of the Central Jukes Fault. These have rendered the structural details in this locality very complicated. The general direction of dip given above, however, prevails on the whole, and takes the conglomerate series to the western foot of the mountain.

It will be observed that the greatest angle of dip so far mentioned is 50°, and, as a matter of fact, this angle is not exceeded on the central or western portions of the mountain.

Coming to the eastern side of the mountain we first notice the East Jukes Peak on which the conglomerate beds occur either in horizontal beds or having a slight inclination towards N. 20° E. A few chains east of this, however, the conglomerate series is seen to be dipping at angles of from 75° to 85° to S. 65° W., and in places vertical with, however, the general strike of N. 25° W. In the King River Gorge the beds of conglomerate are seen to continue with this dip from the lip of the gorge down to the present river level. It is also seen to continue across the gorge into Mt. Huxley, where it plunges at an angle of 80° from the top of the mountain down to the river below, a total depth of over 3000 feet. This occurrence of the conglomerate series dipping at this high angle continues to the southwards along the line of strike through the East Jukes Spur, with very few breaks, to the neighbourhood of the 10-Mile. Such breaks in its continuity have undoubtedly been caused by denudation.

On the East Jukes Spur the lower members of the conglomerate series are seen on the western side, and apparently overlying the higher members which occur to the eastward. Locally also the felsite appears to be resting on the conglomerate.

This is a repetition of the structural feature which occurs at Mt. Lyell in the vicinity of the ore-deposits on that field, and, in fact, we have here the southern continuation of what Gregory has termed the Great Lyell fault.(39)

The only interpretation of these present structural features which seems feasible to the writer is that the mountain masses of this field consist of residual fragments of a former overturned or inverted anticlinal fold on a large scale, the continuity of which has been broken by minor faulting. The western is the more gradually sloping limb of this fold, while the hanging portion is now represented by the steeply-inclined conglomerate beds of the eastern side of the mountain range. This fold has been so dissected by denudation that only portions are now visible.(40) The relation between the probable original form of this fold and the outline of the present topography is illustrated in Plate VI., which is a section across Mt. Jukes in the neighbourhood of the Proprietary and East Jukes Peaks.

There is an interesting and important point in regard to the composition and character of the lowest beds of the bottom étage of the West Coast Range conglomerate series. As stated previously, the brecciated conglomerate forms the real basal beds of the whole series, and it was also pointed out that this rock type varied in thickness from point to point. Not only is this the case, however, but in places the brecciated conglomerate is wholly missing from the base of the conglomerate series. The interesting and important point, however, is that where this brecciated conglomerate is missing, the lowest bed of the conglomerate series is very rich in rounded pebbles of the porphyroids. This is especially well seen at the southern foot

(39) See "The Mount Lyell Mining Field," by J. W. Gregory, D.Sc, pp. 78-80.

(40) Inasmuch as most anticlines, &c., on a large scale are probably never continuous and unbroken, but consist in actual fact of a series of faulted blocks tilted at various angles, this overfold and the dip and strike faults mentioned above become parts of one and the same structual feature. Thus the conception of this overfold coincides in effect with the faulted blocks of Professor Gregory's description of Mt. Lyell, and his Great Lyell Fault is thus seen to be continuous right to the south end of Mt. Darwin.

of the East Jukes Peak, where the porphyroid pebbles are quite as numerous as those of quartz or quartzite. The inference to be drawn from this is obvious, but a full discussion of this matter is given in a subsequent chapter of this bulletin.([41])

There is apparently a complete absence in this series of any definite trace of organisms which are of value as palæontological evidence of age. In many of the sandstone layers there are numbers of indeterminate and indefinite impressions that may represent traces of organisms, but nothing which could be construed as an undoubted organic structure has yet been observed in them. On the Jukes plateau, however, in the highest members of the conglomerate series there occur an abundant development of "pipestems." These occur in a yellowish sandstone, and the whole appearance except for the colour is identical with the tubicolar sandstone of Zeehan.([42]) These "pipestems" are supposed to represent the tubicolar casts of some annelid. They have been observed in widely-separated localities in Tasmania,([43]), but always seem to occur either in the uppermost members of the conglomerate series or in a sandstone lying conformably thereon. So much so, that the beds in which they occur have been accepted as occupying a definite geological horizon which is in reality at the top of the West Coast Range conglomerate series. The nature of the organism producing these casts, and the exact stratigraphical value thereof, are discussed at some length by Mr. Twelvetrees in Bulletin No. 14 of the Geological Survey, and the reader is referred thereto for further information as to these "pipestems."

Mr. G. A. Waller reports the finding of imprints of *Rhynchonella* on the eastern side of Mt. Jukes, in a sandstone interstratified with the conglomerate, but the writer was not successful in confirming this discovery. *Rhynchonella* undoubtedly occurs in the sandstones at Crotty, but these are not to be regarded as part of the conglomerate series, being of undoubted Silurian age,([44]) although the two series seem there to be conformable.

([41]) See below pp. 58, 59.

([42]) See reports of the Secretary for Lands and Surveys for 1907-8 and 1908-9, and also Geol. Surv. Tas. Bull., No. 14, "The Middlesex, and Mt. Claude Mining Fields," pp. 16-20.

([43] Report on the Mt. Farrell Mining District, by G. A. Waller, 1904.

([44]) See below pp. 54-56.

(3)—*The Fossiliferous Silurian Sediments.*

(*a*) *Limestones with associated Slates and Quartzites.*—The greatest development of this series occurs on that portion of the field situate south and west of the 5-Mile, but they are also present in the country lying at the foot of both sides of the mountain range.

The series is characterised essentially by the presence of extensive beds of limestone, but there are associated therewith intercalated beds of slate and quartzite. This relation can be seen to especial advantage in the railway cuttings south of the 5-Mile. The series is there seen to consist of a succession of synclinal and anticlinal folds of alternating beds of limestone, slate, and quartzite. The limestone varies in purity in the different beds, the purer varieties being bluish-grey to black in colour, while the impure varieties are of a greyish hue. These impure limestones are either argillaceous or siliceous.

At the 3½-Mile the anticlines and synclines can be well seen, the beds at this point consisting of impure siliceous limestone, which has resisted the weathering agents sufficiently to form high hills, through which the Bird River has corroded its present channel. It is in the gorge of this river that these folds are so well shown.

As noted previously [45] the purer limestone has been so rapidly eroded that it generally occupies low-lying or flat country. This is well seen in this district, for, wherever these pure limestone beds occur, the country is inclined to be flat.

At the 4½ mile there is a development of caves in the limestone, and these are regarded by the people in the district as of great beauty. They are typical limestone caves, but the writer had no opportunity of exploring them.

At the 2½-Mile, the limestone is succeeded by the Tertiary sediments of Macquarie Harbour.

This limestone series is also seen in the Clark Valley, from about 3 miles above the point of the debouchure of that river northwards. The same alternation of limestone, both pure and impure, with the quartzites and slates occurs here.

Going northwards along the North Lyell Railway from the 10-Mile, no limestone is observed until Darwin is reached, where it occurs outcropping in flat country. At

---

([45]) See above pp. 21, 22.

this point the purer limestone beds occur. They have been worked as a source of limestone for fluxing in connection with the North Lyell smelters. At the 14½-Mile the limestone and quartzites are seen in a cutting about 15 feet deep.

Between the 11 and 15 Mile the limestone always appears at a lower level than the white Crotty sandstones which overlie the series we are now considering. Very often the only indication of the presence of the limestone is a soft black pug, which represents the residue left from the process of decay of the limestone, where such products have not had an opportunity of being removed, owing to the protective action of the overlying more resistant sandstone.

Northwards of the 15-Mile the limestone solely occurs outcropping either in the flats or in the river beds. The significance of this has already been discussed.

This limestone series also occurs on the western side of Jukes. It can be seen outcropping in the bed of the Newall River, and the whole series with the associated quartzites occurs in the neighbourhood of Kallemback's Creek.

The strike of this series is markedly constant, varying from due north to N. 20° W. Only in one case was the strike observed to swing to the east of north, and only very occasionally is it as far to the west as to give a northwest strike. The series being folded, the dip varies from point to point, being generally vertical, but sometimes inclined to the east or west at high angles.

The rocks of this series are fossiliferous, the organic remains being confined to certain beds of limestone. It is very difficult to collect a representative suite of fossils from the limestone, as they are only shown on the weathered surface of the rock, and even then only in restricted horizons. The best development of these fossils occurs at the Darwin quarry. From the palæontological evidence here gathered, these limestones may be correlated with those occurring at Zeehan [46] and Queenstown. The Gordon River limestones also belong to the same horizon.

(*b*) *Slates and Sandstones.*—Overlying the limestone series conformably, is a series of slates and sandstones with occasional beds of greenish shale. The slates are both light and dark-coloured; the sandstones vary from white to reddish-brown in colour.

[46] See Geol. Surv. Tas. Bull. No. 8, pp. 38-39.

This series is affected by the same folding as the limestone, and the strike and dip obey the same general rules.

This series is seen from the 5-Mile northwards, and continues as far as the King River, and also extends to the eastwards of the railway-line, as well as to the north of this area. These rocks are also developed on the western side of the mountains. In the neighbourhood of Crotty the sandstones form isolated hills, having an elevation of from 600 to 800 feet above sea-level.

Certain beds of sandstone in this series are fossiliferous, there being in places a rich assemblage of casts of brachiopods, &c.

The series of slates and sandstones may therefore be correlated with the similar beds at Zeehan, in accordance with the palæontological evidence available. The Zeehan beds occupy a higher geological horizon than the limestone, and therefore correspond with the relationship observed in this field. The Nelson River, Queenstown, and Queen River sandstones may also be correlated with this series and that at Zeehan.

The complete series of limestones, together with the overlying sandstones and slates, have, on the strength of the palæontological evidence contained therein, been placed in the Upper Silurian system. The evidence for this is, however, not quite conclusive.[47].

(4)—*The Tertiary Deposits.*

These occur exclusively in close proximity to the shores of Macquarie Tarbour, extending back therefrom from 1 to 2 miles. At Kelly Basin they are seen to be about 100 feet thick, and consist of horizontal beds of clays, sandstones, mudstones, and lignite.

This series has been described by R. M. Johnston,[48], who has placed them at the base of the Palæogene period, *i.e.*, at a lower horizon than the similar beds of the Tamar and Derwent.

They are undoubtedly a freshwater series containing no traces of marine life, but being replete with traces of plants.

They lie, in this district, unconformably on the Silurian limestones.

---

(47) See Zeehan Bulletin cited above, pp. 40-41.

(48) See "Geology of Tasmania," by R. M. Johnston, pp. 293-294.

At Kelly Basin, the beds of clay in this series have been used in connection with the manufacture of bricks by the North Lyell Company.

(5)—*Glacial Till and Alluvial Deposits.*

Generally, these deposits occur on the flat country east and west of the mountain range, but some alluvial or detrital deposits occur high up on the mountains, as for instance on the Darwin plateau and above the East Darwin waterfall.

The glacial till occurs on the Crotty and Smelter Plains and extends as far south as the 14½-Mile. This till consists of a heterogeneous accumulation of partly rounded to sub-angular masses of rock (porphyroids, quartzite, conglomerate, &c.), varying in size from three or more feet in maximum measurement down to a few inches. Associated with this coarse till are beds of sand and clay, showing rude stratification. These are seen in a cutting on the road near Crotty Station. In places on the Crotty Plain huge erratics of conglomerate can be seen. The maximum height to which this glacial till extends is 660 feet above sea-level. This is the height of the remarkably level surface of the site of the old Crotty smelters.

These glacial deposits have been eroded to some considerable extent, the general surface of the Crotty Plain, which has been formed as the result of this post-glacial denudational action, being approximately 140 feet below the original upper surface of the moraines. This plain is now covered with a coarse alluvial deposit, which has been laid down by the streams which have cut their way downwards through the true glacial deposits until they have reached their present base-levelled condition relative to the King River.

The glacial and detrital deposits of Mt. Darwin are nowhere very thick, the thickest layers being about 4 feet thick, and they are generally less than this. They were formed contemporaneously with the glacier's existence, and the capricious distribution of gold in these deposits is directly the result of glacial action [49] They consist of angular to sub-angular fragments from 1 foot in diameter down to coarse gravel.

From evidence gathered elsewhere in Tasmania the glacier stages must have been Post-Tertiary. Further,

---

([49]) See below p. 84.

since glacial deposits are found in valleys below the old surface of the Henty peneplain,(50) we must admit that the period of glaciation succeeded the formation of that peneplain. This, according to L. K. Ward's deductions, was accomplished in Pleistocene time. Since, however, this latter estimate is based on the assumption of the Pleistocene age of the glaciers, and there is some difference of opinion as to whether the latter were not of more recent date, it would be best to rest content for the present in placing the glacial deposits and the admittedly later alluvial deposits in the Quaternary period, without any attempt at locating them in definite subdivisions.

(2)—The Relative Ages of the Porphyroids and the West Coast Range Conglomerate.

By regarding the brecciated conglomerate as part of the conglomerate series, we must necessarily admit that this series is younger than the porphyroids, because of the fact that this brecciated conglomerate is composed of fragments of the latter rock series, as fully described above. The undoubted occurrence, also described above, of porphyroid pebbles in the conglomerate series itself must inevitably confirm such a deduction as to the posterior date of the West Coast Range conglomerate. The absence of pebbles derived from the porphyroid series has previously been used as strong negative evidence for the placing of the West Coast Range conglomerate in a lower scale of the Geological Record than the porphyroid series. In his bulletin on the Mt. Farrell field, L. K. Ward (51) comments on this notable absence and, admitting from stratigraphical evidence the younger age of this conglomerate, explains this phenomenon as follows:—" One is inclined to suppose that a tilting of the region took place at the time of the formation of the conglomerate, which brought the sea-level to a line at the base of these quartzites (*i.e.*, the Pre-Cambrian quartzites lying to the eastwards), and below which the slates and porphyroids were so far submerged as to be beyond the reach of wave-action."

The actual finding by the writer, in the Jukes-Darwin field, of undoubted porphyroid pebbles in the conglomer-

(50) See " Glacial Geol. of Tas.," by J. W. Gregory, *loc. cit.*, p. 52.

(51) See Geol. Surv. Tas. Bull. No. 3, by L. K. Ward, pp. 26–27.

ate at once shows the unreliability of conclusions based on negative evidence. Yet, at the same time, it is quite a remarkable fact that it is only in the very lowest beds of the conglomerate series that the porphyroid pebbles occur, for no trace whatever of these could be found in any of the overlying beds. This fact is easily explicable by some such supposition as that put forward by Mr. Ward and quoted above, for once the felsites, &c., had been relegated to the bottom of the sea or had even been covered by the lowest beds of the conglomerate series (and this seems to have actually taken place, for every indication seems to show that the conglomerate was once continuous over the whole porphyroid series), they would be completely prevented from contributing in any way to the supply of pebbles, &c., for the sedimentary series then in process of formation.

When, however, we attempt to determine the exact geological age of the porphyroids and the West Coast range conglomerate, we are confronted with some considerable difficulties and contradictions.

It was stated previously that these porphyroids, as they have been termed, constitute a series of old igneous rocks which occur together with associated truly sedimentary rocks in the western and north-western portions of Tasmania. On the assumption, which is quite justifiable, that this series was contemporaneous in its origin throughout the whole of its area of distribution, we are enabled to correlate such observations and deductions which have been made at localities where this series has been carefully studied.

Thus we have the established fact that in the Leven gorge, the porphyroids are older than the limestone, which is of undoubted Silurian age. At Lodder's Point they are seen to be younger than the Pre-Cambrian schists.([52])

From this evidence they must have been formed between the close of the Pre-Cambrian and the beginning of the Middle or Upper Silurian periods. The evidence gathered during the survey of the Jukes-Darwin field has shown indisputably, and for the first time, that the West Coast Range conglomerate series is younger than the porphyroids. This, therefore, shows the latter series to be considerably older than Middle Silurian. When, however, an attempt is made to determine the age of this conglomerate series we encounter several puzzling features.

([52]) See Geol. Surv. Tas. Bull. No. 5, p. 10.

In this field the Silurian sediments have the same strike as the conglomerate series, and every indication seems to point to the fact that they are to be regarded as a conformable composite series or system.

At **Zeehan** ([53]) and Middlesex,([54]) the conglomerate series, together with the conformably overlying tubicolar sandstone, appears to be succeeded conformably by the undoubted Silurian limestones and sandstones.

On this evidence, therefore, we would have to regard the West Coast Range conglomerate as being of Silurian age, but the possibility arises, as suggested by L. K. Ward, that this conformability is only accidental, being caused by an uplift subsequent to the formation of the conglomerate and associated tubicolar sandstone, followed by an exact reversal of the movement, no tilting occurring in either case. If such a supposition is justified the conglomerate can on this consideration alone be placed in any position below the Silurian.

This allotting of a Pre-Silurian age to the conglomerate appears, moreover, to be necessitated by a consideration of the fact that in the Florentine Valley, Dikelocephalus sandstone has been found, apparently overlying the conglomerate. Since these Dikelocephalus beds are of undoubted Upper Cambrian age, this would necessitate the placing of the conglomerate in the Middle or Lower Cambrian periods. The connection of the conglomerate with the other more complete development of the true Cambrian strata at Caroline Creek, near Latrobe, is very obscure, and admits of no definite deductions.

On the other hand, the finding by Mr. G. A. Waller of *Rhynchonella* in the conglomerate series, seems to preclude any justification of Ward's suggestion.

The possibility exists, therefore, that the conglomerate series is of Silurian age, but, in view of the contradictory observations mentioned here, it seems most advisable to designate this series tentatively as Pre-Silurian. This practice will be followed until more conclusive evidence is available.

It is therefore clear that at present no conclusive deduction can be drawn as to the exact geological period to which the porphyroids are to be assigned, from any consideration of their being of greater age than the con-

([53]) See "Report on the Zeehan Silver-lead Mining Field," by G. A. Waller, 1904.

([54]) See Geol. Sur. Tas. Bull. No. 14, p. 21.

glomerate. The most that can be said in the present stage of this discussion is that they must be placed in the geological record between the close of the Pre-Cambrian as their lower limit and the base of the Upper Silurian as their uppermost limit.

Returning now to the porphyroids themselves as supplying *per se* any evidence as to their age, we at once notice the important and suggestive character of pronounced schistose structure. When contrasted with the relatively unmetamorphosed condition of the conglomerate series and the Silurian sediments, this schistose character must inevitably point to a much greater age. The interval between the deposition or extrusion of the porphyroid series and the laying down of the conglomerate, must necessarily, therefore, have been characterised by a period of diastrophism, which was instrumental in developing to some considerable extent this present schistose structure, and a considerable break in the matter of time must have intervened. This metamorphism previous to the formation of the conglomerate is also evidenced by the porphyroid pebbles in the conglomerate possessing apparently as great a schistose character as the porphyroids *in situ*.

To allow for such a period of diastrophism, there is no absolute necessity to place this rock series as older than the Ordovician, for the break between this period and the Silurian proper has been accompanied elsewhere by a period of diastrophism. This consideration, therefore, places the upper limit of the possible position of this series at the close of the Ordovician period. At the same time, it seems to the writer that such a period of diastrophism followed by a prolonged continuance of denudation would point to a somewhat greater age than that indicated by placing this rock series in the Ordovician.

Mr. T. S. Hall (55) has described the occurrence of graptolites in the Dundas slates, which must be regarded as constituting part of this series of porphyroid (55). On the evidence of these graptolite remains he places these slates in the Ordovician system.

Coming now to evidence as to age, which is furnished by analogous occurrences elsewhere in Australia, we find that the Heathcotian series of Victoria has close affinities to our porphyroids. This series has been closely studied by Prof. J. W. Gregory (57) and Prof. E. W. Skeats (58), and

(55) T. S. Hall, "Evidences of Graptolites in Tas.," Roy. Soc. Tas., 1902.
(56) See Geol. Sur Tas. Bull. No. 6, p. 33.
(57) Trans. Roy. Soc. Vic. Nov. 1902, pp. 148-174.
(58) Trans. Roy. Soc. Vic. June, 1908, pp. 303-348.

their relationships with adjacent fossiliferous sediments discussed. There is here, however, a decided difference of opinion, for whereas Gregory accords to them a Pre-Cambrian age, Skeats assigns to the series a Lower Ordovician age. Even if we were justified in correlating the Heathcotian series with the Tasmanian porphyroids, we could at present obtain no definite fixation of their exact position in the Geological Record.

Summing up the evidence, we see that the lowest position they could occupy would be the close of the Pre-Cambrian period, and the uppermost limit, the close of the Ordovician. Practically, therefore, it may be said that these porphyroids are either Cambrian or Ordovician in age, but it is by no means certain that they cannot occupy a high position in the Pre-Cambrian. The term Cambro-Ordovician has been used in previous publications of the Geological Survey to indicate the age of this rock series, but the writer would prefer to use the term Pre-Silurian as indicating the present position of our knowledge as to the age of the porphyroids. This nomenclature is adopted in this bulletin, and will be adhered to until some more definite information is available as to the exact position in the geological scale of both the porphyroids and the West Coast Range conglomerate series.

Finally, therefore, we are quite justified in making the statement that the porphyroids are considerably older than the West Coast Range conglomerate; that the conglomerate, although probably of Silurian age, must at present be regarded as Pre-Silurian; that the porphyroids cannot be more definitely placed than ascribing a Pre-Silurian age to them also, but that the succession is undoubtedly as follows:—

Silurian— { Sandstones and slates.
Limestone.

Problematical Break.

Pre-Silurian— { **Tubicolar sandstone.**
West Coast Range conglomerate.

Period of Diastrophism.

Pre-Silurian—Porphyroids.

Period of Diastrophism.

Pre-Cambrian—Quartzites, Quartz-schists, &c.

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

(1) *The Extrusion of the Felsites, &c.*—The geological history of the region began with the outpourings of lava which are now represented by the felsites, &c., of the porphyroid series. It seems probable that some at least of these lava flows were submarine, since we find beds of slate ploughed and furrowed on the surface by the outpouring of the overlying lava sheet, accompanied by some inclusion of slate particles in the lower part of that sheet.

The accompanying breccias and tuffs were deposited under similar conditions, these being the fragmental products of the volcanic activity.

The amount of truly volcanic material poured out on the surface was certainly very considerable. In this region this rock surface on which the volcanic material was outspread cannot be seen. The present tectonic structure of these volcanic materials is that of a series of beds or strata upturned on their edges,(59) and, therefore, by measuring the horizontal distance over which these beds occur we can obtain an approximate idea of their original thickness. In this district these rocks are seen to occur over a horizontal distance of at least 4 miles. This gives the original thickness of the series of superimposed beds as, roughly, 21,000 feet. This is almost certainly much less than their actual original thickness, for it is certain that the portion outcropping in this field does not represent the complete series, for we have this same porphyroids accompanied by associated slates, &c., developed some considerable distance westwards of the northern continuation of the line of strike of the rocks in this field, at Zeehan and Dundas. There may, however, be some repetition of the beds due to the intense folding, which has been responsible for the present vertical position of the beds. More detailed investigations are necessary before any, even approximately, correct estimate of the thickness of this great series can be justified.

It is quite clear, nevertheless, that this period of volcanic activity was a great and prolonged one.

(2) *The Uplift, Inversion, and Metamorphism of these Rocks, and the Irruption of the Darwin Granite.*—This period of extrusion of lavas, &c., was succeeded by one

(59) See below.

of great diastrophism,[60] by which the whole area was uplifted. This was accompanied by an orogenic crumpling and compression in the West Coast mountain region at least, which was instrumental in developing a series of isoclinal [61] folds in these rocks, and inducing to a great extent their present schistose character.

This intense folding movement was accompanied, or immediately succeeded by, the intrusion of the granite, which, rising up from below and forcing its way between the several vertical beds of lava, reached finally a position which was yet very far from the surface, which at this time was constituted by the crests of the isoclinal folds. In its upward passage, this granite magma broke across the now vertical beds in places, and rising on either side of such a bed was instrumental in bringing into its present position the felsitic rock, which constitutes the pronounced ridge running in meridional direction on the Darwin plateau, and completely surrounded by granite.

This granite intrusion was the final phase of that prolonged period of igneous activity, which resulted in the development of our porphyroid series.

(3) *The Formation of the Brecciated Conglomerate and Conglomerate Series.*—There then ensued a prolonged period of denudation, during which the crests of the isoclinal folds were truncated. The erosion was continued to such an extent as to lay bare the granite, which clearly must have consolidated at some considerable distance from the surface. The assumption of the occurrence of this great amount of denudation is rendered necessary by the presence of granite boulders in the overlying brecciated conglomerate.

The latter was deposited on this land surface as alluvial fan formations and detrital material.

After a few oscillatory movements a general depression of the land surface took place, which brought about the conditions under which was deposited the conglomerate series as littoral deposits, *i.e.*, as deposits of rounded shingle, on the shore-line, which was subsequently consolidated by the infiltration of cementing material.

(60) This term "diastrophism" is used to designate all differential movements of the earth's crust; "orogenic movement" is that manifestation of diastrophism which effects crumpling of narrow belts of land such as mountain ranges; "epeirogenic" is applied to those movements, which effect the uplift or depression of large continental areas.

(61) Isoclinal folds are those in which the two limbs are compressed so closely together that they are both vertical.

(4) *The Second Period of Sedimentation.*—After the deposition of the uppermost beds of the conglomerate series, viz., those containing the "pipe-stems," some considerable downward movement must have taken place, since the next succeeding beds are the Silurian limestones, which are typical deep-water deposits.

This was succeeded by an uplifting movement which brought about the conditions necessary for the deposition of the overlying slates and sandstones.

(5) *The Folding and Faulting of the Region in Devonian Times.*—The next important event in the geological history of the region was a period of diastrophic movement by which the whole of the rocks formed up to this time were thrown in a series of folds, this folding being necessarily accompanied by some considerable fracturing and movement along thrust-planes, which are now represented by the faults of the district. This formation of thrust-faults seems to have been especially marked in the Mt. Lyell district, for, although the previous existence of the overturned fold is clearly recognisable, its present form is greatly complicated by movements along thrust-planes.([62]) This folding may either have immediately preceded, or was practically contemporaneous with, the irruption of the Devonian granite, there being, in fact, a causal relation between them.

The compressive forces which were responsible for the formation of these folds were certainly very intense, as, in addition to the very sharp anticlinal and synclinal folds which occur to the east and west, the mountain range itself is in reality the remnant of an overturned anticline. Since this anticline is overturned towards the east the direction of the thrust must have been from west to east.

This overturned fold seems to have been the largest of the individual folds formed at this time, and in the writer's opinion was thrust upwards to a greater height than the smaller folds on either side. In this way the West Coast Range was given birth to, the present configuration having been brought about by the successive vicissitudes in its subsequent history. In its infancy, therefore, this range, at least in the area under discussion, consisted in its highest portion of Silurian sandstones and slates with underlying limestones; these in turn were succeeded downwards by the tubicolar sandstone and the conglomerate series, under which lay the brecciated con-

([62]) J. W. Gregory, cited elsewhere.

glomerate, and forming the core of the mountain range, were the porphyroids.

(6) *The Events Subsequent to the Devonian Orogenic Movements.*—In the Jukes-Darwin field there is a total absence of any formation intervening between the Silurian sediments and the Tertiary strata. It is quite certain, however, that the area has been subjected to an enormous amount of denudation subsequent to the formation of the folds in Devonian time. This denudation has been sufficient to remove the whole of the Silurian sediments from the crest of the great overfold, and, on Mt. Darwin itself the whole of the conglomerate series, with the exception of a few isolated patches.

It is also quite clear that this cycle of denudation has not been continuous, but the evidence leading to such a view is to be collected only from localities outside this area. Thus, on Mt. Sedgwick, situated to the north, we find a capping of diabase; in the Linda valley Professor Gregory records the finding of Permo-Carboniferous *Fenestella* shales *in situ;* at Zeehan the basal conglomerates of the Permo-Carboniferous system occur, together with the coal-measures of the same system at Eden.[63] Since diabase is a rock which has a typical hypabyssal or intrusive character, and therefore must have intruded any rocks which had been formed up to the close of the Mesozoic period, we must assume that some overlying strata have been removed from above the present peak of Sedgwick. What applies to that locality would in all probability apply to the whole West Coast Range, including this field.

It seems probable, therefore, that, after having been subjected to the action of a prolonged period of denudation, which was sufficient to bare to the surface the Devonian granite (*e.g.*, the Heemskirk *massif*), the whole area sank beneath the sea, on the bottom of which were deposited the Permo-Carboniferous basal beds, and subsequently the upper members of the system. Above these may have been deposited the Mesozoic sediments, but in any case the diabase was intruded into and beneath the Permo-Carboniferous beds. This can now actually be seen in the central plateau region to the eastward.

The occurrence of the Permo-Carboniferous beds at such a low level at Linda and Eden is striking and puzzl-

(63) See Geol. Surv. Tas. Bull. No. 8, p. 44.

ing, but the following suggestion may explain this feature:—

May not the denudation which took place after the irruption of the Devonian granite, and previous to Permo-Carboniferous times, have been instrumental—when acting on a mountainous region, the general outlines and existence of which were pre-determined by folding—in developing a general surface configuration having a close approximation to that which now obtains. By a subsequent sinking of the whole area the beds of the Permo-Carboniferous system would be deposited and gradually built upwards. By a subsequent uplift dry land conditions were resumed, and a long period of denudational activity recurred, which has been sufficient to remove the whole of this Permo-Carboniferous system, with the exception of a few isolated patches.

This seems very probable, but further research is needed before any definite pronouncement thereon can be made.

The general events which have brought about the present details of the topography have been described previously.[64]

([64]) See above, pages 17-19 inclusive.

V.—ECONOMIC GEOLOGY.

(1)—General Remarks.

The discussion or description of the economic geology is the main *raison d'être* of such a publication as this. Thus the whole preceding portion of this bulletin has been written with the one object of leading up to and supplying the necessary foundation for the complete elucidation of the factors governing the mode of occurrence and tenor of the ore-deposits of this field. Thus it is absolutely necessary that the reader should grasp the meaning and significance of the contents of the chapters preceding this, and he will thereby be enabled to benefit to the fullest degree from a perusal of what follows. At the same time, it is necessary for the sake of clearness in the presentation of the many arguments advanced, that some repetition and emphasis should be placed on certain important geological and physiographical features, and also that some explanation be given of certain technical terms used in describing ore-deposits.

The Jukes-Darwin field is essentially a copper mining centre, the copper values being accompanied by certain proportions of gold and silver. In making an investigation of the mode of origin of these ore deposits carrying copper, it is essential, however, that cognizance be taken of other ore occurrences, which may not be of economic value in themselves, but which supply important and indispensable data for studying the genesis of these more important copper-bearing deposits. Thus the magnetite and hematite deposits will most probably never be valuable as sources of metallic iron, and the veins carrying epidote are certainly of no commercial value, yet it is advisable that a description be given of all these occurrences, so that the data for any logical deductions be contained *in toto* in this bulletin.

The problem of determining the genesis of the ore deposits of this field, and the factors governing their form and mode of occurrence, is admittedly a very complex one, and the complete data necessary for the satisfactory solution thereof are not wholly contained in this field alone.

It is therefore necessary to take advantage of all data which are available as to the character and nature of similar ore-deposits in other parts of Tasmania. This is parcularly emphasised also by the absence of any workings of considerable extent which would supply any information as to the behaviour of these ore bodies in depth, and by the fact that such extensive workings do exist elsewhere. This, therefore, leads us to an investigation of these workings as supplying data missing in the Jukes-Darwin field alone. In particular, the Mt. Lyell field, being a part of the same geological and physiographical unit as the Jukes-Darwin field, ought to supply us, by reason of the relative magnitude of the underground workings, with an immense amount of information as to the features, geological, mineralogical, and structural, which characterise the ore deposits of this region.

The absence of any detailed description of the geology and ore deposits of the Mt. Lyell field by any officer of the Geological Survey has been severely felt in the compilation of this bulletin. The only available source of information concerning this field is contained in a monograph by Professor J. W. Gregory, D.Sc., entitled "The Mount Lyell Mining Field, Tasmania," and published in 1905, and a paper written by R. C. Sticht, General Manager of the Mt. Lyell Mining Company, which appeared in the "Mineral Industry" for 1908. These have been fully availed of, and acknowledgment is here made of the information contained therein. The writer's personal observations in that field were limited to a few days only.

Not only should the Mt. Lyell field supply data for the elucidation of the problems presented by the Jukes-Darwin field, but this latter region has presented features which are apparently absent at Mt. Lyell, but which are essential for the complete understanding of the ore occurrences of what is really a composite area, the units of which are indissolubly connected and related.

In the following pages a description of the ore-deposits will be given, followed by a discussion as to their genesis, which latter must necessarily be incomplete until the Mt. Lyell field has been closely studied. As will be seen, however, several conclusions can be arrived at which, in the writer's opinion, warrant the making of a favourable statement as to the prospects of several ore-deposits.

(2)—The Ore Deposits of the Jukes-Darwin Mining Field.

(a)—the mineralogy of the ore deposits.

(*a*)—*The Copper-Silver-Gold Ore Bodies.*

There are two distinct varieties of ore occurrences in this field which contain the three metals, copper, silver, and gold, as part of their contents. One of these classes is characterised by an abundant development of hematite and magnetite. This constitutes a class by itself, and will be described separately under the heading "hematite and magnetite bodies." The other class of deposits which carry copper, silver, and gold values is decidedly of greater importance, and is characterised by the occurrence of chalcopyrite and the absence of both hematite and magnetite. It is with these comparatively richer deposits that this chapter deals.

The minerals occurring in these deposits are pyrite, chalcopyrite, native copper, galena, chalybite, specularite, chlorite, limonite, and quartz.

The relative amounts of these minerals present in the different occurrences of ore vary ve1y greatly. There is no general type characteristic of the field, for all gradations exist from the occurrence of almost pure chalcopyrite in veins and blebs in chloritic schists with very little quartz, down to almost pure quartz with a few disseminated grains of pyrite or chalcopyrite. Thus, at the Jukes Proprietary mine the ore body consists of veins, splashes, and irregular blebs of chalcopyrite, with admixed pyrite in a dark chloritic schist; while at the Darwin Proprietary and neigbouring sections the ore body consists of a metasomatic replacement of grey schist by quartz, pyrite, and chalcopyrite, the relative proportions of these three minerals varying from place to place in the ore body, sometimes consisting of almost pure quartz, while at other points there occurs practically pure chalcopyrite.

Generally it may be stated that pyrite and chalcopyrite are the most abundant of the metallic minerals present, galena and specularite being very limited indeed in amount, the only occurrences noted up to the present being that of galena on Sections 4615-M and 2585-93M, while specularite has been noted in very small amount at East Darwin. Metallic copper has also been noted in small amount occurring as blebs in the dark chloritic schists.

Of the gangue minerals present, chlorite certainly is the most persistent in its occurrence. In every ore deposit of this type on the field, excepting the siliceous ore body of East Darwin, this mineral occurs, and sometimes in large amount. Quartz certainly is at times abundant, and is almost invariably present.

It must be specially noted that chalcopyrite is the important copper-bearing mineral present, the other two minerals which contain copper being present in totally insignificant proportions.

The following is a description of various noticeable characteristics of the several mineral species occurring in these ore deposits:—

Pyrite is generally massive in texture, but in the East Darwin ore body the texture is finely granular. In the massive varieties no crystalline structure is visible, but in the granular varieties complete cubical crystals can be seen, especially where the ore body consists of pyrite disseminated in quartz. This cubical form is the only crystalline habit noted in this field.

Chalcopyrite is always massive, no crystal outlines being distinguishable. The colour is the characteristic bright yellow of this mineral species, but this is sometimes dulled by admixed pyrite.

Galena occurs as disseminated masses in quartz, which are composed of subhedral crystals. The only occurrence of this mineral observed by the writer was in the western portion of the East Darwin ore body near the contact of the grey schist and hard red felsite. It is also reported to have occurred on Section 2585-93M, but none was visible at the time of the writer's visit.

Limonite occurs as a decomposition product of pyrite or chalcopyrite, filling irregular cavities in the schists, which undoubtedly were originally occupied by either of these two minerals.

Quartz is always massive and anhedral. There is a complete absence of cavities lined with euhedral crystal forms, excepting in the case of the ore occurrence on Section 5936-M, which is a fissure-filling. It is always milky white in colour.

Chlorite is always in the massive or earthy form, and has a characteristic dark olive-green colour. No crystalline outlines are visible. The hardness is about 2·5, and the streak is light green or grey. It approaches most nearly to the variety delessite.

Chalybite is occasionally present in aggregates of brown rhombohedral crystals.

The gold and silver values are apparently contained in the chalcopyrite, and perhaps also the pyrite, but as the gold values increase with the copper contents it is most probably associated with the chalcopyrite. No free gold or silver is to be seen.

(b)—*The Hematite and Magnetite Bodies.*

As mentioned previously, the ore deposits which come under this category carry to a varying extent values in copper, silver, and gold, but by virtue of their being characterised by the presence of hematite and magnetite, and of their occurrence in deposits altogether separate from the copper-silver-gold ore-bodies already described, it is necessary to class them as a distinct class of deposits.

The predominating mineral constituents are magnetite and hematite, and the ore deposits consist of admixtures of these two minerals in varying proportions, ranging, in fact, from almost pure magnetite to pure hematite free from magnetite. Pyrite and chalcopyrite occur associated with these minerals, as also do the gangue minerals quartz and chlorite. The following is a description of the leading characteristics of the several minerals.

Magnetite occurs in the form of aggregates of octahedral crystals of a jet black colour. It is highly paramagnetic. Complete octahedra can be observed amongst the subhedral grains.

Hematite occurs in several different habits. The first is the micaceous variety, which is specially developed on the eastern side of the granite stock at South Darwin, and consists of an aggregate of scaly plates having a bright silvery lustre. Another variety is the compact non-crystalline, red hematite, which occurs in irregular masses in the felsites.

Pyrite occurs as compact irregularly-shaped aggregates of euhedral grains in the magnetite and micaceous hematite deposits. It is absent completely from the red hematite masses. Crystal outlines can be distinguished by the naked eye.

Chalcopyrite occurs under the same conditions as the pyrite, and the two minerals are usually admixed in the one pyritic aggregate.

(*c*)—*The Blue Hematite-Bornite Veins.*

These veins are wholly confined to one locality, namely Lake Jukes, on Section 4811-M and 4812-M. They consist of admixtures of hematite, bornite, and quartz in varying relative proportions in different veins and in different portions of the same vein. The whole composition and mode of occurrence of these veins differs widely from any ore-occurrences elsewhere in this district. The striking feature mineralogically is the presence of bornite and copper glance, as well as the bluish grey hematite associated therewith. In no other part of the field does bornite or copper glance occur.

Hematite is of a characteristic bluish-grey colour, which gives, however, the usual red streak. The structure is finely granular, and small almost perfect crystals are sometimes found lining vughs.

Bornite and Copper Glance occur as blebs and larger masses in the hematite. These large or small masses of bornite are practically pure, no gangue minerals being present therein.

Malachite and Azurite occur as superficial alterations of the bornite.

Quartz is present generally in small amount, but always shows more or less crystal facets. This quartz is always associated with the hematite and not with the bornite or glance.

(*d*)—*The Barytes Lodes.*

The predominating and characteristic constituent of this type of ore deposit is barite, which occurs in the lodes as an aggregate of translucent, platy crystals arranged in parallel groups. The colour is in the purer varieties pure white, but grades to pale pink. The white crystals are transparent in thin flakes. The other minerals present are very small in amount, and consist of pyrite and chalcopyrite embedded in, and completely wrapped round by, the barite. This chalcopyrite shows in places a thin coating of covellite. These minerals are, however, very rare in the barytes lodes, the contents assaying as high as 97 per cent. of barium sulphate in clean samples, and seldom if ever running less than 80 per cent.

(*e*) *The Quartz Lodes.*

There is only a very subordinate development of this type of ore deposit in this field. The mineralogical characteristics are the predominating quartz gangue with associated pyrite and chalcopyrite, chalybite, specularite, and limonite. The quartz is apt to assume crystal facets where opportunities were offered for such development in vughs, &c. The pyrite occurs as more or less complete crystals embedded in the quartz matrix; the cube is the only form represented. Chalcopyrite occurs similarly, but without definite crystalline form. Chalybite occurs as aggregates of rhombohedral crystals also embedded in the quartz. Specularite occurs as blebs having a bright metallic lustre, but is small in amount. The limonite posses the distinctive feature of pronounced botryoidal form with internal fibrous structure. The surface of the botryoidal masses has a shining lustre and a jet black colour; the hardness is about 5·5; the streak is yellowish brown.

There is a variant from this normal type which is characterised by an abundant development of chlorite in massive earthy aggregates (delessite). This type carries free gold as well as a small amount of pyrite and chalcopyrite. There is only one marked occurrence of this type, namely at Lake Jukes, but throughout the field and generally associated with other types of deposits there occur quartz veins with associated delessite. These, however, never have the well defined development which characterises the occurrence at Lake Jukes, and are included in the description of the ore deposits in which they occur.

In this place must also be mentioned the occurrence of small quartz gash veins in the conglomerate series, which are characterised by the occurrence of well crystallised specularite in white milky quartz. They contain no copper, silver, or gold values.

(*f*)—*The Epidote Veins.*

These veins are confined to only one small area in this field (Lake Jukes), and are characterised by the abundant development of the mineral epidote, and the complete absence of metallic minerals. The associated minerals are calcite, quartz, and chlorite.

The epidote is present in the form of columnar aggregates of well-formed crystals possessing the characteristic pistachio-green colour.

The calcite is well crystallised, as is also the quartz. Chlorite is in the massive earthy form (delessite), having a dark olive-green colour.

(B)—THE GEOLOGY OF THE ORE DEPOSITS.

(a) *The Distribution of the Ore Deposits.*

It is necessary to determine the relation of the ore deposits to the several rock types present in the field before any discussion as to the mode of origin can be attempted. It is also important that the geographical distribution of the ore deposits be described. At this stage of the investigation it is only necessary to give a purely descriptive account of these factors, the inferences to be drawn therefrom being left for discussion in a subsequent chapter.

It is at once apparent to the observer that the ore deposits are confined in a remarkable way to one series of rock types. This is the porphyroid series, which, as stated previously, represents the metamorphosed condition of an old suite of igneous rocks. The other prominent rock type of the field, conglomerate, is devoid of ore deposits, with the exception of the purely local development of gash veins containing quartz and specularite.

Coming now to a consideration of the distribution of the several varieties of ore deposits in the different members of this porphyroid series, we observe that the copper-silver-gold ore deposits of any importance are confined wholly to those members which possess a marked schistosity, namely, the grey schist of East Darwin or the green chloritic schist at Jukes-Proprietary, Findon's section, R. S. Taylor's section, and Section 4655-M. It does not necessarily happen that the whole of these schistose rocks contain such ore bodies, but it is certainly a striking fact that they are limited to these rocks. Certain small stringers and specks of mineralisation do occur in the hard felsite, but these are very sparsely scattered, and are of no economic importance.

The ore deposits which are characterised by the presence of magnetite and hematite apparently occur in rocks independently of their hardness or impermeability. Thus, several deposits of micaceous hematite occur in the granite itself on the east side of the South Darwin plateau, and the most prominent magnetite deposits occur in the hard, dense, flinty felsite a few chains west of the granite contact. Similarly, the deposits containing both hematite and magnetite in other parts of the field, are found, for the most part, in hard, dense felsite, as at the Jukes-Proprietary and neighbouring sections, where they have been exposed by surface trenching.

The hematite-bornite veins occur in hard, dense felsite, as also do the epidote veins.

The quartz lodes, likewise, do not seem to favour the more schistose rock, these lodes occurring in hard felsite and granite.

As regards the geographical distribution of the ore deposits, the general statement may be made that they are confined wholly to the mountain region. This indicates their distribution, with the exception of a few occurrences of bog iron in the flat country east of the range, and the alluvial deposits carrying metallic gold in the Clark Valley.

The main magnetite deposits occur at South Darwin, on the western side of the Darwin plateau. The micaceous hematite is limited to the eastern side of the Darwin plateau. The massive red hematite is seen at two noteworthy localities, namely, at the old Crown Jukes section on the northern end of Mt. Jukes, and on Section 4414-93M, on the south-western end of the same mountain, but occurs also widely distributed throughout the field.

The hematite-bornite veins and the epidote veins are restricted solely to Lake Jukes.

The copper-silver gold ore-bodies are not restricted to any particular portion of the field, and their distribution will be fully described in the chapter under the heading of "Mining Properties."

(b)—*The Structural Features of the Ore Deposits.*

The description of the structural features of ore deposits includes both an account of the external form and shape, as well as the details of the internal structure and interrelations of the several mineral constituents. In the following descriptive matter, therefore, both internal structure and external form are noted and discussed.

It is expedient, however, before proceeding to such a description, that the exact meaning and significance be definitely indicated of the words "replacement" and "metasomatism," which will be frequently used in the following pages.

The word "metasomatism" has been adopted to indicate the general process which is responsible for the formation of ore deposits in rock masses, where there originally existed no cavity of the dimensions now represented by the ore body. The *modus operandi* of such process consists in the interchange of one or more of the constituents of a solid and a solution in contact* this mutual exchange being accomplished by a migration of the respective molecules from the solid to the solution, and *vice versâ*, which proceeds so completely and definitely that the resultant new solid has an entirely new crystalline structure, which may be either that of the original substance or that which is characteristic of the solid of new composition. This new solid is termed a "replacement." Perhaps the best illustration of this process is afforded by the replacement of the iron of a knife blade, when dipped into a solution containing any copper salt. This change will proceed so far as to ultimately leave a complete replica of the knife blade composed wholly of copper.

It is important to note that the water which brings the replacing substance in solution is itself affected by this metasomatic action, for the material which leaves the solid which is metasomatically replaced is carried away in solution by that water.

It is also important to consider that the conditions in the rock mass must be such that a solution can reach such a position as to be in contact with the solid which is to be replaced. This necessitates, in the case of most rocks, the existence of channels of access, which afford a passage for the circulation of mineral-bearing solutions, but which are of insignificant width as compared with the resulting "replacement deposit."

Finally, therefore, we may state that in this bulletin the terms "metasomatic replacement" or simply "replacement," are used to indicate deposits which were formed in this way, and the term "metasomatism" is employed to designate the general process.

We now proceed to a description of the internal and external structure of the several classes of ore deposits developed in this field.

(*) The same process takes place also under the following conditions:— Gas and solid in contact; liquid and liquid in contact; gas and liquid in contact; and solid and solid in contact, although this latter most probably takes place per medium of a separating film of liquid.

(1)—*The Copper-Silver-Gold Ore Bodies and Fahlbands.*—The ore occurrences which come under this head are somewhat varied as regards the amount of valuable minerals present, *i.e.*, the relative amounts of rock and pyrite and chalcopyrite vary within rather wide limits. All gradations may be traced from the schistose rock carrying a few grains or veinlets of pyrite or chalcopyrite distributed along the planes of schistosity, to deposits consisting of practically pure pyrite or chalcopyrite. The former class really belongs to the type of ore occurrence known as "fahlbands."

Since a number of the ore occurrences of this field (which contain values in copper, silver, and gold sufficient to render them of possible economic value) consist of the mineral chalcopyrite in veins, blebs, and irregular masses in barren rock, they really should be classed and known as fahlbands, but in this bulletin the practice has been adopted of denoting both the lowest-grade deposits and those deposits which may be of economic importance by the general term "ore-bodies." The designation of any portion of this sulphide-bearing schist as a payable ore-body is therefore purely arbitrary, being governed solely by the metal contents, which render it payable under certain conditions. These conditions of payability may vary from time to time, and, therefore, it is quite possible that what is now regarded as a valueless fahlband, may, under other conditions, assume the character of a valuable ore-body.

The boundaries of these ore bodies are irregular, being limited in the direction of their width generally by the boundary-line separating the schist from hard felsite, the change towards this contact being a gradual one characterised by a diminution of the sulphides and a corresponding increase in the amount of rock.

This same gradual diminution of the value of the ore-body by the decrease in the relative proportions of sulphide and rock also occurs along the line of strike.

In some cases the schist is mineralised for its whole width, but in other instances only a portion of its width is thus affected. In the former case, the mineralisation extends in smaller unimportant veinlets for some distance into the hard adjacent felsite. Thus, the East Darwin ore body occurs in grey schist, and has as its western boundary hard, dense, red felsite, against which the ore body ends abruptly. The eastern boundary of this ore body is less sharply delineated and consists in reality of a gradual diminution of the proportion of sulphides present.

The ore-bodies on Sections 6012-M, 5925-M, 3107-M, 4655-M, and 1594-M, all possess similar characters. The ore in these deposits consists of an intimate admixture of chalcopyrite and pyrite. These mixed sulphides are arranged along the planes of fissility of the schist. They are in the form of irregularly-shaped masses connected by a thin film or veinlet of sulphides traversing the planes of schistosity. The bunches of ore, therefore, are in reality the result of the deposition of ore from a solution which traversed these planes and replaced the schist itself with sulphide minerals on either side of such fissures. From these, there project tributory veins, which run approximately at right-angles to the main fracture planes, and ultimately connect with similar deposits strung out along a parallel plane of schistosity. In this way there is developed the structure of a ramifying system of bulging veins of pyrite and chalcopyrite, totally enclosing roughly circular or polygonal masses of schist.

These veins are absolutely devoid of any trace of crustification.

Microscopic examination shows the rock to be a schist, the original character of which is not perfectly clear. The present structure is schistose, with a large development of irregular aggregates of green chlorite. With this are associated granular aggregates of secondary quartz, and also secondary quartz crystals. The pyrite is seen as masses always associated with the chlorite, which it seems to have to some extent replaced.

The origin of the pyrite and chalcopyrite, therefore, is clearly due to a replacement of the original schist.

The constant association of the sulphide minerals with chlorite (delessite) is important, for in no case (excepting the East Darwin ore-body) is this massive earthy form of chlorite absent from those ore bodies containing copper. The exact significance of this association is discussed at a later stage of this bulletin.(65)

The East Darwin ore-body is of a somewhat different character from the type just described. As stated previously, this ore body occurs in a grey schist, the western boundary of both the schist and the ore body being hard red felsite. The length of this ore body, or rather the length over which the sulphidic mineralisation extends as shown by present workings is about 2300 feet. The width

(65) See below, p. 94, *et seq.*

of the mineralised belt varies from about 5 feet to 40 feet, but as stated above the eastern boundary is undefined and no hard and fast line can be drawn as to where the ore-body ceases and passes into barren schist. Certainly the greatest lineal dimension is along the line of strike of the schist.

The characteristic feature which differentiates this East Darwin occurrence from the other copper-silver-gold ore bodies of the field, is the great amount of silicification that has taken place. In the mineralised zone the schist is almost completely replaced by silica, and the resulting rock resembles a hard dense quartzite in general appearance. In this silicified schist are disseminated the sulphide minerals which may increase in amount to such an extent as to convert the already silicified schist into a solid granular aggregate of pyrite or chalcopyrite.

Microscopic examination shows in a beautifully clear manner the replacement of the schistose structure by the secondary quartz, the wavy lines of schistosity being accurately reproduced. The sulphides are seen metasomatically replacing the quartz, euhedral grains of pyrite occurring in such a manner as to abruptly terminate the preserved schistose structure, where a crystal facet is placed in a position at right-angles to the plane of schistoscity.

The distribution of copper values in this ore-body is very irregular, some portions carrying practically no copper, while shoots of almost pure chalcopyrite occur which assay up to 31 per cent. copper.

As regards the existence of fracture planes in the type of ore deposit we are now considering, it may be stated, as far as is observable from the limited amount of development work done on them, that in the ore bodies other than that at East Darwin, these fracture planes strike about N. 20° W., and are vertical or dip at a high angle to the south of west. In the East Darwin ore body there are two sets of such fracture planes; the main "heads" strike a little west of north, and dip to the west; while another set dip at a low angle to the north. It is important, also, to note that the plane of contact of the grey schist with the hard felsite strikes a little west of north, but dips at a steep angle to the east.

(2)—*The Hematite and Magnetite Bodies.*—The general outlines of these masses are irregular. The magnetite ore-bodies of South Darwin are thus irregular in general outline, but their greatest lineal measurement is parallel to the granite contact. The micaceous hematite deposits are more indefinitely irregular than this. The red hematite masses are also irregular in outline, usually consisting of a number of large masses with sharp borders, placed in close juxtaposition, and in part connected by thin veins of the same mineral.

The internal structures of the red hematite is massive, and the contact between the iron ore and the felsite is a sharp and clearly-cut line, no dissemination of hematite occurring in the surrounding felsite. In an examination of a microscopic section of this felsite carrying veins of red hematite, the latter is seen to have replaced the felsite for some distance on either side of a narrow fissure, the cessation of iron being quite sharp when traced outwards from this fissure, which is sometimes seen to be filled with quartz.

In one locality, namely, on the old Crown Jukes section, this red hematite is seen to have been affected by compression, and a slightly contorted and schistose mass is the result.

The magnetite ore bodies are not characterised by such a sharp line at their boundaries as these red hematite deposits, the ore body gradually decreasing in mineral contents at the margins by the increase in the amount of country rock. These ore bodies are undoubtedly a metasomatic replacement of the felsite, the magnetite clearly having been introduced into the rock mass and crystallised in euhedral or subhedral grains at the expense of the rock constituents. The mode of occurrence of the sulphides in this magnetite body is an important point. It is a noteworthy fact that these sulphides occur in crystalline aggregates within the magnetite mass. These aggregates contain no magnetite, and the external boundaries thereof often present complete crystal facets. At the same time there are no disseminated grains of pyrite in the main mass of magnetite, the sulphides being wholly confined to these crystalline aggregates, which vary in diameter from ⅛-inch or less upwards. The line of junction between these sulphide masses and the magnetite is sharp and abrupt, no embaying or concave surfaces being apparent. The possible significance of this will be discussed at some length in a later portion of this bulletin.[66]

(3)—*The Other Lodes and Veins.*—For the purpose of describing their structural features, the hematite-bornite veins, the barytes lodes, the quartz lodes, and the epidote

---

[66] See below, pp. 104, 105.

veins are classed together for the reason that they all possess the distinctive feature of being fillings of true fissures, which existed previously to the introduction of the mineral-bearing solutions.

The hematite-bornite veins are simple fillings of irregularly orientated veins occurring at the summit of the Hog-Back at Lake Jukes. The width varies from a few inches to a few feet, but the dimensions in other directions is very limited, the deposits, in fact, being of the nature of lenses. The greatest length of any one vein is about 10 feet, and the depth to which it extended from the surface was no more than this. These veins, therefore, are fillings of irregular cracks and fissures in the felsite. Some of these veins are vertical, others almost horizontal. There is a noticeable alteration of the country rock at the walls of these veins, the alteration consisting of the staining of these walls to a deep-brown colour. This alteration proceeds no further than a mere pigmentation.

The barytes lodes are true fissure fillings, the most important occurrence of this type being on W. H. Taylour's barium reward section. This is a fissure-filling, the width varying from 1 foot to 8 feet, and averaging 3 feet 6 inches. The length has been shown to be at least 26 chains. Crustification is absent, or at least cannot be recognised on the surface outcrop.

The quartz lodes are also fissure-fillings. Those at South Darwin have a strike varying from north-west, south-east, to east, west, and the dip is roughly 45° northwards. At Lake Jukes the variation of this type, which is characterised by the abundant development of the chloritic mineral delessite, strikes north-east, south-west, and dips at 40° to north-west. There are no features of these lodes which call for special mention.

The epidote vein is also a fissure-filling, and in this case comb structure is apparent. The width is about 1 foot to 15 inches. The strike is approximately north and south, and the vein is vertical. The orientation of the epidote prismatic crystals is at right-angles to the walls.

(C)—THE DETRITAL GOLD DEPOSITS.

These deposits are undoubtedly of secondary origin, and therefore must be treated of separately.

The only metal present of value is metallic gold. This gold is of good quality, the fineness being very high. The remarkable feature of these deposits is the complete absence of fine gold, the metal being present in relatively coarse grains. The largest nugget yet found weighed 6½ oz.

These deposits are wholly confined to the vicinity of Mt. Darwin, only one small patch having been worked at Lake Jukes. They have worked on the following sections:—5207-M, 3295-M, 2581-M, 3196-M, 1203-M, 3352-M, 4812-M, and in the northern portion of the Clark Valley.

The precious metal occurs in creeks and alluvial terraces. A peculiar feature is the promiscuous manner in which the gold is distributed in this wash. Where the wash is thickest, gold is usually absent, and the thin layers of wash are sometimes rich in gold, although this is not an invariable rule. The gold is confined to no particular part of the wash, being found in any position from the bottom to the top. The largest nugget, weighing 6½ oz., was found in the bed of a creek resting on a ledge of rock just above a small waterfall. It had apparently been freed from the alluvial or detrital matter and washed into this position by flood waters. Similarly, gold has been obtained by cleaning out pot-holes, &c., in the creeks. It is quite common to find gold in the cracks in the felsite forming the bed of the creeks a few inches down. The fractured surface in this case has acted as a natural riffle.

These deposits are not yet exhausted, although no work was being done thereon at the time of the writer's visit. In the neighbourhood of Hanlan's Creek, there is some considerable amount yet to be worked.

The origin of this gold has been a subject of much surmise in the district, and all efforts to find the source in the form of a reef or lode have naturally failed. The writer believes the occurrence to have originated in the manner described hereunder.

It has recently been conclusively shown that gold is soluble in alkaline sulphides, and that this alkaline sulphide solution is stable to pyrites, but deposits gold by exposure to air, the sulphide under these conditions being oxidised.([67])

Given, therefore, a solution of an alkaline sulphide, it is quite feasible to suppose that this solution will dissolve any gold with which it comes in contact.

In the particular case in question, there undoubtedly exist deposits carrying pyritic minerals which carry gold. By the decomposition of these sulphides, free gold in a finely-divided state is liberated, and thus we have the first essential for the formation of such a gold-bearing solution.

([67]) "The Transportation and Deposition of Gold in Nature," by Victor Lenher. Economic Geology, Dec., 1912.

The second essential, namely, the alkaline sulphide, is more difficult of explanation. Certainly the alkalies are present as constituents of the igneous rocks, which by their decomposition can supply carbonates of the alkalies. The conversion of these alkaline carbonates to sulphides could possibly be effected by contact with the undecomposed iron sulphide of the ore deposits.(68) The exact mechanism of this process is not quite clear, and needs experimental investigation, but it must be admitted that the formation of alkaline sulphides is quite probable, since we have the alkaline carbonates and sulphides of other metals present in contact. The exact conditions under which such interaction takes place, followed by the upward passage of the resulting alkaline sulphide solution, were of a somewhat exceptional character. It must be presumed, for instance, that free H_2SO_4 is absent. An important piece of collateral evidence in this connection is available in the fact that these occurrences of alluvial gold are wholly confined to the neighbourhood of the barytes lodes and veins. Thus, the presence of barytes has been assured, whereby any free H_2SO_4 could be "fixed" and thrown out of action.

On the assumption, therefore, that this alkaline sulphide solution with its dissolved gold reaches the surface in the manner described, the precipitation of the gold will take place as soon as such solution is exposed to the air, for it has been conclusively proved that pyrite cannot precipitate the gold from a solution of this character. The gold, therefore, being precipitated under these conditions, is more likely to accumulate in relatively large masses, rather than in fine specks.

The subsequent removal by glacial action of the gold, and their consequent dropping from the ice-sheet, would explain their present erratic distribution.

(D)—THE GENESIS OF THE ORE DEPOSITS.

(a)—*Comparison between the Mineralogical Composition and Mode of Occurrence of these Ore Deposits and other similar Ore Deposits in Western and North-Western Tasmania.*

In describing the copper lodes at Mt. Balfour, L. K. Ward draws attention to the repeated occurrence of copper ores in association with hematite and magnetite.(69)

(68) This reaction takes place in the treatment by the cyanide process of ores carrying sulphides.

(69) See Geol. Surv. Tas. Bull. No 10, p. 59.

The Mt. Balfour copper lodes themselves are characterised by their association with these minerals. Copper ores associated with deposits of hematite and magnetite occur at Mt. Farrell, Red Hills, Mt. Lyell, Mt. Huxley, Dial Range, and Blythe.(70)

At Mt. Balfour the copper deposits are invariably in fissure lodes, and thereby differ from those of this field, which are, with a few minor exceptions, replacement deposits.

At Mt. Farrell the occurrences are very similar to those in the Jukes-Darwin field, for the described deposits of copper-bearing ore bodies show them to be separate from the main shoots of massive hematite. In this district also occur veins of pure barite, which are the counterpart of similar deposits on Darwin.

The deposits at Red Hills are altogether similar, the magnetite and hematite ore bodies in that district carrying blebs and masses of sulphides similarly to those occurring on South Darwin.

At the Dial Range the iron deposits (hematite) are distinct from those carrying copper, although occurring in close proximity thereto.

On the Blythe field, also, the large hematite deposits are quite distinct from the copper-bearing lodes, although situated in the same locality and in juxtaposition.

In the Mt. Lyell field also, the iron deposits are quite a distinct occurrence from the copper-bearing ore bodies.(71)

One great point of similarity between all of these occurrences in the several fields mentioned is the fact that the ore deposits, whether characterised by the presence of copper-bearing sulphides or hematite and magnetite, occur in, and are confined to, the rocks of the porphyroid series. In the case of Mt. Balfour, although the connection between the "Balfour slates and sandstones" with this

(70) The references to descriptions of these deposits are fully set out in Sur. Bull. No. 10, above referred to, and need not be repeated here.

(71) The "Iron Blow" from which the Mt. Lyell Mine derives its colloquial name, consisted of massive barytic hematite. This has been regarded as the oxidised outcrop of the pyritic ore-body, but as a matter of fact the juxtaposition was only fortuitous, and the iron deposit really was situated, not above the ore-body, but slightly to one side of it, and extends to some considerable distance away from the pyritic deposit. (See "Mining and Smelting at Mt. Lyell, Tas.," by R. C. Sticht, The Mineral Industry, 1907, p. 400) It may be regarded as conclusively established that this hematite deposit is not connected with the pyritic ore-body in the respective roles of gossan and underlying unoxidised mass.

porphyroid series has not been definitely proved, yet in all probability they do belong to this great period of combined extravasation of lavas, &c., and sedimentation, and in that case the occurrences in that field are wholly analogous to these others. There is one special point to note here: at the Blythe field and the Dial Range the Devonian and porphyroid granite occur in close proximity to the iron and copper deposits in such a way as to suggest the genetic connection between either of these intrusions and the ore-deposits.(72)

As regards the gangue minerals, there is some similarity between the ore-deposits of this field and the copper lodes of Balfour, in that the mineral chlorite is characteristic of both. In the Jukes-Darwin field, however, the variety of chlorite present is delessite, while at Balfour the chlorite is always scaly, and therefore is a different variety.

It is especially noteworthy that the mineral sericite is almost absent from the ore deposits of this field, whereas it is a prominent mineral associate of the copper ores in the North Lyell ore bodies, and is present to some extent at Balfour. The significance of this will be discussed at a later stage of this bulletin.

As noted above, the main, and really the only important, mineral of copper present in the ore deposits of this field is chalcopyrite, the occurrence of bornite at Lake Jukes being purely a local and unimportant occurrence. At Balfour the primary mineral is chalcopyrite, which, however, is altered by secondary actions to covellite. In all of the other districts mentioned above, chalcopyrite is the main copper-bearing mineral. The North Lyell ore bodies must be excepted, as these deposits are characterised by the presence of bornite and copper glance, as well as chalcopyrite. In the Mt. Lyell ore body, pyrite with some chalcopyrite is the predominant mineralogical composition.

(*b*)—*The General Relation between Ore Deposits and Igneous Magmas.*

It has been recognised in recent years, and is now generally accepted by the ablest economic geologists of the world, that there is a close genetic connection between

(72) See "Report on the N. W. Coast Mineral Deposits," by W. H. Twelvetrees, 1905, p. 36.

igneous rocks and ore deposits. Since this causal relation will figure somewhat largely in the following discussion, it is necessary to give at this stage some concise exposition of the general outline of the process of the derivation of metallic ores from an igneous magma.

The term "magma" is used here to denote the original liquid mass which contains in its composition the whole of the elements which are subsequently to be found in the many rock facies and in the varied ore deposits which result from its consolidation.

The first stage of the derivation of ore deposits from this magma consists in its injection into the solid rocks of the earth's crust, from the molten reservoir beneath. The particular form assumed by this irruptive mass varies greatly.(73) Its liquid state is not due to dry fusion, but to aqueo-igneous fusion, which is characterised by the presence of water under conditions of great pressure.(74)

Under its new conditions of complete envelopment by cold rocks the liquid magma begins to cool. This cooling is accompanied by a progressive process of differentiation and segregation, by virtue of which certain compounds begin to crystallise out from the liquid mass as definite mineral species, the water and residual compounds being thus concentrated in the "mother-liquor." This cooling proceeds, accompanied, *pari passu*, by the crystallisation of minerals and the concentration of remaining elements, either free or combined, in a solvent (water), which is gradually increasing in amount.

A definite stage in this progressive crystallisation is the consolidation of the plutonic rock corresponding with the particular composition of the magma in question. Thus, for example, granite consolidates. This consolidation will first take place on the outer edges and upper portion of the irruptive *massif*.

The cooling process then continues in the interior and deeper portion of the *massif*. The cooling and contraction of the already consolidated portion is accompanied by the development of cracks, which are filled with material derived and injected into them from the still fluid nucleus.

The differentiation and resulting concentration of certain components of the original magma in a residual nucleal sub-magma is characterised by two leading

(73) It may be in the form of :—(1) Batholith, (2) Stock, (3) Laccolite, (4) Boss, &c.

(74) Under these aqueo-igneous conditions the solidifying point is far below what it would be if dry fusion conditions prevailed.

features—(1) the tendency of the silica and siliceous materials to become segregrated into this sub-magma; and (2) the concentration therein of the metallic constituents, together with the non-metallic elements which are necessary for the formation of the metallic ores and gangue minerals, such as sulphur, fluorine, boron, &c.

In this sub-magma, also, there is a differential segregation, which is essentially that of the separation and subsequent consolidation of the siliceous portion, accompanied by the still further concentration of the metallic constitutents, still, however, associated with some silica. It is thus clearly seen why the material which fills the fissures in the granite mentioned above is always of a more acid character than the enclosing rock.

The cooling has now reached that stage wherein there exists a soldified, but still highly heated, mass of igneous rock, in the deeper or central portion of which there exists a nucleus, still in a fluid condition and under high pressure, which contains the greater part of the water contained in the original magma, together with the whole of the metallic constituents and certain volatile non-metals, such as sulphur, boron, fluorine, &c., and a greater or less amount of silica.

The progressive cooling of the already solidified rock and of those rocks in its neighbourhood which have been considerably raised in temperature by conduction, produces cracks and fissures therein. This results in the presentation to the fluid nucleus of a means of exit and relief from the high-pressure conditions. Consequently, the solutions are ejected from this nucleal portion into these veins and fissures. The decrease in temperature and pressure as distance is gained from this nucleus must necessarily result in the creation of conditions under which certain constituents of these solutions are rendered insoluble. These are therefore deposited, and there results an ore deposit.

There are many factors which will influence the exact nature of the ore deposit thus formed. Amongst these, temperature and pressure are mentioned above, and these certainly are leading controllers of the formation of these deposits. Since all minerals are deposited under different conditions of temperature and pressure, and since this temperature and pressure in general decreases with increase of distance from the nucleus, it can be thus clearly seen that the character of the minerals deposited will vary with this distance from their nucleal origin. Thus there results the *zonal distribution of ores.*

At the same time, the nature of the fissures and the character of the country rock have a decided influence on the form, structure, and composition of the ore body. Thus, in the case where the fissures are narrow and numerous, there exist conditions under which metasomatic replacement of the rock may take place, and a replacement deposit results. The distinction between a replacement deposit and a true fissure-filling has been previously described.(75)

Returning now to the zonal distribution of ore deposits, it is pertinent to mention at this point that there is recognised a particular variety of ore deposit which occurs at or near the contact of igneous *massifs*. Such ore deposits are characterised by the presence of certain minerals, chief amongst which is magnetite, and are almost invariably replacement deposits. These are produced by the action of the ejected solutions while still at a very high temperature and pressure, and probably even in a gaseous state. In the sense that ore deposits, being connected with an igneous magma as now described, are all essentially derived from the effect of solutions owing their origin to this igneous *massif*, we must undoubtedly regard them as contact-metamorphic deposits if this term is used in its broadest sense. It is generally agreed, however, to restrict this term as applied to ore deposits to those at or near igneous contacts.

It is important to note that the qualification "at or near" is used in regard to the igneous contact. From what has been said previously as to the origin of the fractures, it is apparent that such fissures may exist either *within* the igneous mass or in its immediate neighbourhood. Contact-metamorphic deposits are, therefore, not necessarily confined to the actual contact, but may occur in immediately surrounding fractured rock or within the igneous rock itself.

The corollary can be drawn from all this that ore deposits are not derived from igneous rocks, but that igneous rocks and ore deposits are the products of a magma which contained within it the materials necessary for the composition of both.

Returning now to a consideration of the parent magma, we observe that such intrusions of plutonic *massifs* may occur at different and widely separated geological periods. Thus we realise the occurrence of *metallogenetic epochs;*

---

(75) See above, p. 76. *et seq.*

that is the existence of different series of ore deposits, each genetically connected with igneous *massifs* of varying geological age.

Viewing the broader significance of geographically distinct igneous *massifs*, we are led to the natural inference that these are only upward offshoots of an underlying continuous magmatic hearth or reservoir. A similar process of differentiation is going on in this larger magma, as in the case of the offshoot previously studied. Further than this, there is the tendency, in such a large mass, for the metallic constituents to segregate into a number of nuclei. Further still, each metal has a predisposition to become concentrated in one nucleus in preference to the others. Thus is developed the conception of *metalliferous provinces*, which result from the upward irruption of portions of this magma reservoir, which have already become characterised by a preponderance of one particular metal.

The reader will now have obtained a thorough grasp of the inherent connection between igneous magmas and ore deposits, but he must not lose sight of the fact that any ore-deposit thus formed is subject to subsequent alteration, even to the extent of solution followed by migration, and consequent deposition under totally new conditions. These processes take place through the agency of circulating meteoric waters, and will be somewhat more fully discussed at a later stage of this bulletin.

(c)—*The Significance of the Igneous Rocks of this Field and Neighbouring Regions in connection with the Origin of the Ore-bearing Solutions.*

In pursuance of the lines of investigation suggested by the preceding chapter, we immediately turn our attention to the occurrence in this field, and in others in close proximity thereto, to see whether there exist any exposures of igneous rocks of such a character as to indicate their possible consanguinity with any or all of the ore deposits of the field.

Accordingly, we immediately recognise from our knowledge of the general geology of the field fully described above, that there is an abundant development of rocks of igneous origin. Therefore, we now proceed to discuss the possibility or otherwise of the existence of a genetic relation between the ore deposits and the several igneous rock types of the field.

In addition, we must not ignore the possibility of the existence of plutonic *massifs* beneath the present surface of this region, which, although still invisible, may, nevertheless, have a causal relation to the ore deposits. Hence it will be necessary to turn to adjacent regions and see whether there exist therein any exposures of plutonic igneous rocks which would indicate the possibility of such an occurrence.

(1) *The Extrusive Porphyroids.*—It has been deduced in a previous part of this bulletin that the main portion of the porphyroid suite exposed on this field, with the exception, of course, of the granite, was originally extruded as lava flows or volcanic ash, &c. Since the conditions necessary for the differentiation, which is an essential process in the concentration of the metallic constituents of a magma, are characterised by slow cooling, it can be clearly seen that these extrusive lava flows which suffer rapid cooling cannot fill the same role as a plutonic mass.

We therefore need not further consider these members of the porphyroid series in regard to the origin of the ore-bearing solutions.

(2) *The Porphyroid (Darwin) Granite.*—The structure of this rock is that of a typical plutonic type, and,as explained previously, its present position at the surface is due to denudation.[76]

We may therefore safely regard the magma from which this granite *massif* has been derived as quite capable of filling the role of parental source of ore-bearing solutions.

(3) *The Devonian Granite of Heemskirk, &c.*—The granite which constitutes the *massifs* of Heemskirk, Meredith Range, and Granite Tor, is lithologically quite distinct from the Darwin granite, and is also of much younger age.

In discussing the origin of the present geological structure of this area, it was mentioned that this was due in great measure to the intrusion of the Devonian granite, more especially the anticlinal and synclinal folding of the conglomerate and Silurian sandstones, &c. It is clear, therefore, that there exists a line of crustal weakness in this West Coast mountain region, which has been demon-

[76] See above, p. 64.

strated by the recurrence of several diastrophic and co-ordinate igneous periods. It is therefore quite feasible to suppose that there might exist at some distance beneath this region a granitic batholith of Devonian age.

We must be quite prepared, therefore, for the discovery of criteria which will indicate a genetic connection between the ore deposits and such a hypothetical granite batholith. No signs, however, have as yet been observed of such granitic rock, or even of apophyses therefrom, either in the Jukes-Darwin field or at any part of the West Coast Range south of Granite Tor.

This Devonian granite has in other regions been proved to be consanguineous with many valuable and important ore deposits, particularly tin and lead. Mr. L. K. Ward has expressed his opinion to the effect that all of the ore deposits of Tasmania are genetically connected with this Devonian granite.(77) If this is proved to be the case, then we have in the region now under consideration a metalliferous province characterised by a predominant presence of copper.

Finally, therefore, it may be stated that there exist in this region two magmatic hearths from which the ore deposits of the field may have been derived. These are separated as to the periods of their irruption by an immense interval of time. One of these (that of Devonian age) is known to be genetically connected with valuable ore deposits, while the other, of an uncertain Pre-Silurian age, has yet to be proved to be causally related to ore deposits of value. In other words, there is the possibility of the existence of two metallogenetic epochs, one of Pre-Silurian and the other of Devonian age.

(*d*) *The Importance of the Recognition of Two Metallogenetic Epochs, and their Connection with the Copper Deposits.*

It will be perfectly realised that the older an ore deposit is, the greater is the probability of considerable changes resulting in its form and composition. It may even happen that an ore deposit may be so old as to have been completely removed and deposited elsewhere in a new form and of a new composition. This change in composition may

---

(77) Geol. Surv. Tas. Bull. No. 6, pp. 40-42; ditto, No. 8, p. 99; ditto, No. 10, p. 72. Also is discussed at length in "The Heemskirk Massif," by L. Keith Ward, B.A., B.E. Austr. Assoc. Adv. Science, 1911.

result either in a concentration of the valuable metals or an impoverishment thereof.

Van Hise has investigated the conditions under which such previously existing ores may be thus affected. His most instructive exposition ([78]) of these processes was written with the object of upholding his contention that all valuable ore deposits have their origin in such a process. While this contention has not been fully substantiated, and a great number at least of important ore deposits are undoubtedly connected with igneous intrusions as previously described, yet this essay of Van Hise has supplied us with most important information concerning the method by which new ore deposits can be derived from those already deposited by igneous agencies.

In general, it may be stated that this process depends for its *modus operandi* on two factors—(1) the descent of meteoric water to the lower limit of the zone of fracture of the earth's crust, followed by a lateral movement, which is succeeded by the ascent of this water to the surface; and (2) the increase in temperature as depth is gained, combined with the increase in temperature caused by the generation of heat by diastrophic movements. The rise in temperature in general increases the solvent power of the water, and in this way ores already in existence may be dissolved and carried away in solution. The exact point at which metals in solution may be deposited as definite mineral species in the form of ore deposits will vary according as the particular conditions essential for such precipitation are afforded in different parts of the circulatory channels.

When we take into consideration the number of cycles of erosion and periods of sedimentation which have taken place since the intrusion of the Darwin granite, there is clearly borne in upon us the conviction that if any ore deposits owe their origin to the intrusion of the magma now represented by that granite, then these ore deposits will have been subjected to such prolonged action of circulating waters that they (more particularly those carrying copper) are very unlikely to be now in the same form and of the same composition, or even in the same position as they were originally. There exists, therefore, the possibility that rich or payable ore bodies in this and neighbouring fields represent the concentration at certain points of the copper contents of pre-existing low-grade ore bodies formed during the Pre-Silurian metallogenetic epoch.

([78]) See "Genesis of Ore-Deposits," pp. 282-432.

Since the period which succeeded the irruption of the Darwin granite and preceded the laying down of the conglomerate was characterised by high relief and comparative aridity,[79] such alterations and reconcentrations will have had more opportunity of being brought about than in the case of ore deposits belonging to the Devonian metallogenetic epoch. Since, moreover, the laws governing the distribution and values of such ore deposits will differ from those which regulate such as result from the direct deposition from juvenile or magmatic waters, the great economic importance will be clearly understood of deciding to which of these modes of origin the ore deposits are to be assigned.

There exists also the possibility that both the possible metallogenetic epochs have been characterised by the presence of copper minerals. In this case it may so happen that one of such epochs was characterised by a more abundant accompaniment of copper. If these facts are established, then it is of vast importance to the mining industry to know by what criteria such richer copper deposits may be recognised.

From all this, it will be now perfectly clear that the investigation which has for its object the elucidation of the genesis and life-history of the ore deposits is fraught with inestimable potential benefit to the mining industry.

We now proceed to give a general statement and discussion of the criteria which, in view of our knowledge of the general gealogy of the region, would enable a decision to be arrived at as to such genesis. Immediately following will be given an exposition of such of these criteria as are known to actually exist in this field and in those in close proximity.

(e) *The Significance of Chlorite and Sericite.*

It has been previously pointed out,[80] that in the Jukes-Darwin field chlorite (variety delessite) is a constant accompaniment of the ore-deposits, while in the Lyell field, and particularly at North Lyell, the mineral sericite characterises the ore-deposits. Since the conditions of formation of these two minerals have been somewhat completely studied, it is advisable to consider here their significance with regard to the origin of the ore deposits.

---

(79) See above, p. 46. (80) See above, p. 79.

Van Hise states ([81]) that chlorite develops especially in the upper physical-chemical zone, and particularly in the belt of cementation. The same authority states ([82]) that muscovite, of which sericite is a particular variety, is formed as an alteration product of other minerals under deep-seated conditions.

Van Hise further points out ([83]) that in the zone of katamorphism, *i.e.*, the upper belt of metamorphic action, complex hydrous silicates, *e.g.*, chlorites form, while in the zone of anamorphism, *i.e.*, the deep-seated zone, such minerals as muscovite (sericite) form.

Charles T. Kirk ([84]) has recently shown that chloritisation and sericitisation are the resultant products of the different phases of hydro-thermal alteration; sericite being the final and complete result of such action, while chlorite (and epidote) represents only the initial effect of the process, and further, that sericite is formed nearer the source of such heated solutions, and chlorite further removed therefrom (this latter deduction being applicable to solutions circulating in open fissures).

Since the conditions of Van Hise's zones of katamorphism and anamorphism are functions of the depth beneath the surface, and therefore are functions of temperature and pressure, it is seen that Kirk's results agree in general with those of Van Hise.

When, however, we consider the data given by these authorities as to the temperature necessary for such formation, a difference of opinion is found. Kirk gives a temperature of between 400° C. and 500° C as necessary for chloritic and sericitic action, these figures being based on the sulphidation of the accompanying iron compounds. He is thus in opposition to W. H. Weed, who has stated that sericite may deposit from waters of very low pressure, and at a temperature not above 73° C. ([85]). This statement is, however, strongly refuted by Kirk. The general conditions indicated by Van Hise would necessitate a temperature approximately that given by Kirk, but distinctly higher than that ascribed by Weed.

([81]) 'Treatise on Metamorphism," p. 347.

([82]) "Treatise on Metamorphism," p. 338.

([83]) "Treatise on Metamorphism," p. 180.

([84]) "Mineralisation in Copper Veins at Butte, Montana." Econ. Geol. Vol. VII., No. 1, 1912, pp. 35-82.

([85]) W. H. Weed. 21st Ann. Rpt. U.S. Geol. Surv. 1900, II., pp. 237 and 246.

In our case the chlorite occurs in such positions, *e.g.*, in definite vein fillings associated with quartz, and also in veins in the felsites, that it must have been deposited from solution. The sericite occurs similarly at North Lyell. We must therefore assume that the circulating water which incidentally carried the copper and iron which have been precipitated as sulphides, also contained the constituents of these minerals. These materials would have been derived by the action of such waters on the mineral constituents of the rocks through which they passed, such as orthoclase, plagioclase, biotite, or ferro-magnesium minerals, to be subsequently precipitated when conditions were suitable.

Kirk, in the article above referred to, has laid emphasis on the fact that the formation of chlorite and epidote or sericite are simply phases of the one general process, and not of different conditions of temperature and pressure. Thus, he explains that sericite is produced from chlorite or epidote by the continuance of the same process by which these two latter minerals were formed. It is thus seen that the question whether the process will result in the production of sericite or chlorite is simply a matter of *the total time during which that process has been in action*.

Now, it may be accepted as a postulate that the formation of large massive replacement deposits, whether such be the result of either sulphidation or silicification, or both, is dependent upon the existence of conditions which favour the *stagnation of the ore-bearing solutions*. Thus we see the time element entering into the question of the formation of a large massive replacement deposit.

It must logically follow from these considerations that chlorite will not be characteristic of massive replacement deposits, and that sericite may be so characteristic, for if the materials which are essential to the formation of these minerals are present, then, while the solutions are stagnant and producing large masses of minerals by replacement, the chlorite or epidote which is first formed will be converted to sericite.

The presence of chlorite may therefore be accepted as indicating that that particular deposit has been formed by rapidly circulating solutions, and therefore that the relative amount of country rock will be large. Whether such deposit will be of value will simply depend on whether the sulphides present are mainly those of copper. It is a significant fact in the one ore deposit on the Jukes-Darwin field where the most intense mineralisation, *i.e.*, sulphidation and silicification, has occurred, chlorite is conspicuously absent. The writer has not observed sericite to be be present in that ore body, but this no doubt is due to the coating of all faces in the workings with a thick deposit of slimy ferric hydroxide.

Finally, therefore, we may state that those deposits characterised by the presence of chlorite will consist of sulphides, &c., in a relatively larger proportion of barren rock, although at a much greater depth the conditions necessary for a stagnation of the ore-bearing solutions may have existed, and consequently massive mineralisation may occur. On this consideration, therefore, there is encouragement for testing at a greater depth.

When we proceed to use this chloritisation process as a criterion in connection with the genesis of the ore deposits we are enabled to make one step towards the solution of the problem facing us. Accepting what may be regarded as the most reliable result as to the temperature of formation of chlorite or sericite, namely, that of between 400°C. and 500° C., given by Kirk, we are enabled to calculate the depth at which such temperature would exist if due solely to the normal increase of temperature with depth.

Assuming the rate of such increase to be 1° C. for every 80 feet, we find that 400° C. will be reached in a depth of approximately 32,000 feet. Van Hise gives the depth at which rock flowage occurs as somewhat below 30,000 feet, that is, that at this depth all fractures and openings are completely closed.(86)

Since we must accept the general principle that new ore deposits in general are the result of ascending solutions, the precipitation therefrom being due in the main to decrease of temperature and pressure, we can clearly see that there has been no opportunity at the depth of 32,000 feet for the circulation of such solutions, as all fissures and fractures have been closed under these conditions. The total thickness of sediments which at one time overlay this area, namely, the conglomerate series and the Silurian limestone and sandstones, may have been sufficient to bring about such conditions of temperature and pressure, but in view of the non-existence of circulatory channels such ore deposits had no chance to form.

If we attempt to ascribe to igneous agencies the opening of such fissures and rise in temperature, then we are

(86) "Some principles controlling the Deposition of Ores," in "Genesis of Ore-Deposits," cited elsewhere, pp. 286-288.

really dealing with the Devonian granitic magma, to which the source and formation of such ore deposits under those conditions could be directly ascribed.

We are therefore forced to the conclusion that the copper ore bodies are not due to migration and redeposition of ores of Pre-Silurian age, and we must confine our consideration in this regard to the effect of ordinary *downward* secondary enrichment to ore deposits of that age.

(f) *The Primary or Secondary Character of the Chalcopyrite.*

In dealing with the mineralogical composition of the Balfour copper lodes in a previous page (87) it has been stated that the chalcopyrite is the primary cupriferous mineral. This is the expressed opinion of L. K. Ward, who discusses the question of this primary character in his bulletin dealing with that field.(88)

It has, however, been conclusively proved in several parts of the world that chalcopyrite does exist as a mineral of secondary origin. By this statement it is implied that cupriferous pyrite has been decomposed by the action of meteoric waters with the production of copper sulphate, which, migrating elsewhere (generally downwards), has combined with pyrite to form chalcopyrite.(89) Thus, an occurrence has been noted (90) in which the following progressive changes have been established:—(1) Bornite, (2) covellite and limonite, (3) chalcocite, (4) chalcopyrite and chalcocite.

Other instances could be cited, but are unnecessary here, for it is only desired for the purposes of this stage of our discussion, to recognise the fact that chalcopyrite is not necessarily primary, and that the possibility of its secondary origin must not be overlooked.

In summing up the position in regard to the primary or secondary character of chalcopyrite, J. F. Kemp says (91):—" In passing from chalcopyrite one may again remark that there is no doubt of its occurrence, so far as

(87) See above, p. 84.

(88) See Geol. Surv. Tas. Bull. No. 10, pp. 52-54.

(89) See above, p. 93.

(90) This reaction may be represented by such an equation as this: $2\ Fe\ S_2 + 2\ Cu\ SO_4 = Cu_2\ S, Fe_2\ S_3 + 2\ SO_2 + 2\ O_2$.

(91) "Copper Mountain, British Columbia," by Jules Catherinet, Eng., and Mining Journ., June 19, 1905, p. 125.

our observations go, as an original mineral in many ore bodies; but enough is now known to prevent us attributing this character to it in new instances without close observation and interpretation."

(g) *The Criteria for the Pre-Silurian Metallogenetic Epoch.*

***Criterion* 1.**—Since it has been clearly established that the West Coast Range conglomerate series has been laid down subsequently to the irruption of the Darwin granite, it naturally follows that if there were ore deposits genetically connected with that intrusion, then fragments of such ore deposits are likely to be included in this overlying series. It must be specially noted, however, that inasmuch as the normal conglomerate is markedly devoid of porphyroid pebbles it is proportionately unlikely to contain fragments of ore deposits. The occurrence of such fragments, therefore, may be expected to be confined to the brecciated conglomerate. It may also be accepted that the greater probability exists that such fragments will consist of the more durable character of ore deposit, such as hematite and magnetite.

***Criterion* 2.**—Based on the same fact of the younger age of the conglomerate series, there is the deduction that no ore deposits belonging to this epoch can possibly extend into the brecciated conglomerate or normal conglomerate. This criterion must, however, be used with discrimination and with due regard to other important factors. Thus it is quite possible that the fissures along which the ore-bearing solutions travelled from the Devonian magmatic hearth may not have extended into the conglomerate series. There also exists the possibility that secondary downward migration of ores of either Pre-Silurian or Devonian age may have resulted in the deposition on the conglomerate wall or even in the conglomerate itself in the neighbourhood of the overhanging limb of the reversed anticline described above.

***Criterion* 3.**—From what has been said previously as to the mode of origin of ore deposits from igneous magmas and from the exposition of the sequence of the igneous rocks of this field, it will be seen that such ore deposits which resulted from the Pre-Silurian metallogenetic epoch will be found in the porphyroid series and in the Darwin granite itself.

Criterion 4.—Furthermore, it may be accepted as a criterion for this epoch if there occur deposits, associated with the Darwin granite, possessing the characteristics of contact-metamorphic deposits, both in composition and in position.

Criterion 5.—It is an accepted principle that periods of diastrophism are concomitant with great igneous intrusions. Since the formation of ore deposits is the final effort of this cooling magma, it follows that these ore deposits will not be involved in the crushing and folding resulting from the diastrophic movements. In the case we are now considering, therefore, Pre-Silurian ore deposits will not have been affected by the intense compression, which would be partly anterior to, and partly coincident with, the porphyroid granitic irruption. Such ore deposits may, however, be expected to have been affected by the folding and compression which occurred in Devonian times.

Any signs of crushing in the ore-deposits may, therefore, be accepted as a criterion for this metallogenetic epoch.

However, the occurrence of faults affecting both the rock and the enclosed ore body need not necessarily indicate the connection of that ore body with the Pre-Silurian metallogenetic epoch, as such may have occurred during the final adjustments after the period of Devonian ore-deposition.

Criterion 6.—A significant fact, although not necessarily constituting a hard and fast criterion, would be the constant association of ore deposits, similar to those in this region, with outcrops of the porphyroid granite.

(*h*) *The Criteria for the Devonian Metallogenetic Epoch.*

Criterion 7.—The occurrence of a granite *massif* of Devonian age or of apophyses therefrom in the neighbourhood of this region, would conclusively point to the association of some at least of the ore deposits with that magma. At the same time, additional conclusive evidence could be adduced therefor if a zonal succession such as that already established for the Heemskirk-Comstock-Zeehan region by L. K. Ward ([92]) could be observed.

([92]) See Geol. Surv. Tas. Bull. No. 8, p. 64, *et seq.*, and "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., Trans. Aust. Assoc. Adv. Science, 1911.

Criterion 8.—The Darwin granite has so far not been observed to be associated with deposits containing such pegmatitic minerals as fluorspar and tourmaline. The recognition, therefore, of either of these minerals in an ore deposit of this region would be strong presumptive evidence of its connection with the Devonian granite, since such minerals are known to characterise ore deposits genetically connected therewith.

Criterion 9.—The extension of ore deposits locally, and to a very small extent into the conglomerate series in the neighbourhood of the overhanging limb of the anticlinal fold, as already pointed out, cannot be accepted as a certain criterion for their Devonian age, if we accept the possibility of the partial downward migration of pre-existing ore deposits. In general, however, it may be stated that ore deposits of Devonian age will or may occur in any members of the porphyroid series, in the conglomerate series or in the Silurian sediments. The occurrence of any well-defined or persistent lodes or ore bodies in the conglomerate or Silurian strata would indicate their connection with the Devonian granitic magma.

Criterion 10.—If it can be shown that the position and existence of the ore bodies are governed by faults which are demonstrably Devonian in age, such faults being the channels along which the ore-bearing solutions have been introduced, then it must inevitably follow that those ore deposits belong to the Devonian metallogenetic epoch.

(*i*)—*The Existence of Metallognetic Criteria in the Jukes-Darwin and Neighbouring Fields.*

Criterion 1.—The writer has found fragments of both hematite and magnetite in the brecciated conglomerate. These occur in such a way as to at once throw out of the question the possibility of their being replacements of original quartz or porphyroid pebbles by hematite or magnetite, as the case may be. They are irregularly-shaped, partly-rounded pebbles up to 2 inches in diameter, completely embedded among, and surrounded by, the porphyroid fragments. In no case, however, could any pyrite be observed associated with the iron oxide of these pebbles.

Criteria 2 *and* 9.—In the Jukes-Darwin field the only occurrences of ore deposits of any kind in the conglomerate consist of:—(1) small veins of quartz and specularite occurring on the northern end of Jukes, but only in the lowest members of the series; and (2) quartz veins carrying cubical pyrite, and some free gold at Sailor Jack's, on the western foot of Jukes.

In the Lyell field the ore bodies, although near the conglomerate "foot-wall," *i.e.*, the overhanging limb of the reversed anticline, and in general following the conglomerate "contact" very closely, yet only exceptionally actually touch or penetrate the conglomerate. This is exemplified by the following passage by R. C. Sticht [93]:—"The deposits all lie wholly within the schists, although the conglomerate locally comes close enough to the Mt. Lyell pyritic body to be quite tangent to it, on the one hand, though there is no actual contact; while on the other, almost the same thing may be said about the North Mt. Lyell deposits. In a few instances in the latter, however, the contiguity is still closer, for occasionally bornite is found practically frozen on to the conglomerate wall, if not actually behind it."

Criterion 3.—As mentioned previously, the ore deposits occur within the porphyroid series. In the Darwin granite occur micaceous hematite deposits.

Criterion 4.—The magnetite and hematite deposits of South Darwin, as mentioned previously, are typical contact-metamorphic deposits.

Criterion 5.—The only case in which an ore deposit shows signs of crushing in the Jukes-Darwin field is at the Crown Jukes section, where the massive red hematite is much crushed and crumpled. The workings on this field are not extensive enough to give information as to how the many faults of the area affect the ore bodies.

The Mt. Lyell ore body, according to R. C. Sticht, is traversed by fracture planes showing slickensides in many directions, none of the heads, however, extending into the adjacent rocks. These movements, therefore, must be internal.

Criterion 6.—It has been pointed out previously that altogether similar ore deposits occur at other localities in Tasmania, *inter alia*, at Farrell, Dial Range, and Blythe. At each of these three localities the porphyroid granite is developed, in each case closer to the ore deposits than any Devonian granite.

---

[93] Cited elsewhere, pp. 399-400.

Criterion 7.—There have been observed no signs whatever of Devonian granitic rocks or their hypabyssal relatives nearer to this field than Heemskirk, which in a direct line is 30 miles away. Any assertion as to the genetic connection of the ore deposits of this field with the Devonian granite is based on the purely presumptive evidence of such granitic mass beneath the West Coast Range, which hypothesis is founded upon the general principle mentioned above of the coincidence of orogenic movements and igneous invasions. In this case, certainly, the pre-determining folds of the mountain range originated in Devonian times,(94) and are referable to the general effect of the diastrophism, of which the granite irruptions are only partial manifestations. There may certainly be a granite *massif* beneath this mountain region, but the definite proof thereof is as yet unavailable.

As regards the zonal distribution of ores, it is generally accepted that the galena-blende zone is vertically above the cupriferous-pyrite zone. Why, then, if these ore bodies are connected with the Devonian metallogenetic epoch does the galena-blende zone in the Mt. Lyell pyritic body underlie the cupriferous pyrite zone?(95)

Criterion 8.—Neither fluorite or tourmaline has been observed in the Jukes-Darwin field.

In the North Lyell mine a few small but sporadic occurrences of fluorite have been noted.

Criterion 10.—According to Professor Gregory (96) the ore deposits of Mt. Lyell are closely related to the occurrence of definite fault planes, which cut both the porphyroids and conglomerates. He states that the ore-bearing solutions were introduced along these fault planes.

In the Jukes-Darwin field there certainly occur a series of faults, which have been formed since the formation of the conglomerate, and which have been previously described.(97) They are explained as being the result of the orogenic movements which were causally connected with the irruption of the Devonian granite, but in no case do such faults visibly affect the location of the ore deposits of this field. The amount of work done on these ore deposits is not at present sufficient to give the fullest

(4) See above, p. 65, *et seq.*

(95) See article by R. C. Sticht, cited above, p. 400.

(96) Cited above, pp. 117-128.

(97) See above, p. 49, *et seq.*

information on this point, but what work has been done has proved that the circulatory channels of the ore-bearing solutions have been the pronounced fracture planes of the schist which are parallel to the strike thereof, and are vertical or dip at high angles to the west. The East Darwin ore body seems to owe its present position to the existence of a marked contact line between the grey schist on the east and hard red felsite on the west. The ore deposits in this field are totally independent of the overhanging limb of the reversed anticline.

(j)—*Summary of the Genesis of the Ore-Deposits.*

It will thus be seen that the data available are not sufficiently complete to enable any definite pronouncement to be made concerning the life-history of the ore deposits of this field, or to warrant any statement as to which metallogenetic epoch the copper deposits belong. Certain facts have, however, been established in the preceding discussions which provide a distinct step forward in our knowledge of these ore deposits. It is the object of this epitome to bring together such established facts, and to point out the direction in which other indications lead in regard to this question of genesis.

One fact is perfectly clear, namely, that the present position of the ore deposits at the surface is due to the direct action of denudational erosion, which has removed the masses of rock which originally overlay them, for all of these deposits were primarily formed at some considerable distance beneath the surface.

It may be taken as conclusively proved that the Darwin granite is genetically associated with a metallogenetic epoch which is responsible for the origin of the magnetite, micaceous hematite, and red hematite deposits. Since the magnetite deposits carry copper, the question at once arises as to whether they have been subsequently introduced. If the former conclusion is justifiable, then we establish the existence of a Pre-Silurian copper epoch. The structure certainly gives one the impression of a metasomatic replacement of the magnetite by sulphides. Even if these sulphides are subsequent to the magnetite, it does not follow that they belong to a different metallogenetic epoch than the magnetite, for it is quite possible that, after the high temperatures accompanying the formation of the latter, there followed the ejection of solutions at a lower temperature which deposited sulphides; the two actions, in fact, being different phases of the one period of ore-deposition. The writer holds the view that these ore bodies, as they now stand, are wholly genetically connected with the Darwin granite.

It is a peculiar fact that these hematite and magnetite deposits, with the single exception of the massive red hematite, carry sulphides, and contain a certain proportion of copper. It is further remarkable that these sulphide-bearing hematite-magnetite deposits are in every case quite distinct from the main copper-silver-gold ore bodies, although often in very close proximity thereto. It is equally remarkable that they occur almost invariably in hard felsite, whereas the copper-silver-gold ore bodies invariably occur in the softer schists.

The questions, therefore, that are suggested by a consideration of such facts are these:—

(1) Are these chalcopyrite-pyrite deposits in the soft schists the result of the decomposition of the sulphides in the hematite-magnetite sulphide bodies, such solutions following the most accessible path, namely, through the schistose rocks, and depositing their sulphides as metasomatic replacements of the schists?

(2) Are the chalcopyrite-pyrite deposits the result of a phase of ore-deposition immediately subsequent to the intense action of contact-metamorphism, the solutions then following the more easily fractured schists?

As seen above,[98] question 1 must be answered in the negative.

However probable question 2 may seem, a positive statement that this is the mode of origin of the ore bodies is at present not justifiable.

The evidence which is available for the establishment of a genetic connection between these ore deposits and a hypothetical underlying Devonian granitic *massif* is inconclusive being based at present on the wholly exceptional contact of the ore bodies at Lyell with the conglomerate, the general conformity between the boundaries of the ore

[98] Pages 97-98.

bodies and the conglomerate "contact" and the occurrence of sporadic and very limited fluorite in the North Lyell mine. In opposition to this is the reversal in the Mt. Lyell ore body of an established zonal distribution in connection with an origin from this granitic magma. If Professor Gregory's contention is confirmed that the ore bodies in the Lyell field have been formed in their present positions *via* fault planes of Devonian age, then they are certainly genetically connected with the Devonian granite. The rest of the evidence on which such a connection is based is purely suppositive and hypothetical.

Strong presumptive evidence of the genetic connection between the ore deposits and the Darwin granite is certainly afforded by the remarkable association of iron and copper deposits with this porphyroid granite in other regions.

However, the evidence is so incomplete one way or the other that no definite expression of opinion is justifiable at present, and further consideration of this question of genesis must be postponed until a thorough examination of the adjacent and similar field of Mt. Lyell be concluded.

In one case, however, the mode of origin of the ore-deposit is, in the writer's opinion, quite clear. This is the occurrence at Lake Jukes of the blue hematite-bornite veins. These are clearly the result of secondary deposition, from a solution high in iron and low in sulphur and copper, in small irregular open veins at the summit of the Hog-Back. This solution filtering down from above (being derived from the decomposition of an overlying copper-iron deposit since removed), reached these open fissures and there deposited its mineral contents as a true fissure filling. It is a well-established principle that sulphur has a greater affinity for copper than iron, either under conditions of dry fusion or in aqueous solution. The sulphur, therefore, took up all available copper in the form of cuprous sulphide, thus effecting its most economical utilisation. The remainder of the sulphur then combined with iron to form ferric sulphide, which, combining with three molecules of the cuprous sulphide, formed bornite. The remainder of the iron was deposited as blue hematite. Where the sulphur was locally deficient, chalcocite, glance, or pure cuprous sulphide was deposited; at other points there apparently was just enough sulphur and copper present to form three molecules of cuprous sulphide to one of ferric sulphide.

(E)—THE PERSISTENCY OF THE ORE DEPOSITS.

We have now before us the total amount of data at present available which will enable us to discuss the probable extent of the ore deposits of this field. It will have been seen that such data are not complete, yet they are sufficient, in the opinion of the writer, to enable us to formulate some general deductions as to the persistency of the ore deposits in depth.

It has been seen that the important copper-silver-gold ore bodies are confined to the schistose porphyroids. It has further been deduced that the copper mineralisation has had its origin primarily in *ascending* solutions, whether these have been derived from the Darwin or Devonian granitic irruptions. The question, therefore, as to whether these ore bodies will continue to a depth is inherently connected with the question of the extent of these schist belts in a vertical direction or in their direction of dip.

We have also arrived at the conclusion that these schists were most probably originally deposited as pyroclastic products, such as tuffs, &c. We may justifiably assume that such products are not very limited in extent, and that the finer varieties are especially prone to cover comparatively large areas. There is every reason, therefore, for regarding these schists as likely to extend to some distance downwards, since it has been explained previously that the respective porphyroids in this field are in the form of almost vertically-upturned beds.(99)

It conclusively follows, therefore, that these ore bodies in the schists, will in all probability persist to some considerable depth.

Having thus deduced this corollary as to the persistency in depth of the ore body *of whatever tenor or value*, we pass on to the consideration of the *persistency of values* as depth is gained.

It has been specially pointed out (100) that the mineral chalcopyrite, which is the most important cupriferous mineral in the field, can in some cases be the undoubted result of secondary enrichment. The question then at once arises—" Is the chalcopyrite of the Jukes-Darwin field a primary or secondary mineral?" This certainly is a most difficult question to answer, and it must be here admitted that at present a definite statement thereon can-

(99) See above, pp. 63-64. (100) See page 98.

not be made, as no indication in this matter is afforded by the mineral associations.

This question, in fact, is inherently connected with that of the genesis of the ore deposits. If these belong to the Pre-Silurian metallogenetic epoch, then it is, in the writer's opinion, very probable that this chalcopyrite is of secondary origin, for ore deposits of this age would have been subjected to conditions which were eminently favourable to secondary concentration.(101) If it subsequently eventuates that the Devonian age of the ore deposits is conclusively established, then this chalcopyrite may be regarded as mainly of primary origin, although this is by no means quite certain, as we are here in some doubt as to the topographical history since Devonian times.(102)

The final answer to this question, therefore, must be postponed until further investigations will have enabled us to definitely determine the age of the ore deposits of this field, and the complete details of their life-history.

From the point of view, however, as to whether justification exists for the initiation of a bold policy of exploitation, the effects of both of these modes of origin coincide to some extent. The cycle of denudation, during which the abovementioned secondary enrichment of ore deposits of Pre-Silurian age was effected, would undoubtedly have favoured the development of a very deep zone of secondary alteration and enrichment, as the ground water-level of a region characterised by high relief and comparative aridity would have been a considerable distance beneath the surface. The amount of erosion of the ore deposits which has been effected during the present cycle of denudation may be calculated in this connection by observing how far the present surface exposures are below the base of the conglomerate series, which was once above them, but is now removed. This distance, where greatest, is not more than one, or at most two, hundred feet. Such being the case, it may be expected that even secondary chalcopyrite will in this case persist to an appreciable depth, and will not be a thin surface feature. The change in the character of the mineral constituents of the ore deposits of Devonian age will most probably be such as is characteristic of the zonal distribution which is spread vertically over appreciable distances.

---

(101) This is fully discussed on page 94.

(102) See above, p. 67. *et seq.*

Thus the statement is justified that there exists every inducement to test these ore bodies at a greater depth than has been attempted up to the present time. This is confirmed by the experience gained at Lyell as to the depth to which the ore deposits extend, as these in general must obey the same broad laws as those in this field.

As regards the consideration of the persistency of the deposits of magnetite and hematite, the following statement is justified:—Since these ore bodies are contact-metamorphic deposits, and therefore their present position at the surface is quite a fortuitous circumstance, due to the particular extent of erosion in that locality; and also because the formation of such deposits is dependent on the position of the granite periphery, and in no wise connected with the proximity of a land surface; and since such line of contact in this case will descend almost vertically for some considerable distance, the conclusion inevitably results that these contact-metamorphic deposits will continue to appreciable depths.

As, however, contact-metamorphic deposits in general are characterised by much irregularity of outline and extent, it must be expected that instead of one ore deposit thus persisting, it will rather be found that such persistency will consist in the occurrence of a succession of irregularly-shaped deposits, irregularly distributed. Exploitation, therefore, will in this case be more difficult than in the previous class of deposits.

As regards the question of the persistency of values of these contact-metamorphic deposits, it may be stated that the values at present disclosed are in no way enrichments, and may, to some extent, be the result of impoverishment. There certainly exists the possibility that certain portions of these deposits may be found to be much higher in value. It may definitely be accepted that they will not decrease in value.

VI.—THE MINING PROPERTIES.

A great number of properties have been forfeited on this field, and are at present vacant. Since these were originally known by definite names, the practice on the field is to designate all sections by those names which they originally held, irrespective of their present state, whether vacant or otherwise. This does not clash with existing usage, as no property has been refloated under a new name. To facilitate reference to the mineral charts, however, the practice has been adopted in this bulletin of designating each section by its present number.

(A)—SECTIONS ON THE NORTHERN END OF MT. JUKES.

(1)—*Section* 6012-M.

The present lessee is H. H. Souter, and the property consist of one 80-acre section, which comprises two 40-acre sections, one originally held by the Mt. Jukes Proprietary Copper Mining Company, and the other by the Jukes Comstock Company.

This property is situated on the northern end of Jukes, on the saddle which connects the Proprietary Peak to the East Jukes Peak. It is 1850 feet above sea-level, and 1690 feet above the King River, which flows immediately below.

It may be reached by pack-track from two points, viz., Crotty and Lynchford. The former route is at present used.

This is the only section on the field on which any work was being carried out at the time of the writer's visit.

On this property there occur several outcrops of ore bodies of greater or less value. The most prominent, and what has proved up to the present to be the only occurrence of value, is indicated by a well-defined brown ridge, the colour being due to the oxidation of the pyrite to limonite. This outcrop is seen at the surface to have a strike of a little east of north.

An adit has been driven in a due westerly direction to cut this ore body. This was effected at 18 feet in. The ore body was passed through and proved to be 18 feet wide, carrying veins, bunches and blebs of chalcopyrite and pyrite, for this distance, in a dark chloritic schist.

The adit was continued for a further 154 feet, but no further mineralisation of value was met with, the country consisting of alternating bands of dark and light-coloured schist with, in places, some disseminated sulphides.

A winze was sunk on the ore body from this adit to a total depth of 122 feet. At 52 feet a drive was cut along the hanging wall of the ore body in a southerly direction for 50 feet. At a point 26 feet from the winze a crosscut was driven across the ore body for 26 feet, which was thus shown to be here 24 feet wide. A sample taken across the whole width at this point by Mr. Souter is stated to have assayed :—

Copper = 4·10 per cent.
Silver = 0·53 oz. per ton.
Gold = 0·27 oz. per ton.

The ore body here undoubtedly shows nice mineralisation. The winze below this level was full of water at the time of the writers' visit, and consequently could not be inspected. It was stated, however, that the ore body was just as good in appearance in the bottom as at the 52-feet level. This No. 1 adit is 1850 feet above sea-level.

At 310 feet below the level of this No. 1 adit and situated to the north-north-east thereof, another crosscut tunnel (No. 2) was driven apparently with the object of intersecting the northern extension of the same ore body. The first 407 feet of this adit have a bearing of 188°, and is in hard green felsite, showing a few sporadic splashes of sulphides, generally in veins associated with quartz and chlorite in more or less definite "heads"; some veins consist wholly of chlorite (delessite). These occurrences are partly fissure fillings and partly replacements. The sulphidic mineral present is generally almost pure chalcopyrite. The bunches and veinlets are, however, so widely scattered as to render this portion of the workings valueless.

The next 108 feet of this adit has a bearing of 237°, and still continues in hard felsite of a general greenish colour, but with splashes of red felsite towards the end. In this portion of the adit there also occur occasional makes of sulphides, which are, however, too small to be valuable.

At 515 feet in, a well-defined head was encountered which carried as a vein-filling and metasomatic replacement about 4 feet of good ore. This was followed by a drive of 79 feet in length, the general bearing being 160°.

The make of ore soon petered out, and the end is in hard, red felsite, showing a few veinlets of quartz and chalcopyrite. The eastern wall of this head is green felsite, and the western wall is red felsite.

The main adit was continued for a further distance of 117 feet, with a bearing of 230°, in mottled green and red felsite, and a few sporadic splashes of sulphides were observed. The end is in red felsite, carrying pyrite, hematite, and magnetite, which is evidently the downward extension of a similar deposit seen outcropping in the creek directly above this point.

It is thus seen that in this adit there have been disclosed no ore deposits of value. In the past there have been published assay results as high as 29 per cent. copper in samples taken from this adit. Such certainly may have been the results from picked specimens carrying much chalcopyrite, but it would be impossible to get bulk samples representing any ore occurrence other than a thin stringer to give results appreciably high in copper.

The ore body shown in No. 1 adit has not been cut in the No. 2 adit. It would be necessary to drive a distance of 162 feet in a S. 20° W. direction, in order to reach a point vertically below the winze.

The present owners have started the driving of an intermediate adit 127 feet below No. 1 adit and about 320 feet in a direct line therefrom. The adit is in a direct line therefrom. This adit is in soft green chloritic schist, showing marked fissility and schistosity. The total distance driven is at present about 80 feet, and for this distance shows appreciable copper values, in the form of chalcopyrite and native copper. Much of the copper has, however, been leached out. The intention is to cut the ore body shown on the surface. This should require about 130 feet of driving, but as it has eventuated the whole of the country passed through by this adit is very promisingly mineralised. It will, therefore, very probably be impossible to tell when the objective ore body has been reached, and in this case a drive will be commenced towards the winze when a point 130 feet in is reached. When the ore body is cut a drive 200 feet in length will bring the end 5 feet vertically below the bottom of the winze. The ore-body can be thus exploited at that depth.

This ore-body, shown in No. 1 adit, the winze, and the intermediate adit, is the only one yet disclosed of any present economic importance on this property. There is, however, on this and neighbouring sections a belt of mineralised country, indicated by a more or less prominent limonite-stained rock surface, roughly triangular in shape, and near its base measuring about 20 chains in width. The character of the enclosing rock and of the ore deposits varies from place to place within this belt, hard, dense felsite giving place to relatively soft chloritic schist, both along the line of strike and at right-angles thereto. The extent, therefore, of any promising ore formations is thus limited by the abrupt termination of the congenial rock-mass.

Such ore bodies have been exposed by surface trenching in different parts of the property, but in every case have proved to be of very low value. Thus, in creeks both east and west of No. 2 adit there are seen belts of replacement deposits consisting of pyrite, a little chalcopyrite in places, and hematite and magnetite in hard felsite. None of these have proved of value. In the north-west corner of the section there occurs an outcrop of massive hematite accompanied by some barite. This, as will have been gathered by studying the chapter on economic geology, may be regarded as of no value, and indicating no improvement in depth.

About 300 feet below the No. 2 adit is a tunnel driven by the Jukes Comstock Company in hard felsite, showing splashes of sulphides. Nothing of value has been disclosed. Approximately, 250 feet below this is another tunnel driven into an almost vertical cliff a little east of south for about 80 feet. The face of the cliff shows copper carbonate stains on hard, red felsite. Some small veins of quartz and chalcopyrite were met with, but nothing of value was opened up. The country rock in this locality is mostly hard, dense felsite.

The only ore body of value on this property, therefore, is that on which work is now being done. The average assay taken across a width of 24 feet at the 52-feet level is very promising, and is specially notable by reason of the high content of gold. At parcel of 20 tons of ore from this ore body was sent to the Mt. Lyell Company, being sledged down to Crotty. The assay of this parcel was practically identical with that of the assay previously mentioned, which may be regarded as very satisfactory. The writer is indebted to Mr. H. H. Souter, the present lessee, for these assay returns.

(2)—*Section* 5936-M.

The present lessee is E. Slater, and the area is 40 acres. This was originally the northern of the two sections comprising the King Jukes Mine. No work was being done at the time of the writer's visit. The Lynchford track passes through the centre of this section from east to west.

Above this track an adit has been driven for about 87 feet in a south-easterly direction in hard, grey felsite. No mineralisation is shown.

Below the track, and just within the north sideline of this section, another tunnel has been driven in a direction 20° east of south for a distance of 190 feet, and a further 20 feet in a due southerly direction. At 123 feet in, a crosscut was driven for 40 feet; at 156 feet a 60-feet crosscut was driven. This adit was driven in the first instance on a definite band of mineralisation, which was identical in strike with well-defined fracture planes or heads, which run a little west of north. The end of the tunnel shows a considerable development of sulphides. The eastern wall of the adit shows abundant leachings of copper sulphate and carbonate, but the western wall shows none.

No. 1 crosscut shows very little mineral, the end being in hard red felsite. No. 2 crosscut shows sulphides for the whole length. No assays are available as to the value in bulk samples along this crosscut, but most probably they would not be very high.

There is a small stack of ore at the mouth of this lower adit which shows some good chalcopyrite contents. The ore consists of quartz, chlorite, and chalcopyrite and pyrite, and here certainly the structure is that of a vein-filling rather than a metasomatic replacement. The nature of the rock here is such that such veins will only be of small extent. Consequently, no important continuation thereof may be looked for. Any possible ore body of value will be in the form of a metasomatic replacement. As this will depend on the existence of "congenial" schist, and as no such rock-type has been shown to exist on this section, the indications are not very favourable.

(3)—*Section* 2699-93M.

This section, at present vacant, was originally held by the North Mt. Jukes Company. It is situate north of and adjoining the former section. One adit has been driven in hard felsite, and a little mineral is shown on the tip at the mouth of the adit, but owing to the presence of a considerable stream of water in this tunnel, and the partial caving in of the roof at the mouth, entrance thereto was impossible.

(4)—*Section* 3526-93M.

This section was originally known as the Jukes Consols, but is now vacant. The area is 80 acres. The King River traverses it from east to west. At a point about 20 feet above the King River, and about 1660 feet below No. 1 adit at the Proprietary, a tunnel has been driven for about 80 feet in a southerly direction in dark-green felsite. Some veins and blebs of sulphides are to be seen here, but nothing of value was disclosed.

(5)—*Section* 2547-93M.

This was originally held by the Imperial Jukes Company, but is now vacant. It is situated east of Section 6012-M. The only work consists of a short tunnel driven in an easterly direction in a grey felsite. No mineralisation whatever is visible.

(6)—*Section* 5241-93M.

This was formerly known as the Crown Jukes section, but is now vacant. The area is 40 acres. It is situated on the extreme northern end of the Jukes plateau, and due west of the Main Peak. A tunnel at an elevation of 2950 feet above sea-level has been driven in a southerly direction for about 60 feet, with the object of cutting the downward extension of prominent crags of red hematite in felsite.[103] It was evidently thought that these were the oxidised outcrops of copper ore bodies, but such has been distinctly proved not to be the case. This section therefore possesses no feature of promise.

(7)—*Section* 3530-93M.

Now vacant, but formerly known as the Queen Jukes property. It is situated at the head of the southern branch of the Traveller River. An adit has been driven in a westerly direction for 50 feet in hard, pink felsite. A very small amount of sulphide is showing in small veins, but nothing is visible to warrant any further exploitation.

---

(103) See above, p. 81.

(8)—*Section* 1596-M.

This section is also vacant. It was formerly known as the Crotty Jukes, and is situate south of the former section. A small adit has been driven beneath the Yellow Knob, which is on this section, but nothing of value was disclosed. The country rock is a felsite, which has weathered to a yellow colour. No indications of mineralisation of importance exist in this section.

(B)—SECTIONS AT LAKE JUKES.

(9)—*Sections* 4811-M *and* 4812-M.

The former of these two sections has an area of 40 acres and the latter 80 acres. They are situated in the Lakes Jukes glacial cirque, and are practically at the foot of the cliff. They were last charted in the name of E. F. Ryan, who forfeited them six months ago, but were previously to that known as the Lake Jukes Copper Mining Company's sections. This property is reached from Crotty by a pack track, which is described above,(104) and is at present in rather a bad state.

The ore deposits on these sections are confined to a prominent ridge or hog-back of granophyre, between which and the mountain cliff lies Upper Lake Jukes. The main workings are in Section 4812-M.

At the eastern foot of the Hog-Back, No. 1 adit has been driven in a direction 10° south of west. The total length is 400 feet. The approach is 2490 feet above sea-level. The only ore-deposit disclosed in this adit was a fissure lode of quartz and delessite, which dips to the north-west at an angle of 40°, and is from 2 feet wide downwards. This lode has been followed upwards for 10 feet, and stoped to this height for a few feet. In the direction of dip the lode has been stoped underhand for a depth of about 10 feet. The lode petered out in all directions. This lode was tested, and statements were made to the effect that it would bulk 10 dwt. gold per ton. A five-head battery was erected to treat the product. Only one crushing was put through, and the yield worked out at about 2 dwt. per ton. This did not pay expenses. It was found impossible to keep the battery going on the product from the lode alone. Consequently, a quantity of the adjacent felsite rock was crushed at the same time.

(104) Page 27.

The object of driving this adit in the first place was to cut the downward extension of veins of blue hematite and bornite shown on the summit of the ridge. None of these, however, were met with.

These blue hematite-bornite veins occur as irregular fissure fillings, and are shown at the summit of the knob to be extremely rich. No. 3 adit, about 100 feet above No. 1, was driven on one of these veins near the summit in a westerly direction for a distance of about 20 feet. In this adit the bornite vein was 2 feet wide, and phenomenally rich, but petered out in every direction. This also occurred in the case of every such vein followed.

No. 4 adit was driven near the top of the ridge in hard felsite, and followed a small vein of hematite and bornite, which, however, dwindled to nothing. This adit is about 50 feet above No. 2.

No. 2 adit, which is 30 feet below No. 1, and is situate due south thereof, has been driven for 200 feet, evidently with the object of intersecting the downward continuation of the bornite veins. The only mineral met with, however, was a small bunch of chalcopyrite on the northern side of the adit. The country rock is hard, dense felsite, rather dark in colour. The direction is westerly, but towards the end it swings towards the south-west, and then swings back towards the north-west.

On the western side of the ridge is a small adit about 30 feet in length driven in a south-easterly direction. The approach is in conglomerate and felsite wash, but the end of the tunnel is in hard felsite. No mineral was encountered.

In a trench a few chains north-west of this latter adit a few veinlets of bornite are exposed, but here the characteristics of those on the ridge are repeated, namely, irregularity and inconstancy.

The abovementioned five-head battery was erected on the western portion of Section 1592-M. It was driven by a waterwheel. The power was obtained by tapping Upper Lake Jukes at its southern end, and the water thus obtained was led by a race and fluming to the battery. The amount of water proved sufficient for the purpose.

This property was first exploited in connection with the bornite veins, but on the failure to locate any valuable deposits thereof, attention was paid to the quartz-delessite vein for its gold contents, and the battery was erected. Only one crushing was put through, and turned out unpayable, and operations then ceased.

Subsequently, G. Hyde erected a short aerial wireway from No. 3 adit to the more level country east of the ridge, and gouged out the contents of some of the bornite veins. The ore was lowered in bags by means of the wireway and sledged to Crotty, and thence to Mt. Lyell.

The indications on this property are such as to warrant the expression of opinion that no further expenditure of capital is justifiable.

(10)—*Section* 1594-M.

This was originally charted in the names of Bean and Thow, and consists of 37 acres situate east of Lake Jukes Company's sections. The Lake Jukes track passes through it. On this section is seen a band of green chloritic schist, which carries sulphides in an altogether similar manner to that at the Jukes Proprietary. A few shots have been put in west of the track, and some good mineralisation exposed. South of this, two trenches, each 20 feet in length and 6 feet deep, have been cut across the schist belt. Here there are veins and bunches of irregular shape in the schist carrying chalcopyrite, but at the depth exposed a great deal of the sulphides have been leached, and only fillings of limonite remain. The schist belt is seen to have a strike of north-west, south-east, and runs persistently to the Yellow-Knob. This belt is favourable for mineralisation, particularly on this section, and deserves exploitation, as the work done on it at present is trifling. The relief of the surface in this locality is not high, and consequently facilities for adit driving are not great; but the ground falls away to the south-east, and an adit could be driven from that direction along the schist belt and crosscuts put out at intervals. Otherwise a shaft would be necessary.

This property certainly deserves attention in preference to the section last described.

(C)—SECTION ON SOUTH END OF JUKES.

(11)—*Section* 4414-93M.

This is now vacant, but was formerly known as the Lake Jukes Proprietary, and was owned by a Queenstown syndicate.

There occur on this property prominent serrated crags of massive red hematite, which, as in the case of the similar occurrence at Crown Jukes were taken as the oxidised portion of a pyritic ore body.

The section is situated on the precipitous western face of Mt. Jukes, and there is no track leading to it. Access may be obtained to it either by climbing the slightly broken cliff face south of Upper Lake Jukes, to the plateau, and then crossing the same and descending the steep western face of the mountain; or by following side-lines from the Intercolonial spur. Both of these routes involve arduous climbing.

At an elevation of 2750 feet above sea-level a tunnel has been driven for 234 feet in a north-easterly direction through the red hematite masses, with the object of striking the conglomerate contact which it was presumed would be vertically beneath the conglomerate cliff situated to the north-east of the mouth of the tunnel. It was hoped to disclose an ore body at this contact.

What was thought to be the contact was struck, but no ore body was opened up. It is doubtful, however, whether such a contact was encountered, as the rock in the end is a variety of the porphyroids which possesses distinct banding. As will be gathered from the description of the general geology in a previous portion of this bulletin, the conglomerate does not in this locality extend downwards, being here merely a more or less horizontal capping of conglomerate lying on the upturned edges of the porphyroid series.

There is no inducement whatsoever to warrant the expenditure of more capital on this property unless the object is to develop a source of hematite.

(D)—SECTIONS ON THE INTERCOLONIAL SPUR.

(12)—(*Section* 5925-M).

R. S. Taylor is the present lessee. The area is 40 acres. Situated on the western slope of the Intercolonial spur. No work was being carried out at the time of the writer's visit.

This section was originally known as the Hal Jukes, but subsequently was prospected by G. Hyde, and worked by the Mt. Lyell Blocks Copper Mining Company, who are stated to have spent about £1000 on it.

The Hal Jukes Company drove a short tunnel near the eastern boundary of the section for a length of 50 feet. This tunnel is 1420 feet above sea-level, and is driven in a direction 60° east of north. A belt of dark-green schistose felsite was passed through in this tunnel, carrying splashes of chalcopyrite and pyrite.

Subsequently G. Hyde showed, by putting in several shots in the steep cliff bank of the creek further to the north, that there exists a belt of green chloritic schist highly impregnated with chalcopyrite and pyrite for a width of about 100 feet. The strike of this sulphidised belt is north and south, and it appears to be vertical. The surface outcrop is marked by the brownish colour of the rock-surface, although, as is usual in this field, no gossan has been formed.

An adit was started at a lower level in the creek to cut this belt at a depth. Here a mistake was made in the first place, for instead of driving due east, which would have cut the mineralised belt in the shortest distance, the adit was driven in a direction 40° east of north. The total distance driven was 120 feet, which was not sufficient to cut the sulphide belt shown in the creek. The country rock is hard, green felsite, varying to dark chloritic schist. Some splashes of sulphides occur near the mouth and along the drive, but do not seem to be plentiful. It is stated, however, that a bulk sample for the whole length assayed 1 per cent. copper. It is certain, however, that the more important mineralised belt was not intersected.

Some portions of the mineralised belt are very rich, and assays high in copper could be obtained in picked samples, but the bulk average over any considerable distance will probably not be very high, although the indications seem to the writer very promising. One grab sample which by its general appearance seemed to be representative of the poorer portions of the mineralised bands when assayed by Mr. J. Levings, Assistant State Mining Engineer, gave the following result:—

Copper = 1·4 per cent.
Silver = 0·5 oz. per ton.
Gold = trace.

This property certainly deserves attention, which at present is not at present being paid to it. The work already done has not served to establish the value of the deposit. The longer adit should be continued until the main mineralised belt is intersected. What appears to the writer to be the best method of establishing some idea of the value of the deposit would be to drive an adit at a point about 50 feet below the old Hal Jukes tunnel in a northerly direction, following the western wall of the schist. Cross-cuts put out at intervals across the ore body would give the requisite information as to its value.

(13)—*Sections* 1900-34 *and* 1900-35.

These are at present vacant. Each has an area of 10 acres. They were originally taken up for gold, and worked as the Sailor Jack Gold Mine. All the workings are now under water. An inclined shaft was put down to an unknown depth.

The country rock is sandstone belonging to the conglomerate series. This carries veins of quartz in which occur well-formed crystals of pyrite. These veins carry some free gold, but the quantity is very small, and under present conditions could not possibly be worked profitably. The situation also militates against cheap mining, as the property is situated in flat country at the western foot of Mt. Jukes, and at an elevation of 810 feet above sea-level.

At the time of the writer's visit some prospecting was being carried out on these sections by a State prospecting party, but nothing was disclosed beyond the existence of a small content of free gold, which did not warrant further attention.

(14)—*Section* 3868-M.

This section was granted to W. H. Taylour as a barium sulphate reward. The area is 80 acres. It is situated at the southern end of the Intercolonial Spur, at an elevation of 2000 feet above sea-level. It is reached by means of two tracks, the more direct of which leaves the North Lyell railway at the 14½-mile, and which winds upwards to the summit of the Intercolonial Spur. To reach the barytes lode a deviation from this track is necessary at a point where a blazed track from Darwin joins it. This latter track has been cut from the Darwin township, and following a somewhat tortuous route, passes close to the barytes lode. The former track could possibly, in good weather, be used for sledging, but the latter is merely a foot-track. This section is, roughly, a mile and a half in a direct line from the railway, and is 1450 feet above it.

The barytes lode is seen outcropping at the surface, and is noticeable by reason of its white colour. It is first seen about 2 chains west of the eastern boundary of the section, and then can be traced continuously in a due westerly direction until the western boundary is reached. It continues past this boundary to an undetermined distance. The lode is vertical.

The width varies from 8 feet to 1 foot, and averages about 3 feet 6 inches for the 26 chains. The lode has been opened up by a few shots at various points, and has been stripped of superficial cover for practically the whole 26 chains. The deepest hole sunk is 8 feet.

It is a true fissure lode. The walls are hard, dense felsite. The quality of the barytes is good, picked samples containing up to 97 per cent. $BaSO_4$, while bulk samples have assayed from 80 to 86 per cent. It is white to pale-pink or purple in colour.

At its western end this lode carries a considerable proportion of sulphides, both chalcopyrite and pyrite being present. The remainder of the lode on this section seems to be very free from sulphides, at least from present surface appearances.

The conditions for cheap mining are certainly very favourable. An adit could be driven along the lode in a westerly direction, and plenty of backs thus obtained in the 26 chains of length of lode.

Barium sulphate is widely used in manufacturing processes of many kinds. It is used in weighting paper and leather; also as a filling in flannelette. Its most extensive use, however, is in the paint trade, the product called lithophone finding its special application therein. In addition, it is used in the manufacture of rubber articles, linoleum, oilcloth, sealing wax, &c. It is also used as a source of barium sulphide, which is the basis of self-luminous paints. It is also used in the manufacture of barium peroxide, which is now having an extended use as an oxidising agent, and as a means of manufacturing oxygen.

Thus, the uses of barite are seen to be manifold. The price is, however, rather low, and the ruling price for crude barytes in U.S.A. is from 15s. to 20s. per ton at the shipping port. In Australia the price is from 35s. to 40s. per ton at the shipping port.

All attempts at obtaining a profitable market for this mineral in the case under review have failed. This is due to the high transport charges. It is certainly impossible to work this deposit profitably under present circumstances.

The facilities for the placing of an aerial ropeway down to the railway are suitable, and in this way the heaviest item in the transport charges may be eliminated.

If there is sufficient demand for barytes in Australia, then it is an economical problem as to whether the expenditure on such a ropeway is justified.

It is a belief held by many people that this barytes lode will carry high copper values in depth. There is nothing, however, which in the writer's opinion justifies such a belief.

(E)—SECTIONS ON EAST DARWIN.

(15)—*Section* 4655-M.

The present lessee is J. Wood, and the area is 40 acres. It was originally held by the Mt. Darwin Proprietary Company. No work is being done at present.

In the bed of a creek which flows in a deep gully through this section from west to east there has been exposed a belt of schist carrying veins and masses of chalcopyrite and pyrite. Picked samples of this gave very high values in copper, gold, and silver, the gold in particular being remarkably high.

An adit was driven at a point lower down this creek in a direction 30° south of west, with the object of intersecting this ore body. At 130 feet in a south drive was put in 90 feet, and then a crosscut started parallel to the main adit. The country rock is greyish-coloured schist. Little bunches of good copper ore were met with all along the drive. The end of the main adit is in green felsite carrying chalcopyrite. This is the belt of mineralisation seen in the creek above. On the eastern side of this ore body there occurred a make 4 feet wide of quartz and hematite carrying chalcopyrite and pyrite. Assays as high as 15 dwt. of gold per ton, and 15 per cent. copper have been obtained in picked samples. Since work was abandoned on this section the roof at the end of the adit has fallen in, and the creek above now finds a partial passage through this adit.

The main adit is 580 feet above the railway, which is 70 chains to the east thereof.

The ore body on this section most decidedly warrants exploitation. The work already done is not in any way sufficient to give the requisite information as to extent and value. The surface falls away very steeply to the east, and there is every facility for the driving of an adit at a much lower level to test the ore body at a considerably greater depth than has been done as yet.

As explained below, this ore body is probably an extension of the important belt of mineralisation in the two sections now to be described, and therefore the remarks made in connection therewith may be taken as applicable to this section also.

(16)—*Sections* 4615-M *and* 4654-M.

The present lessee is J. Wood. Both these sections have an area of 40 acres. Section 4654-M was originally held by the Mt. Darwin Proprietary. Section 4615-M formerly belonged to the South Mt. Lyell Company.

These sections are situated to the south of the last section described, and on the eastern slope of Mt. Darwin about 700 feet above the railway. Access is possible to them by means of a well-graded pack-track ([105]) from the Darwin station, which follows a somewhat tortuous route up the mountain side. A foot-track diverges from this track a few chains from the railway, and is a short cut, but much steeper. The East Darwin waterfall is situated in the southern portion of these sections.

In the eastern portion of these sections the country rock is dark-green chloritic schist. This is succeeded on the west by a grey schist, which is identical with the schist which is the repository of the ore bodies at North Lyell. Westward, this schist is succeeded by hard, dense, red felsite. The schist belt strikes almost due north and south.

The ore body occurs in this grey schist as a metasomatic replacement. Its characteristic is the strong silicification which has taken place in addition to the sulphidation. The general characters of the ore body have been previously described.([106])

The ore body is shown in several surface trenches, and cuts in both these sections, and it is notable that no gossan capping occurs, the fresh sulphides persisting right to the surface. In one trench just south of the north side-line of Section 4615-M the ore body is partly exposed, and here is seen to consist of 5 feet of solid pyrite, with some chalcopyrite. A sample taken from this trench is stated to have assayed 33 per cent. sulphur. At a point higher up the same ore body is seen on the track, where a hole has been sunk on it for a few feet, which at present is full of water. The development of sulphides is, however, very pronounced. At many other points the same belt of sulphide-

([105]) See above, p. 27. ([106]) See above, pp. 79, 80.

bearing schist can be seen, and a few shots at each point disclose the sulphide ore body.

Adits have been driven at several points to cut this ore body. They will be described hereunder in the order of their relative heights from top to bottom.

Dillon's No. 2 Tunnel.—This is situated in Section 4615-M, about 5 chains east of the centre of the west side-line thereof, and about 840 feet above the railway-line at Darwin. It has been driven in a due westerly direction for a total length of 120 feet. Country rock is grey schist. At 90 feet in an ore body 2 feet wide was encountered striking north-west, carrying a considerable amount of chalcopyrite. This breaks into several veins, but is solid underfoot. One ton of ore sent away from here is stated to have assayed 9 per cent. copper.

Souter's Tunnel.—This is situated to the east of and 90 feet below the former tunnel. It is driven in a westerly direction for 180 feet in grey schist. The end is in hard red felsite. The contact of this felsite with the grey schist was followed by a drive in a northerly direction for 180 feet. A crosscut was driven in an easterly direction for 170 feet. At 30 feet from the contact drive a short drive of 40 feet was put in, in a north-westerly direction, and one 10 feet in length in a south-easterly direction. All these workings are in grey schist.

In the main adit splashes of chalcopyrite occur. A 6-inch seam of solid chalcopyrite was passed through about 10 feet back from the end.

In the contact drive a formation consisting of quartz carrying chalcopyrite and galena from 3 feet to 4 feet wide was encountered. This practically followed the contact with the hard felsite, which courses a little west of north, and dips at a high angle to the eastwards. A sample from here is stated to have assayed 6 per cent. copper and 20 grains of gold per ton.

In the crosscut seams of chalcopyrite occur at intervals until the north-west south-east drive is met with. At this point a 6-inch vein of solid chalcopyrite occurs, which assayed 31 per cent. copper. This seam petered out in the roof of the crosscut, but is slightly wider on the floor.

In the north-west south-east drive a belt of sulphides varying from 1 foot to 4 feet, carrying chalcopyrite, was followed. Bulk samples from here are stated to have assayed 6 per cent. copper. The strike of this sulphide belt is north-west, and it dips to the south-west at 60°.

As it was followed to the north-west it got lower and lower in the drive, cutting out above, until in the end it is only seen in the floor of the drive. There are in this locality two sets of fracture planes—(1) the normal fractures, which are coincident with the planes of schistosity; and (2) a set which has an east and west strike, and dip at a very low angle to the north. These latter heads appear to cut off the ore channels upwards, and in the north-west drive described above it is a pronounced head of this description which truncates the sulphide belt upwards.

In the crosscut about 15 feet east of the north-west drive is a seam of solid chalcopyrite about 1 inch wide, succeeded by 12 feet of sulphidised and silicified schist, showing a fair amount of copper. About 5 feet further to the east is a similar belt of sulphides about 2 feet wide. A sample taken over a width of 15 feet on this mineralised belt assayed 6 per cent. copper and 1 oz. silver per ton.

The whole of the schist in this crosscut and north-west drive is strongly silicified, and may in places be taken to be a quartzite. Microscopic examination, however, proves that it is a metasomatic replacement of the schist by silica. All the developments of sulphides show nice copper contents, and some wonderfully pure seams occur. In every case also the belts of sulphides are wider in the floor of the drive than above.

In the contact drive some of the chalcopyrite has a thin coating of covellite, and a sample taken has assayed copper 23 per cent. and silver 22 oz. per ton.

The contact between the grey schist and the hard red felsite to the west is seen in this tunnel to be striking a little west of north, and dips at a high angle to the east.

Dillon's No. 1 *Tunnel.*—This is situate due north of Souter's tunnel, and 60 feet below it. It is just within the north side-line of Section 4615-M.

It has been driven in a direction 20° south of west for a total length of 312 feet. The end is in hard, red felsite, the remainder of the drive being in grey schist.

At the mouth of the adit is a belt of sulphides carrying some copper. At about 100 feet in, an ore body 28 feet wide was passed through. This is of exactly similar character to those met with in the other tunnels, namely, pyrite and chalcopyrite, with silica as a metasomatic replacement of the schist. Mr. W. H. Taylour, who has had numerous assays made of these ore occurrences, states that this 28 feet will bulk 4 per cent. copper. Certainly the chalcopyrite is plentiful in amount.

At 130 feet in a winze was sunk on this ore body. The depth is 40 feet, and is in ore all the way down. The ore body has a dip towards the west, and consequently in the bottom of this winze it is going out to the west.

In the adit at a point about 15 feet west of the winze is a seam of chalcopyrite and pyrite 1 foot thick, which assays in bulk 5 to 6 per cent. copper.

Pearse's Tunnel.—This is situate a little east of north of the former tunnel, and about 7 chains distant therefrom in Section 4654-M. It is 80 feet Dillon's No. 1 tunnel.

This crosscut adit has been driven in a south-westerly direction. The approach and the first few feet are in green schist, which further in gives place to the grey schist. Incidentally, this main adit is the cleanest and neatest piece of tunnel-driving the writer has yet seen, the work being a credit to the man who was in charge of it (Mr. B. Pearse).

The total length driven in the south-west direction is 443 feet. It then turns to the west for 54 feet. At 450 feet in a drive has been put in for 80 feet in a northerly direction, and for 159 feet in a southerly direction. The north drive is in the ore body for the whole distance; at a point 30 feet from the main adit a crosscut in an easterly direction 35 feet in length has been driven, and is wholly in the ore body. At 70 feet from the main adit a westerly crosscut was put in for a distance of 27 feet, and ends in hard, red felsite, but the first 4 feet are in the ore body, which is thus seen to be here 40 feet wide. Its character at this point is similar to the other exposures in this locality. It is, however, very difficult to form any opinion as to the amount of chalcopyrite present, as the whole of the faces are now covered by a thick layer of slimy red ferric hydroxide, which has been formed by leaching and subsequent oxidation taking place for a period of about 12 years, during which the workings have lain idle. This slimy mass has collected in places in the workings to about three feet thick. Some idea of the value, however, can be obtained by examining the tip outside, and also by the returns of ore sold, which are given below. The copper contents are certainly appreciable.

The south drive has been extended for a total length of 159 feet. At 69 feet from the main adit an easterly crosscut was driven for 30 feet, and a westerly crosscut for a distance of 39 feet. The orebody at this point is shown to be split, as it occurs in both the east and west crosscuts, with a blank band of schist between. The total width, exclusive of the blank band, corresponds with that shown in the north drive.

Both the ends of the main adit and of the west crosscut from the north drive are in hard, red felsite, which shows a little sulphide in patches. The contact of the schist and felsite runs a little west of north, and dips to the eastwards. This contact is very clearly marked.

It is thus seen that at this point, which is that at which the ore body has been cut at the greatest depth, its dimensions are greatest. This seems to agree with the observations made in the upper tunnels that the ore bodies are wider underfoot.

This belt of grey schist can be traced for more than half a mile in the direction of its strike, and the mineralisation which, as described above, occurs in this schist has been shown to extend for about 2300 feet in that direction. Whether the mineralised belt is continuous over this length has not yet been conclusively shown, but it has certainly been proved to occur at frequent intervals throughout this length. The width of the mineralised belt has been shown to vary from about 5 feet in the highest levels to 40 feet in the bottom workings. If the ore occurrences in the section immediately to the north (4655-M) are continuous with this belt (which is very probable) then the total length is about 2600 feet.

Although four adits in all have been driven on this ore-body on these two sections, it certainly cannot be said that its value and extent have been fairly tested. This should be undertaken in a bold manner, as half-measures on such an ore body as this are fruitless and abortive. Facilities exist for the driving of adits at much deeper levels than those already driven, particularly east of and below Souter's tunnel. When such an adit has intersected the ore belt a drive could be driven along it, and crosscuts put in at intervals would test the extent and value at that depth. Preferably, however, prospecting should, in the writer's opinion, be carried out by means of the diamond drill. This question of exploitation by means of the diamond drill is mentioned in the concluding chapter of this bulletin, but it may be stated here that this property is one in particular to which such a method is eminently suited. A combination of both these methods may, however, be advisable, namely, the driving of an adit and main drive, with the employment of the diamond drill to test the width and value at various points along that drive. This resolves itself virtually into a question of economics, and its consideration belongs rather to the province of the mining engineer than to that of the geologist.

Access at present from the railway is not very difficult, as a well-graded track exists from Darwin station, but if work on any considerable scale is attempted an aerial ropeway or haulage will have to be constructed. Facilities for either of these exist, as the property is, roughly, 700 feet above the railway, which is only 60 chains distant.

The only output to date from these three sections (4655-M, 4654-M, and 4615-M) consisted of a parcel of 9½ tons, which was obtained from the various workings in the process of driving. This parcel was made up of the following amounts and values from the several workings:—

Source.	Amount.	Assay.		
	Tons.	Cu.	Ag.	Au.
Workings in creek, Section 4655-M	2	6·35	trace	8 dwts.
Dillon's No. 1 and Pearce's tunnels	5·5	4·66	10 dwts.	trace
Dillon's No. 2 tunnel and winze on track...........	2	9·0	trace	trace

The writer would here state his opinion that the ore body on these sections is the most promising on the field, and most decidedly warrants the adoption of a bold and progressive policy of exploitation.

(17)—*Section* 2161-93M.

This section is now vacant, but originally constituted one of the sections of the Hector Darwin Company. The area is 40 acres. Several chains of trenching have been done in green felsite and chloritic schist, but no mineralisation of value was encountered. Further work on this section is at present not justified.

(18)—*Section* 3109-M.

The area is 40 acres. It was originally held by the Mt. Lyell Extended Company, but is now vacant. It is situate south of the former sections, two 40-acre vacant sections intervening between this section and the most southerly of J. Woods. It is high up on the precipitous eastern face of Mt. Darwin, and is 1470 feet above the railway-line.

The country rock here is mainly chloritic schist, which in places shows some disseminated pyrite and chalcopyrite. Two cuts have exposed a small belt of sulphides, but of no appreciable value. An adit has been driven in a direction south 25° west for a total length of 300 feet. A belt of mineralisation was passed through in the mouth of this tunnel, which proved to be about 10 feet thick, but at this point is low grade, giving an assay, according to Mr. Souter, of 1 per cent. copper. The remainder of the adit shows a few occurrences of mineral, but of no value. The end is in light-grey felsite.

At present there is little inducement to do any further work on this section, although ideal facilities exist for the driving of an adit at a deeper level, when the progress of the field might warrant the exploitation of the lower-grade deposits.

(19)—*Section* 2585-93M.

The area is 80 acres, and was formerly held by the Lyell Consols Company, but is now vacant. It is situate south-west of and adjoining the former section. The elevation is about 1720 feet. The surface rises steeply to the south towards the summit of Mt. Darwin.

A tunnel has been driven in a direction 20° east of south for a total length of 130 feet. The rock is a hard, light-coloured, flinty, quartzite-like rock, which is apparently a silicified felsite. At 60 feet in, a formation was met with consisting of a scaly variety of chlorite and white unctuous sericite ("pug"). This formation carries a little sulphide, and galena is stated to have been observed in it, but none could be seen by the writer. This chlorite-sericite formation has been followed by a crosscut to the west, but no sulphides of value were observed.

There appears on this property to have been some extensive mineralising action, although in the workings at present, no sulphidising action action to any extent has occurred. In depth this formation of sulphides may have occurred, but at present the writer does not feel justified in recommending the expenditure of capital on this section.

(F)—SECTIONS ON NORTH-WEST DARWIN.

(20)—*Section* 2101-93M.

The area is 79 acres. It is at present vacant, but was originally held by C. J. Miles. It is situated on the western slope of Snake Spur, at about 1300 feet above sea-level.

A trench 5 chains in length has been driven in a direction 60° east of north, cutting bands of the porphyroid series, which strike north 40° west, which are thus exposed, and afford a good illustration of the relations of the several members of this suite of rocks. A wonderful variety of these rock-types are here shown in the relatively short distance of 5 chains, varying from green chloritic schist to a rock having the appearance of a fissile sandstone. These bands merge imperceptibly one into the other at right-angles to their strike.

At various points in these belts of various rock-types occur splashes of pyrite, chalcopyrite, specularite, and red hematite. The writer was not favourably impressed with the amount of mineral showing. It is stated, however, that Mr. Miles sampled every 5 feet of this trench, and obtained assays from 5 per cent. copper downwards, and half an ounce of gold per ton downwards.

(21)—*Section* 3107-M.

This section is now vacant, but was formerly held by J. Findon, and is generally known as "Findon's Section." It is situate due west of Snake Peak, and at an elevation of 1880 feet above sea-level. It can be reached from Darwin station by means of the pack-track to just south of Snake Peak, whence the approach to the section may be made by an ill-defined foot-track.

This property was reported on by Mr. G. A. Waller in 1903. Since that time very little work has been done. Consequently, Mr. Waller's description still obtains for the greater portion of the workings. His report, as far as it bears on the workings, is repeated below, and is followed by a description of the work carried out since the writing of that report. Some of the holes which Mr. Waller examined were, at the time of the writer's visit, full of water. Therefore, Mr. Waller saw more than is at present visible.

Report by G. A. Waller.

"*Geological Features.*—The country rock consists of a somewhat dense felsite, rendered partially schistose in many places. The planes of lamination strike about 30° west of north, and dip to the west at an angle of 60°. The copper-bearing formation, which has been exposed by trenches from about the centre of the section northwards, appears to conform in strike and dip with these planes of lamination. It consists of schistose felsite, more or less completely converted into chloritic rock, and impregnated with copper and iron pyrite. The pyrites is fine-grained and fairly evenly distributed through the stone. The width of the formation cannot be accurately ascertained at the present time. It appears to vary from 20 to 60 feet, but sufficient work has not been done to enable the full width of the formation to be examined. For some feet from the surface the greater part of the copper has been leached out of the stone, leaving small iron-stained cavities, and it is only from those trenches which have got below this leached zone, which, naturally, is deeper in some places than in others, that the best copper-bearing stone has been obtained.

"*No.* 1 *Prospect Hole*.—This is the most southerly opening which has been made on the formation, and is situated a little to the north of the centre of the section. It is 8 feet long, measured across the lode, and 3 or 4 feet deep. All the stone at grass carries nice copper pyrites distributed through it. A bulk sample taken by me and submitted to Mr. W. F. Ward, Government Analyst, yielded 2·9 per cent. of copper. It is probable that this result would have been somewhat higher had the sample been taken from the bottom of the trench, as, having been taken from the whole of the stone at grass, it included a good deal of surface stone from which the copper had been leached.

"*No.* 2 *Trench*.—This trench is 1 chain north-west from No. 1 prospect hole. It is 60 feet in length, and has been put right across the formation. The western half of this trench is quite shallow, and has not got below the leached zone. The stone, however, looks as if it would make into copper at a short depth. A couple of shots put into the bottom of this portion of the trench revealed small quantities of copper pyrites in a favourable chlorite rock, with native copper in the joints. At about the centre of the trench a shaft 20 feet deep has been sunk. Unfortunately, owing to the heavy rain which fell on the day I arrived on the section, this shaft was full of water, and could not be examined. Mr. Findon tells me that a short distance from the surface the stone was very good. Then an 'intrusion' of barren rock came in, but this was passed through, and there is good stone showing in the bottom of the shaft at the present time. I took a bulk sample of the copper-bearing stone in the tip from the shaft, and this yielded 3·0 per cent. of copper. Another sample from the shaft consisting of about 20 lb. of large lumps of ore selected by Mr. Findon yielded 5·0 per cent. of copper.

"To the east of the shaft the trench cuts into rising ground, and is 8 feet deep in the end. Only the first 7 feet, however, contain appreciable copper, and that only on the south side of the trench. A head appears to cross the formation at this point, and temporarily cuts off the good stone. For 3 feet to the east of the shaft I could not get at the side of the trench to sample it. It looks fair stone, and I should judge it to contain 3 per cent. of copper. The next 4 feet was bulked, and yielded 1·9 per cent. of copper, and a selected sample taken from the bottom of the trench yielded 4·1 per cent. of copper. The next 5½ feet bulked yielded only 0·5 per cent. copper. The remaining 6 feet to the end of the trench is also poor, and I did not think it worth sampling. It thus appears that the principal copper-bearing formation, where exposed in this trench, is 43 feet wide. Of this, 20 feet should bulk from 2 to 3 per cent. of copper. The remaining 23 feet is not exposed at a sufficient depth to warrant any estimate being formed as to its copper contents.

"*No.* 3 *Trench*.—This is a shallow trench 45 feet to the north-west of No. 2, and, except in a sink at the west end, has not got below the leached zone. This sink was full of water, but in one place the copper-bearing stone was showing above water-level, and a sample from 18 inches of stone yielded 3·2 per cent. of copper.

"*No.* 4 *Trench*.—This trench was put in at the time of my visit, under the direction of Mr. Orange. It is about 5 chains north-west of the workings already described, and is situated on the east side of a prominent knob in the north end of the section. The trench is in a favourable-looking chlorite rock, which, however, has been for the most part leached of its copper contents. In the deepest part of the trench, at the west end, some nice-looking copper is showing, and a bulk sample of 2 feet of stone yielded 2·5 per cent. copper. The width of the formation here is not determined. The trench is 14 feet long, and all of this will, I think, be copper-bearing at a short distance from the surface. After my sample was taken, another shot exposed 2 feet more of similar stone, and this still continues in the face.

"Mr. Orange proposes to put in a prospecting tunnel below the formation at this point. From the level of the spot which has been chosen for the approach about 30 or 40 feet of backs will be obtained with 120 feet of driving. The backs will then be increased by driving southward on the formation. If the copper contents prove satisfactory at this level, then it is proposed to bring in a low-level tunnel from the other (west) side of the spur.

"*The Knob*.—There appears to be some probability of a parallel formation being discovered a couple of chains to the west of the present workings. On the top of the knob mentioned above there is a good deal of iron-stained chloritic rock, which is in all probability the capping of a copper-bearing formation. Indeed, a few shots put in under Mr. Orange's direction revealed the presence of a little native copper in the joints of the stone, the whole of the pyrites having been leached away. This formation would be tested by the deep-level tunnel from the west side of the ridge, or by continuing the proposed prospecting tunnel from the east side.

"Although there is not sufficient work done on this section to warrant any reliable estimate being made of the amount or value of the stone present, from the indications I have seen, and from the samples I have taken, which I believe fairly represent the bulk values of the stone exposed, there appears to me to be a reasonable prospect that further work at a moderate depth will succeed in disclosing large bodies of stone carrying from 2½ to 3½ per cent. of copper. I am inclined to think that as depth is gained the average stone will assay somewhat better than my samples, owing to the fact that the copper has been leached out near the surface, and it is probable that some of this leached stone was included in all my samples. Even allowing for this, however, the proposition must be regarded as a low-grade one, and can only be dealt with profitably if operations are carried out on a scale which will allow of the most economical methods of mining and handling the stone. I may here mention that the stone only carries small quantities of the precious metals. My samples were not assayed separately for gold and silver, but equal quantities of each of the eight samples were taken and assayed as one sample. This yielded: gold, trace; silver, 2 dwt. per ton.

"The facilities for mining the deposit by means of tunnelling are good. On the west side of the knob there is a deep gorge, from which 700 or 800 feet of backs are obtainable. The slope of this hill is about 1 in 2, but no backs would be gained for the last 300 feet of tunnelling, as the deposit is on the east side of the knob, which is about 300 feet in width. The formation, however, probably dips westward at about 60°, so that for the deeper levels this will not make so much difference. The product from the mine would be brought to the surface on the west slope of the main ridge, and might, as stated above, be conveyed by means of a self-acting ropeway over the saddle into the valley on the east side, where I think it probable that water-power would be available. Certainly, abundant timber both for mining and steam-production is available in either valley.

"As regards prospecting and development, I think the right thing is being done in putting in first of all a shallow level tunnel from the east side of the spur. This tunnel should be extended southwards as a drive along the lode, crosscuts being put in at short intervals. This will give a good idea of the value and width of the deposit, and enable further development work to be laid out to the greatest advantage. At the same time, surface prospecting along the course of the lode should not be neglected. There is at present no reason to believe that the deposit does not extend beyond the present workings, and it would be well to ascertain its extent in this direction as soon as possible. If this work gives satisfactory results, then development work should be laid out with a view to providing for a large output."

The tunnel recommended by Mr. Waller to be driven on the east side of the spur has since been driven in a south-westerly direction for 130 feet. The approach to the tunnel is in hard, pink felsite. The end is in green chloritic schist, showing sulphides similar to the surface exposures. This mineralised belt has been driven on for 10 feet. Sulphides are showing, but the values do not appear to be as rich as they are in the surface workings.

Operations were suspended when the developments to be expected by further work—namely, driving along the strike of the schist belt to reach a point vertically below the main surface outcrops—were well within reach.

The writer is of the opinion that this property deserves and warrants exploitation on somewhat the lines suggested by Mr. Waller.

(G)—SECTIONS ON SOUTH DARWIN.

(22)—*Section* 1203-M.

This section (area 40 acres) is now vacant, but was formerly held by the Thompson Prospecting Association. It is situated on the northern end of the South Darwin plateau, at about 2270 feet above sea-level. The country rock is hard felsite, slightly schistose in patches. An adit has been driven in a westerly direction for 220 feet. At the entrance there is some hematite and pyrite, with a little copper. In the remainder of the drive patches of native copper are sparsely scattered in the rock. About 50 feet below this is a tunnel about 50 feet in length, which also shows a little mineral at the entrance.

There do not seem to be any indications here which would encourage prospecting at present.

In the section adjoining this to the west there occur two quartz lodes, which carry a little sulphide mineral. These have been prospected at the surface by means of two small trenches and one short tunnel (10 feet). Nothing to warrant further expenditure was encountered. It does not appear to the writer that these lodes are likely to contain sufficient values to justify exploitation, in the present state of the field, although when access to the field and facilities generally are more favourable there would be some inducement to test them below the surface.

(23)—*Section* 3867-M.

This was formerly held by the Prince Darwin Copper Mining Company, but is now vacant. The area is 80 acres. It is situated on the precipitous slope which descends from the western edge of the South Darwin plateau down to the Clark valley.

This section is reached from the 10-Mile by a foot-track, which surmounts the 10-Mile Hill, subsequently rising to the plateau, which it crosses, and then descends the steep western slope. Its distance in a straight line from the railway is $1\frac{3}{4}$ mile, but the distance by track is much more than this.

The country rock on this section is hard, dense, felsite, with some development of the igneous breccia. The ore deposit is seen at the surface, and consists of a large belt of magnetite and hematite carrying some pyrite and chalcopyrite, traversing the section from north to south.

The upper or northern tunnel is 50 feet in length in a north-easterly direction. It was not extended far enough to intersect the ore body.

The main adit is situated to the south of the former tunnel, and is about 10 feet lower. It has been driven in an easterly direction from a point in an almost vertical cliff face for a total distance of 140 feet. This adit is 1820 feet above sea-level, and therefore 260 feet below the plateau and 980 above the 10-Mile. The whole length of this adit is in the ore body which contains an appreciable proportion of sulphides. The end is still in ore. No assays are available which represent the average along this adit, but samples are stated to have assayed as high as 7 per cent. copper and 3 oz. silver and 1 dwt. gold per ton. The average certainly could not nearly approach this, and would, in the writer's opinion, be not higher than in the neighbourhood of 1 per cent. It should, however, be carefully sampled.

The general character of this type of ore deposit has been fully described in a previous portion of this bulletin. It is a typical contact-metamorphic deposit, being a metasomatic replacement of the felsite by the respective metallic ores, and in this case is 15 chains from the granite contact as seen on the surface. The width of the ore body is up to 200 feet on the surface, and in the main adit is seen to be greater than 140 feet. Its length is undetermined. In general such ore deposits as this are irregular and inconstant in shape, and their thorough exploitation is therefore somewhat difficult.

There is a deposit of hematite about 3 chains east of the west side-line of this section which, up to the present, has had no work done on it.

The facilities for mining on this section are certainly very good, as the surface is almost vertical for several hundred feet. Its position, however, on the western side of the mountain is a drawback.

This ore deposit is an important one, but will, in the writer's opinion, prove to be of comparatively low grade. It should be exploited at lower levels, and its longitudinal dimensions should be investigated. This property will in all probability not pay to exploit until the opening up of some of the richer deposits have improved the means of access to the field, and have provided greater general facilities for the field as a whole.

(24)—*Section* 5561-M.

This is charted in the name of H. Hessenauer. The area is 40 acres. No work was being done at the time of the writer's visit. It is situate on the southern portion of the Darwin plateau, near its eastern boundary.

On this section the ridge of included felsite which runs persistently from north to south along this plateau has been partially trenched across, disclosing a soft schistose rock carrying pyrites. Very little copper is visible.

There is just sufficient indication here to warrant some further attention at this point, but the prospects are certainly not as good as in many other properties previously described.

East of this ridge, and just within the granite boundary, is a body of micaceous hematite carrying some pyrite. This is a metasomatic replacement of granite. No work has been done on it. It is essentially an iron-ore deposit.

(25)—*Section* 5560-M.

This section (area 80 acres) is charted in the name of Herman Hessenauer. It is situated on the western slope from the Darwin plateau, and at the southern end thereof. It includes what was formerly known as the Tasman Darwin. No work is at present being done.

This section is reached from the 10-Mile by the same track as that which leads to Section 3867-M, a branch leaving the latter track on the plateau and, running in a south-westerly direction, reaches the edge of the plateau and then descends by a path which is followed by instinct, passing, as it does, over hackly bare felsite to the sections below. Access to this property is certainly the most difficult of any in the field, excepting the Lake Jukes Proprietary.

A tunnel has been driven in a south-easterly direction for 50 feet. Apparently the object was to cut a hematite ore body seen on the surface above, which is from 3 to 4 chains wide. The distance driven, however, was not great enough.

On this section, and also on neighbouring sections, occur a large number of magnetite or hematite ore bodies, some of which carry sulphides. These having been described as to their general character previously, they need not here be specially mentioned. Their positions are shown on the geological map accompanying this bulletin. One in particular, however, has had a few shots put into it.

This is an ore body of magnetite with some pyrite and chalcopyrite, which can be traced for a length of 5 chains with an average width of 30 feet. Samples have assayed from 0·5 to 1·0 per cent copper. The remarks made on the ore body on section 3867-M apply here also. A notable body of hematite occurs just east of the west side-line of this section. This is 5 chains in length, and averages 10 feet in width.

Facilities for driving adits or for testing by means of the diamond-drill are very favourable here, and when access to this locality is made easier there will be no difficulties on that score.

(26)—*Section* 5562-M.

This is charted in the name of H. Hessenauer, and has an area of 40 acres. It is situate on the southern end of the Darwin plateau, and is wholly in granite country. It is reached by making a detour from the track to the previous section.

In a creek there has been exposed an irregular quartz vein in granite carrying a considerable quantity of coarsely crystalline pyrite, which has assayed 7 oz. of silver per ton, with no gold or copper. The lode can be traced for no distance, and facilities for adit driving are absent. It should be tested, however, to some extent in summer time by sinking a few feet on it to see how it behaves in that distance.

VII.—CONCLUSION.

(1)—EXPLANATORY REMARKS.

It may be thought that these bulletins contain a disproportionate amount of theoretical matter which is apt to be disappointing to the miner who, above all, looks for definite practical information and a precise pronouncement of opinion concerning the value and permanency of the ore-bodies of the field described.

This latter demand is quite a legitimate and justifiable one, and it certainly is the highest aim of the economic geologist to thus supply the practical miner with exact information as to the extent, structural relations, and genesis of the ore body which he intends to exploit. It must be remembered, however, that every region possesses its own peculiar aspect, which is generally very different from others in other parts of the world. Thus, as stated by De Launay (107): "If a miner were transported from the basin of the Mediterranean to Norway he would fail to recognise the types to which he had been accustomed, and if he endeavoured to apply brusquely the empirical results of his previous experience to these new types, he would have every chance of going wrong."

The necessity will be realised, therefore, of making a thorough investigation of the ore deposits of a new region. Further, it cannot be expected that a complete understanding shall have been obtained of such ore deposits after a few visits to widely-scattered units of that region. It is only by gradually building up piece by piece and unit by unit the information thus gained at different times and by different observers that a final and complete elucidation can be hoped for. If such information is not put on record it will not be available for future investigators. In addition, if definite statements are made and opinions expressed without giving the grounds on which such opinions are based, then they degenerate into dogmatic assertions which are as valueless to the miner as they are objectionable to the conscientious investigator.

Though, therefore, it may appear to the practical mining man that some of the subject-matter of these bulletins is irrelevant to the investigation of ore deposits, he must

(107) "The Formation of Metalliferous Deposits,' by M. De Launay. The Mining Journal, June 28, 1913.

accept the assurance that such recorded details are published to supply for future investigations that complete information which will be necessary for a final elucidation of their genesis, character, and extent. The greatest value of some of these bulletins lies, therefore, in the future, rather than in the immediate present.

In every bulletin, however, an endeavour is made to use such deductions, as on the evidence available seem justifiable, in directing the operations of the miner. The writer proposes, therefore, to include in this final chapter a concise epitome of the net results of the investigation of the field, and to point out as shortly as possible the policy which, in his opinion, is most likely to enable progress to be made in the exploitation of the ore deposits and the development of the field. In no way, however, must this be regarded as displacing the main portion of the bulletin, a complete study of which is essential to a full understanding and appreciation of the potentialities of the field.

(2)—Summary of Results of the Present Investigation.

The present investigation has resulted in the establishment of the following:—

(1) The important part played by glacial action in the development of the present topography of the region.

(2) The establishment of the younger age of the West Coast Range conglomerate, as compared with the porphyroid series.

(3) The establishment of a genetic connection between the Darwin granite and certain of the ore deposits of this region. These are the magnetite-pyrite-chalcopyrite deposits, the micaceous hematite deposits, and the red hematite deposits.

(4) The secondary origin of the bornite veins at Lake Jukes, and the deduction that they are of no economic importance.

(5) The present values near the surface of the main ore deposits of the field are not superficial enrichments.

(6) The secondary origin, by deposition from solution, of the alluvial gold on Mt. Darwin.

It has not been conclusively shown, however, whether the main copper deposits of the field are genetically connected with the Darwin granite or the Devonian granite, that is whether they are of Pre-Silurian or Devonian age. The conclusion has, however, been deduced that there is every inducement for the exploitation of the deposits to an appreciable depth.

It has been shown that out of a total of approximately 200 sections which have been surveyed on this field and at one time held, there are only 10 which the writer can recommend as warranting the adoption of a progressive policy of development work. The most important of these contain the East Darwin ore body, which is shown on sections 4615-M, and 4655-M.

(3)—The Mineral Resources of the Region.

It has been seen that the present values of the ore deposits of this field will continue to depths which would enable mining to be carried on on a considerable scale. It is rather difficult to gain any conception of the exact value of those deposits which have been more or less opened up, owing to the absence of assays of samples taken systematically. What assays are available, however, give a metallic content which may be regarded as very encouraging. The returns from the parcels of ore sent away from the field, totalling in all about 30 tons, show the following average values:—

Copper = 5·38 per cent; silver = 6·99 dwt.; gold = 4·03 dwts. per ton.

In the writer's opinion the most important occurrence on the field is the ore body on Sections 4615-M, 4654-M, and 4655-M (J. Wood, lessee), which seems to be of considerable extent, but which has not yet been fairly exploited. The ore bodies on the following sections possess features which may be described as indicating the existence of considerable amounts of copper, silver, and gold, but which have not as yet been exploited to the extent which they seem to warrant:—6012-M (H. H. Souter, lessee), 5925-M (R. S. Taylor, lessee), 3107-M (now vacant, but formerly known as Findon's), 1594-M (also vacant), 3867-M (also vacant, formerly Prince Darwin), and 5560-M (H. Hessenauer, lessee).

In all of these sections the ore bodies contain the valuable metals, copper, silver, and gold. The relative proportions of these three metals vary, but the general notable feature is the relatively high content of gold. This is not regularly characteristic of all the deposits, but seems to be more pronounced in Sections 6012-M and 4655-M. In general, therefore, the value of these ore-deposits may be expected to lie in all three of the metals copper, silver, and gold. There are no metals present which will have any deleterious effect on these three metallic products.

The field possesses one notable barium sulphate deposit, which is capable of supplying large quantities of that mineral. This is on Section 3868-M (W. H. Taylour, lessee).

There are undoubtedly on this field large deposits of iron ore, but these are, in the writer's opinion, not destined to play any important part in the iron industry, since they are to a considerable extent contaminated by sulphur and some copper, and are, in addition, so far removed from a seaport as compared with other larger and purer deposits that they will be ignored for generations at least. They may, however, have some application as a basic flux in metallurgical operations.

The output of alluvial gold is difficult to estimate, but is stated to have been at least 500 oz. up to the present date. It is certain, however, that the greater part of this alluvial gold has already been won, and that the portion yet awaiting exploitation is relatively small.

There also exist on this field immense quantities of pure limestone.

In the writer's opinion, all occurrences of ore, other than those on the sections specifically indicated above, are not destined to play any part in the development of the field for some considerable period, and therefore they may for the present be neglected, thus allowing attention to be concentrated on those deposits which are mentioned above as possessing decided promise.

(4)—Metallurgical Treatment of the Ores.

Any discussion of the metallurgical treatment of ores does not rightly come within the province of the Geological Survey. Yet, in dealing with this field, which has suffered to a marked degree from metallurgical disasters in connection with the North Lyell smelters, it seems advisable to mention in a very brief manner the direction in which a solution of the metallurgical and freight problems should be looked for.

The ores of the field, with the exception, perhaps, of the siliceous ore body of East Darwin and the magnetite bodies of South Darwin, are characterised by the relatively large amount of igneous rock in their constitution. Thus is explained the high alumina content of the ores, which at the Jukes Proprietary averages about 18 per cent. Al_2O_3. This alumina, as is well known, offers considerable difficulty, and entails extra expense in smelting. In addition, as will be pointed out subsequently, the freight charges to the Mt. Lyell smelters are rather heavy.

Consequently, the necessity will be realised of eliminating this excessive alumina content, and at the same time reducing the tonnage of valueless, and even deleterious, gangue material.

It may be stated, at once, however, that ordinary water concentration will be sure to end in failure.

The process which suggests itself as a very probable solution of the problem is that of flotation, which is at present being successfully employed in different parts of the world on low-grade copper deposits. At the present time the Mt. Lyell Company are conducting extensive experimental research into this question of flotation in connection with the treatment of their low-grade siliceous, and especially aluminous, ores.

The results of such investigations into the applicability of this process to the treatment of such ores as occur on this field will be of vast importance to the Jukes-Darwin field. If the process proves successful on these ores, and there is every reason to expect that this will be so, then it seems to the writer that the ores as mined should be thus concentrated into a high-grade copper ore, the freight on which to the Mt. Lyell smelters, which are destined to be the centre of smelting in this region, will be much lower per ton of copper than if sent away unconcentrated.

In view of the relatively high freight charges, it is in such a procedure as this that the salvation of the field lies.

(5)—Causes of the Present Inactivity.

The Jukes-Darwin field is at present in a comatose condition, and has been so for some considerable time. At present there are only 10 sections being held, and of these work is only being carried out on one (Jukes Proprietary), which is employing two men only. There certainly must be some definite cause or causes which have led up to this deplorable position. The writer regards the following factors as having been instrumental in bringing about this period of stagnation and inactivity:—

(1) The difficulties of access to the mining sections, and the excessive cost of transporting tools, material, supplies, &c., to the mine workings, together with the prohibitive freight charges on the crude ores obtained on the field.

(2) The closing down of the North Lyell smelters at Crotty and the consequent removal of a convenient market for copper ores. This gave the field a distinct set-back, which was accentuated by the resultant withdrawal of the incentive to North Lyell investors to persevere in the attempt to locate sources of ore adjacent to their smelting works.

(3) The mistaken assumption which has been fully explained in this bulletin, that all hematite deposits were the cappings of sulphide ore bodies led to the expenditure of testing such outcrops at a deeper level. This capital was wasted, and the moral effect of these failures has been the neglect of the field by capitalists.

(4) The formation of small local syndicates with a small capital generally followed the hysterical announcement of the discovery of the outcrop of a professedly rich ore body. The expectations of such a syndicate fell short of nothing less than a phenomenally rich deposit. The failure to locate such a deposit before the limited funds ran out, disgusted the shareholders, who then refused to persevere. The failure of these small syndicates, together with the non-success of the larger companies in locating ore bodies of exceptional value, has also had a bad moral effect on the mining community.

All these factors combined have been instrumental in bringing about the disinclination of capitalists to investigate the field—an investigation which has been now shown to be warranted by geological considerations.

(6)—Policy for the Future.

Knowing, then, that the geological conditions of the ore deposits on the sections mentioned in this chapter are favourable, there exists every inducement for the expenditure of capital in exploiting such deposits. This work of development should be undertaken in a bold and courageous manner, but, withal, must be characterised by a due regard to economic and scientific principles. It is only by attacking this problem in such a comprehensive manner that success may be expected; half measures are futile.

The topographical features and the structural relations of the ore bodies coincide in presenting conditions which are eminently suitable for the employment of the diamond-drill in exploitation. The writer wishes to lay emphasis on the desirability of adopting this means of exploitation.

When the producing stage is reached and the metallurgical investigations have resulted in the decision to adopt such a process as that of flotation, then the ore must be conveyed by means of aerial ropeways to the plain at the eastern foot of the mountain range, where the treatment plants should be located.

The concentrates from the concentration processes should be sent to the Mt. Lyell smelters, as from all points of view this is preferable to an attempt at the erection of a local smelting works.

By sending the concentrates *via* Linda the excessive cost of carting to the foot of the Mt. Lyell haulage is necessitated. The practice of the Mt. Lyell Company has been, in moving material from the Crotty smelters to Queenstown, to rail to Kelly Basin, thence by boat to Regatta Point, and thence to Queenstown, and thus right to the smelters. The freights from Darwin or Crotty to Kelly Basin are respectively 9s. 6d. and 10s. 10d. per ton. These rates are, of course, subject to negotiation on the basis of large and regular consignments.

If such a scheme is inaugurated, it will most probably result that improvements and economies in the mode of working, as the outcome of experience, will enable deposits to be worked at a profit which were, at the inception of operations, regarded as unpayable.

LOFTUS HILLS, M.Sc.,
Assistant Government Geologist.

Launceston, 24th October, 1913.

Tasmania

DEPARTMENT OF MINES

Maps and Sections

TO ACCOMPANY

GEOLOGICAL SURVEY BULLETIN

No. 16

Issued under the authority of

The Honourable EDWARD MULCAHY, Minister for Mines

Hobart

JOHN VAIL, GOVERNMENT PRINTER

1914

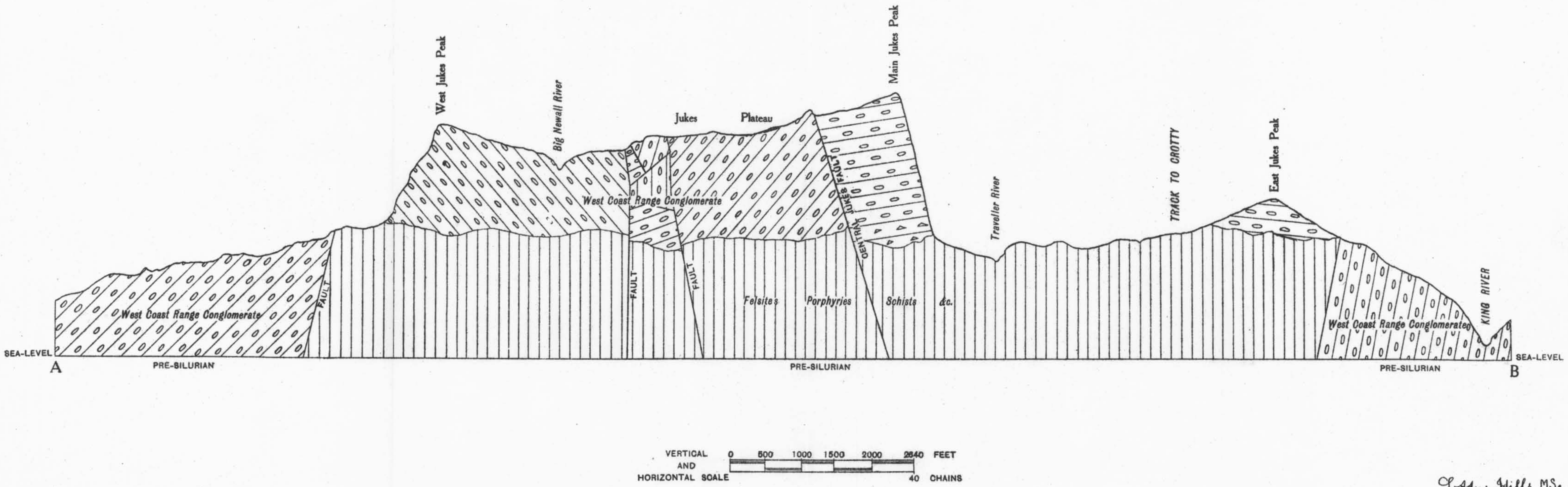
KEY TO NUMBERS OF MINERAL SECTIONS.

Number of Section.	Acres.	Lessee.
6012-M	80	H. H. Souter
5936-M	40	E. Slater
5925-M	40	R. S. Taylor
3868-M	80	W. H. Taylour
4615-M		
4654-M	40	J. Wood
4655-M		
5560-M	80	
5561-M		Herman Hessenauer
5562-M	40	

Photo Algraphed by John Vail Government Printer Hobart Tasmania.

PLATE VI.

SKETCH GEOLOGICAL SECTION ON THE LINE A B



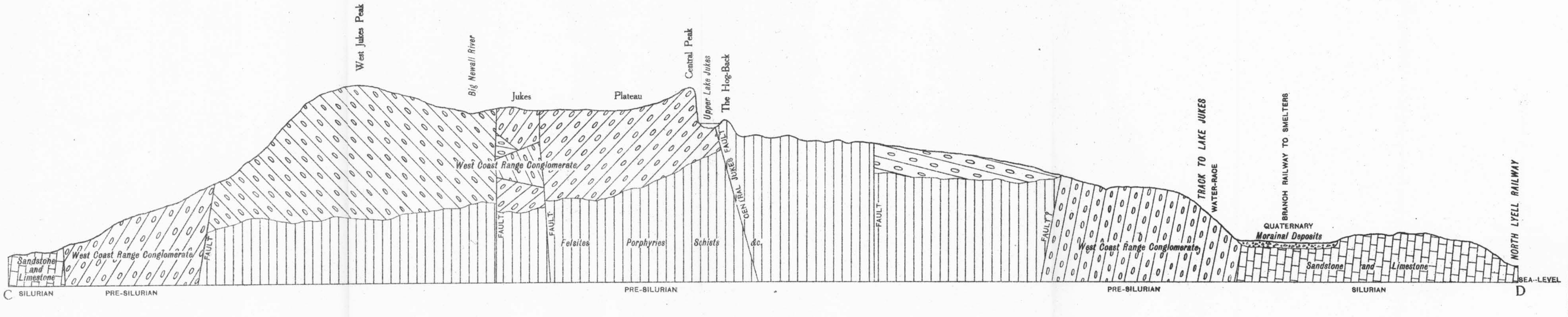
5 cm

Loftus Hills MSc.
Assistant Government Geologist
24·10·1913

Photo Algraphed by John Vail Government Printer Hobart Tasmania

PLATE VII.

SKETCH GEOLOGICAL SECTION ON THE LINE C D



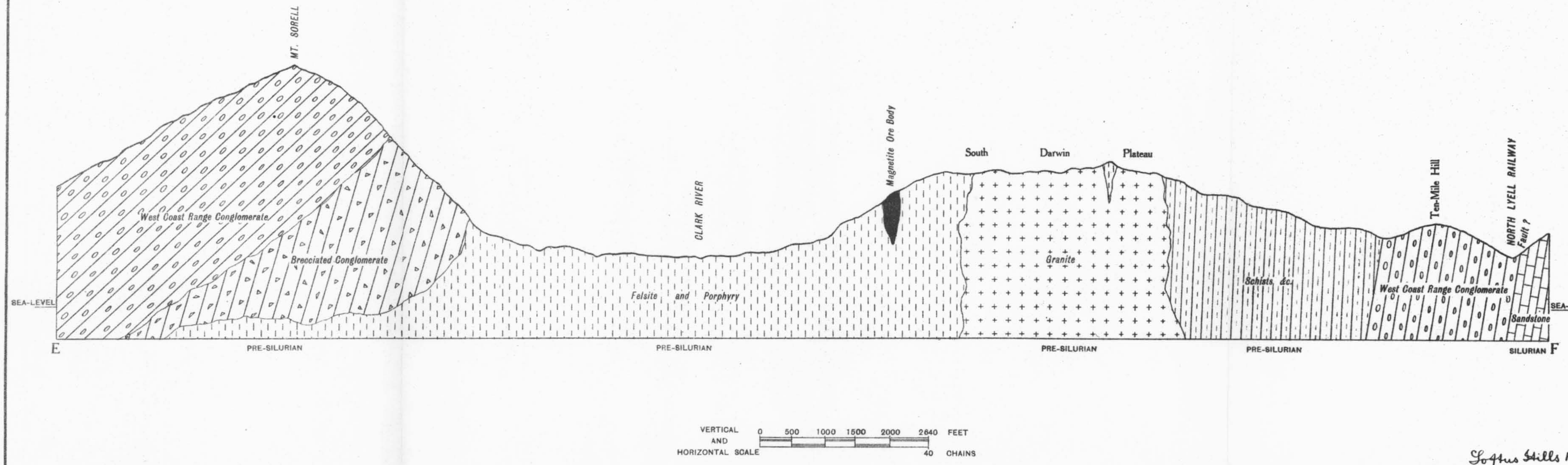
VERTICAL AND HORIZONTAL SCALE 0 500 1000 1500 2000 2640 FEET; 40 CHAINS

Loftus Hills M.Sc.
Assistant Government Geologist
24-10-1913

Photo Lithographed by John Vail Government Printer Hobart Tasmania

Plate VIII.

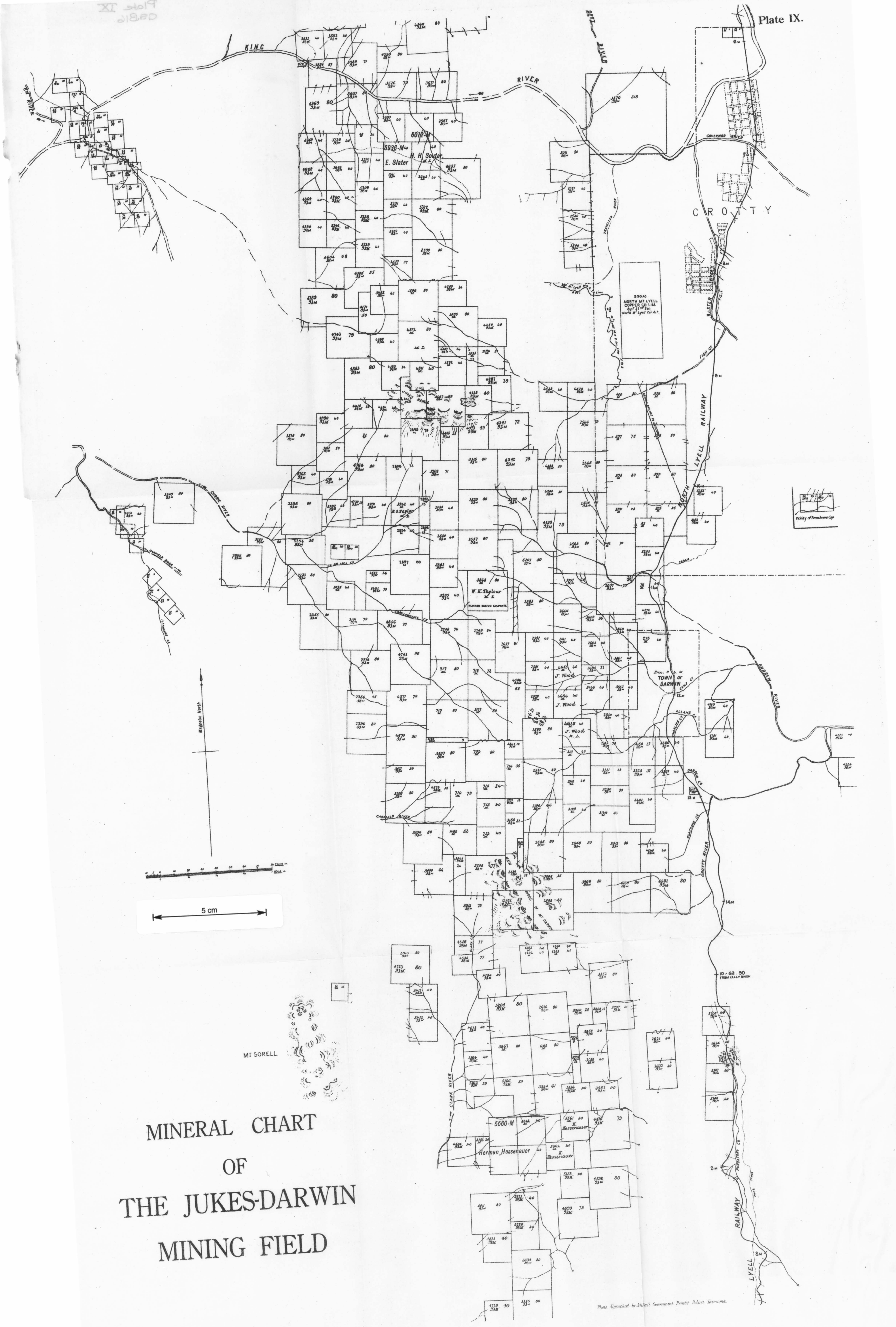
SKETCH GEOLOGICAL SECTION ON THE LINE E F



Loftus Hills M.Sc.
Assistant Government Geologist
24-10-1913

Photo Algraphed by John Vail Government Printer Hobart Tasmania.

Plate IX.



MINERAL CHART OF THE JUKES-DARWIN MINING FIELD