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Tasmania

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The Geology and Mineral Deposits of Tasmania

BY

P. B. NYE, M.Sc., B.M.E., Government Geologist

and

F. BLAKE, Field Geologist

With an Appendix by J. B. SCOTT, Secretary for Mines

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The Geology and Mineral Deposits of Tasmania

I.—GENERAL STATEMENT.

THE island of Tasmania represents an extension of the south-eastern portion of the Australian Continent, its separation having been caused in recent geological times by the flooding of a low-lying portion now represented by Bass Strait. It is separated from Australia by 140 miles of the shallow sea of Bass Strait. Its greatest length north and south is 180 miles, its greatest breadth east and west is 190 miles, and its area, including adjacent islands, is 26,215 square miles.

The general similarity of rock types, the occurrence of rocks belonging to the same systems, and the continuity of structures in Tasmania and South-Eastern Australia support the idea of general geological unity of these lands. There are, of course, rock systems and rock types present in Tasmania that are not present in the latter, but these do not necessarily disprove the unity of the two lands.

The surface of the State is extremely rugged, and is for the most part covered with a thick growth of trees, shrubs, &c. These features render the work of geological surveys very slow and arduous, while the undergrowth, &c., effectively conceals outcrops, and generally renders survey work difficult.

In spite of these obstacles, great progress has been made during the past decades, and the rock systems present can be described with a fair degree of accuracy and certainty. At the present time less knowledge exists with regard to Proterozoic and Lower

Palæozoic systems than the later ones, and much detailed work will be necessary before the stratigraphy of these systems and their attendant igneous intrusions is elucidated. Nearly all of the rock systems of the world are represented in the State.

Tasmania contains deposits of many valuable minerals and metals. The primary deposits of metallic minerals include those of copper, tin, lead, zinc, gold, silver, osmiridium, tungsten, nickel, &c., while the secondary ones include those of gold, tin, and osmiridium. The non-metallic mineral deposits include coal, oil shale, limestones, building-stones, asbestos, barite, talc, &c.

The metallic and certain non-metallic mineral deposits are restricted to north-eastern, north-western, and western regions. All these are genetically associated with the intrusions of igneous material in the Devonian period. The osmiridium and copper-nickel are associated with the serpentine and gabbro rocks, while the remainder accompanied the granite and porphyry intrusions. As regards the rocks intruded, gold is associated with the Mathinna slates and sandstones, while the remainder are associated with the Cambro-Ordovician and Silurian systems in western and north-western regions. Tin and tungsten deposits are most commonly associated with the granites. Only a few minor deposits occur in the Proterozoic schists, while (except at Cygnet) no primary deposits occur in rocks younger than the Devonian. Thus the favourable districts in the State for the discovery of primary deposits are those occupied by Lower Palæozoic rocks with Devonian igneous intrusions. Such districts include the western, north-western, and north-eastern regions. The secondary deposits are associated with the corresponding primary ones.

Coal is prominent in the Triassic and (to a less extent) in the Permo-Carboniferous rock systems. Oil shales are restricted to the latter system. Limestone occurs in Cambro-Ordovician, Silurian, Permo-Carboniferous, and Tertiary. Barite, talc, asbestos, &c., occur under similar conditions to the primary metallic minerals.

II.—PHYSIOGRAPHY.

(1) Chief Physiographic Units.

The chief physiographic units of Tasmania are—

(*a*) The Central Plateau.
(*b*) The Southern Highlands.
(*c*) The Ben Lomond Highlands.
(*d*) The North-Western Peneplain.
(*e*) The Eastern Peneplain.
(*f*) The Western Coastal Plain.
(*g*) The Launceston Tertiary Basin.
(*h*) The Northern Coastal Tract.

(*a*) *The Central Plateau* occupies the central portion of the State. The surface is not uniformly level, but ranges in height from 2500 to 5000 feet above the sea. The general slope is to the south, especially of the eastern half, which corresponds to the drainage, being effected by south-flowing streams. The western boundary is represented by the West Coast Range, which presents a steep face to the west. The northern and eastern boundaries are represented by the Western Tiers, which present very steep slopes to the north and east. The steep face disappears to the south and west of Lake Sorell, but its continuation to the south is suggested by Woods' Quoin, Mt. Dromedary, Mt. Wellington, &c. The lower altitude of the southern part of the plateau is due largely to the erosion by the Derwent and its numerous tributaries.

(*b*) *The Southern Highlands* represent the southern continuation of the Central Plateau. Only a small portion now remains above 3000 feet above sea-level, but this appears to have been due largely to the erosion of the Derwent, Huon, and Gordon River systems.

The eastern boundary is represented by the highly dissected continuation of the Western Tiers south from Lakes Sorell and Crescent, as indicated above in the discussion of the Central Plateau. The western boundary is represented by the high ranges which trend parallel to the south-west coast. The north-western portion is continuous with that of the western portion of the Central Plateau. To the south the highlands extend as far as the south coast.

(*c*) *The Ben Lomond Highlands* represent the elevated regions in North-Eastern Tasmania, with elevations between 2500 and 5000 feet. They are separated from the Central Plateau by the Launceston Tertiary Basin. To the north, east, and south they are surrounded by the Eastern Peneplain.

(*d*) *The North-Western Peneplain* was first recognised by J. W. Gregory.(1) It extends generally between the Pieman and Arthur Rivers, with an eastward extension towards Moina. It is particularly noticeable around Waratah and Middlesex, where its surface is covered by basalt flows. Towards the west its surface is largely dissected, and the Norfolk Range repreents its westerly extent. Mounts Heemskirk, Zeehan, &c., probably represent dissected remnants of its southern extension. Its western boundary is formed by the Western Coastal Plain. Its eastern boundary is formed by the West Coast Range and the western and north-western edges of the Central Plateau. To the east it cannot be traced further than the Moina district. The northern boundary is indefinite, due largely to the erosion of the north-flowing streams entering Bass Strait, and probably to other causes, such as downwarping, &c.

(*e*) *The Eastern Peneplain.*—The region east of the Western Tiers-Mt. Wellington line, with the exception of the Ben Lomond highlands and the Launceston Basin, represents a dissected peneplain, with an elevation of 2000 to 2500 feet above the sea. The northern portion includes the Pre-Permo-Carboniferous peneplain, which has been almost completely re-exposed by denudation. A number of monadnocks rise above the general level of this portion of the peneplain, which surrounds the Ben Lomond highlands on the northern, eastern, and southern sides.

(*f*) *The Western Coastal Plain* consists of a narrow tract, ranging in width up to 12 miles, which fringes the west coast from Arthur River on the north to Davey Head in the south. It may extend further north than the Arthur River, and also east

(1) Gregory, J. W.: Some Features in the Geography of North-Western Tasmania. Proc. Roy. Soc. Vic., Vol. XVI., Pt. 1, 1903.

along the north coast, but has not been definitely recognised. It is generally found to extend to the present west coast, and to be terminated by cliffs averaging 100 to 200 feet in height. Inland its surface (now partly dissected) rises gradually to heights of 700 to 900 feet above the sea. Numerous portions of this plain have been recognised and named by investigators, such as Western Peneplain and Henty Peneplain (Gregory, 1903),[2] Pieman Peneplain (Ward, 1909), Little Henty Peneplain (Twelvetrees and Ward, 1908), and Coastal Peneplain (Ward, 1910), and Darwin (Hills, 1913).[3] It has also been described at other places in unpublished geological reports of the Mines Department. In some portions, and particularly in the Low Rocky Point district, shallow layers of gravel occur on its surface. In the North Dundas, Strahan, and Low Rocky Point districts, glacial or fluvio-glacial deposits occupy portion of its surface, such deposits being most extensive in the Strahan district.

Though referred to as a coastal plain, there is no evidence of marine deposits upon it, unless the Miocene limestones, &c., at Temma occupy such a position. Its age, however, is probably later than Miocene, and the limestones at Temma may be incorporated as part of the surface of the plain.

It must be noted that Ward (1909) connected the Pieman Peneplain with the North-Western Peneplain, and that Waterhouse (1913) also connected the Western Coastal Plain with the North-Western Peneplain. Hills (1913) correlated all the peneplains, and in 1921[4] referred to them as the Darwin Peneplain.

However, the Coastal Plain is so definitely a coastal feature, with a seaward slope, and as its surface inland does not exceed 1000 feet above the sea, it appears to be distinct from the North-Western Peneplain (2000 feet), and should be separated therefrom. The possibility of it forming a warped or tilted portion of the North-Western Plain cannot, however, be entirely overlooked.

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(2) *Ibid.*, p. 179.

(3) Tas. Geol. Surv. Bull. Nos. 6, 8, 10, and 16.

(4) Hills, Loftus: Progress of Geological Research in Tasmania since 1902. Proc. Roy. Soc. Tas., 1921.

(*g*) *The Launceston Tertiary Basin* is a tract of country not exceeding 1000 feet above sea-level, and representing the greater part of the drainage system of the Tamar and South Esk Rivers. It lies between the Central Plateau on the west and the Ben Lomond highlands and Eastern Peneplain on the east, and has a general trend from south-east to north-west.

(*h*) *The Northern Coastal Tract.*—This tract is not definitely a physiographic unit as are the above, and it may be composite in origin. Hills[5] considered the Western Coastal Plain to extend easterly to Wynyard. Later he[6] correlated the Coastal Plain and the North-Western (or Darwin) Peneplain as one, and considered it to extend to the Mersey River. The North-Western Peneplain certainly extends as far as the Forth River, but the evidence of the Coastal Plain is not so definite. There may be a tilted block between the peneplain and the coast, but its recognition has been obscured by basalt flows and subsequent erosion.

The Launceston basin crosses the coastal tract further east. East of the Launceston basin there is more definite evidence of a coastal plain extending to the north-eastern corner of the island. In the Lilydale district there is definite evidence of tilting towards Bass Strait from the level of the Eastern Peneplain down to 500 feet above sea-level.

(2) Coastal Physiography.

(*a*) *Features Due to Submergence.*—

Drowned Valleys are a common feature around the coasts of Tasmania, and many fine examples are present at the mouths of the principal rivers. The most prominent are those of the Tamar River, Derwent River, Huon River, Port Davey, and Macquarie Harbour; but many other rivers also exhibit the same feature. On the north coast Duck Bay represents the drowned portion of Duck River, and Port Sorell that of the Rubicon River, while the lower por-

(5) Tas. Geol. Surv. Bull. No. 13, 1913.

(6) Hills, Loftus: Progress of Geological Research in Tasmania since 1902. Proc. Roy. Soc. Tas., 1921.

tions of the Flowerdale, Leven, Forth, Mersey, and Ringarooma Rivers have also been drowned. On the east coast Anson Bay represents the drowned portion of the Anson River, St. George's Bay that of the George River, parts of the Moulting Lagoon and Oyster Bay that of the Swan River, while the mouths of the Swanport and Prosser Rivers have also been drowned. On the south coast the mouths of the Dover, Lune, Catamaran, and New Rivers have been flooded. On the west coast the mouths of the Pieman, Lewis, and probably other streams have been flooded.

The effect of submergence is especially prominent in the south-eastern districts. The drowned valleys of the Derwent and Huon have already been referred to above. D'Entrecasteaux Channel represents the flooded portions of either the lower part of the Derwent River or (what is more likely) of tributaries of the Derwent and Huon Rivers. Frederick Henry and Norfolk Bays (or portions thereof) represent the flooding of the lower parts of Coal and other rivers. Many of the tied islands now joined to the mainland or to one another, such as those of South Arm, Tasman's Peninsula, Bruny Island, &c., were also formed by submergence.

Coastal Islands are fairly common. Bruny Island is one of the best examples of a coastal island, and was isolated by the formation of D'Entrecasteaux Channel, as described above. The Furneaux group of islands (including Flinders, Cape Barren, &c.) have also been formed by submergence (that involved in the formation of Bass Strait).

The Hunter Group (including Hunter, Robbins, &c.), on the north-west coast, are also coastal islands. Maria and Schouten Islands, on the east coast, are possibly also coastal islands formed by submergence. The numerous rocks and islands in Macquarie Harbour, Port Davey, and around the coasts of Storm Bay, and in Frederick Henry and Norfolk Bays, are obviously coastal islands.

(*b*) *Features Due to Emergence.* — Several features due to emergence are recognisable around the coasts. While these are generally of Recent emergence, some are geologically older, possibly extending back to the Pleistocene epoch or slightly older.

Coastal Plains.—The Coastal Plain of the west coast has been described above. While it is not claimed that all of this plain is of marine origin, it is possible that some portions may be. If this is so the emergence occurred before the Pleistocene glacial epoch.

Old Raised Beaches, &c.—On Flinders Island, and probably other islands of the same group, marine Werrikooian beds have been elevated above sea-level. At Mowbray Swamp marine (and freshwater) Pleistocene beds have been similarly elevated. The sands, gravels, and clay of the Gladstone district, the clays and gravels of St. Helens, and the sands of Five and Seven Mile Beaches (Frederick Henry Bay) are generally of similar age. The two latter represent extensive raised beaches, but the others are still more extensive, and are included here for descriptive purposes and because of their part in determining the present coast-line.

Raised Beaches.—Raised beaches of Recent age are fairly common features around the coasts, but very few have been described. Generally they occur at the mouths of streams, and more or less merge into alluvial deposits further inland. The amount of elevation represented by these beaches is 10 to 15 feet. Such beaches are known to occur at Sandy Bay, Kingston, Snug, Cox Bight, Narracoopa, and numerous localities along the northern coast.

An interesting raised beach, some 30 to 40 feet above present sea-level, occurs in the township of Stanley. The beach deposit consists of boulders of basalt up to 1 foot in diameter, with internal casts of a large limpet (probably *Cellana limbata*) adhering to the boulders.

Rock-benches appear to be absent from the Tasmanian coasts.

Tied Islands are common in the south-eastern, and also to a less extent in the north-western, districts. Bruny Island consists of two tied islands, as also does Maria Island. Tasman Peninsula is a tied island, joined to Forestier Peninsula by Eaglehawk Neck. Forestier Peninsula is itself joined to the mainland by East Bay Neck. The South Arm peninsula is joined to the mainland by Ralph Bay Neck, while another neck connects South Arm with the remainder of the peninsula, which is therefore formed by two tied islands. Parts of Freycinet Peninsula are probably tied islands. On the north-west coast the Nut is probably a tied island, forming part of the Stanley Peninsula.

(*c*) *Coastal Faulting*.—The problem of coastal faulting has not been investigated to any extent. In general, it would appear that the Tasmanian coasts have been largely determined by faulting and possibly warping. The east coast between Eddystone on the north and Freycinet Peninsula on the south, with its remarkably straight line, short coastal streams, and the central drainage rising within a few miles of the coast, is strongly suggestive of faulting. If this line were continued to the south, it would pass to the east of Schouten and Maria Islands. A long and narrow trough fault runs parallel to the southern portion of this coastal fault, and a few miles inland therefrom, from a point near Seymour on the north to Oyster Bay on the south. This trough was the determining factor in the formation of the valleys of the Swan (or portion thereof) and Apsley Rivers, and of Oyster Bay. This trough probably continues to the south between Maria Island and the mainland. Between Schouten and Maria Islands, the narrow ridge between the trough and the coastal fault has been destroyed by erosion or cross-faulting, or both.

The south coast between South-East and South-West Capes has probably been largely caused by faulting. The fairly straight line of the west coast is suggestive, but no definite conclusion can be reached.

The problem of the north coast is involved in that of the formation of Bass Strait, which is discussed elsewhere. It is possible that either faulting and/or warping played a prominent part in its formation.

(*d*) *Erosion.*—The greater part of the coast is high and rocky, and erosion is particularly active in such parts. The main effect is the wearing away of the land and the production of steep cliffs. The period during which the present relations of land and sea have prevailed has been too short to permit of the formation of extensive rock-benches at sea-level. It is possible that narrow benches have been formed at a number of places around the south-east coast, such as the Tessellated Pavement at Eaglehawk Neck.

The "blow-holes" in south-eastern districts, e.g., Tasman Arch, Remarkable Cave and Blow-hole, Tasman Peninsula, and Blackman's Bay are of particular interest, and have been formed by erosion in combination with the bedding and joint planes of the Permo-Carboniferous rocks.

The low-lying parts of the coast are found chiefly in bays. The bays have, of course, been formed by coastal erosion, combined with that of the streams entering them.

(*e*) *Deposition.*—Sand dunes occur on all the coasts, but are most common on the south-east, east, north-east, and north-west parts. They are not high, and seldom exceed 50 feet. In only a few places on the north-west coast are the dunes found to extend beyond a few yards from the coast.

Deltas do not occur, due mainly to the short time during which the present relations of land and sea have existed. Deposition is most marked in the shallow bays and inlets, where mud flats appear at low tide.

(3) River Systems.

(*a*) *General Description.*—The main river systems are those of the Derwent, Tamar (South and North Esk), Gordon, Huon, Pieman, and Arthur Rivers.

The Derwent River drains the greater portion of the Central Plateau, the north-eastern portion of the Southern Highlands, and the southern portion of the Eastern Peneplain, and enters Storm Bay through its flooded lower valley. The majority of its tributaries are south-flowing streams, and enter it from the north, the main stream having a general course from north-west to south-east. The main stream and most of these tributaries rise in lakes on the Central Plateau.

The Tamar River system includes a number of streams, of which the South Esk is the most important, the Tamar River being a flooded valley. Its watershed includes the Launceston Tertiary Basin, the greater part of the Ben Lomond Highlands, and the central part of the Eastern Peneplain. The South Esk River rises on the eastern side of Ben Lomond Highlands, and flows round the southern and western sides of them. A number of tributaries rise along the Western Tiers, and flow north and north-east to join the main stream.

The Gordon River system drains the western parts of the Central Plateau and Southern Highlands. The main stream flows south and then west, to enter the west coast through Macquarie Harbour—a drowned portion of its valley. Its main tributaries, including the Franklin River, are south-flowing, and enter it from the north.

The Huon River drains the southern part of the Southern Highlands, and enters D'Entrecasteaux Channel through the flooded portion of its valley. Tributaries enter it both from the north and south.

The Pieman River drains the north-western extremity of the Central Plateau and the southern part of the Western Peneplain. The main stream has a general westerly course, while all its chief tributaries enter it from the north or north-east.

The Arthur River drains the northern part of the Western Peneplain. The main stream has a general west-north-westerly course, and receives all its tributaries from the south.

Apart from the above systems, all the drainage is more or less coastal, and is effected by short streams flowing directly into the sea by the shortest route. The drainage of the north coast is typically of this type, excepting the Tamar River and possibly the Ringarooma River, the Forth and Mersey Rivers being the principal streams. The drainage of the east coast is also typically coastal, as is also that of the south and west coasts not drained by the Huon, Gordon, Pieman, and Arthur Rivers.

(*b*) *Development.*—The production of the present drainage system began after the close of the Triassic or Jurassic (?) sedimentation and the intrusion of the dolerite. The streams began to establish themselves on the Triassic or Jurassic sediments, or, if these were absent over the western part of the island, on the Permo-Carboniferous rocks. One, or two, cycles of erosion were completed, and resulted in the formation of a peneplain at the close of the Eocene or beginning of the Miocene period. During these cycles the Triassic and Jurassic (?) rocks were largely denuded and the dolerite intrusions exposed. In some areas the Permo-Carboniferous rocks were denuded and the underlying basement of Proterozoic and Lower Palæozoic rocks exposed. Thus the streams were largely superimposed ones as regards the dolerite, Permo-Carboniferous rocks, and the basement rocks.

The peneplain was uplifted and deformed in early Miocene time, and the streams rejuvenated in part at least. It is now difficult to trace the former drainage system, but probably the present system developed largely from it. At any rate, the present drainage began after the deformation of the peneplain. Before the Tertiary (Pliocene) sedimentation and the Newer basalt it had dissected the peneplain in places to a depth of over 1000 feet.

The Newer basalt flows were extruded in valleys differing little from the existing ones, and the general effect was merely an alteration of the course of the streams within the confines of their own valleys. The post-basaltic stream in any one valley flowed along one side of the basalt for a certain distance, and then turned across the basalt and flowed along the other side, and twin streams appear to be absent.

In several cases, however, the post-basaltic stream left its old valley for a greater or less part of its length. The most notable example is that of the Ringarooma River, which left its former valley near Herrick, and passed to the east of Mt. Cameron, whereas formerly it passed to the west thereof. Another example is the Macquarie River, which left its former valley near Ross, and assumed a parallel course several miles to the west. Similar changes appear to have taken place in the north-west coastal districts, but they have not been properly investigated.

The Pleistocene glaciation also affected the drainage, filling old valleys with moraines, &c. Some of the present streams in glaciated regions show an absence of glacial deposits, and prove vigorous post-glacial erosion.

The present drainage has therefore reached its present development through many stages, and its normal development has been affected by the basalt flows and the Pleistocene glaciation.

It still remains largely a superimposed system on the dolerite, Permo-Carboniferous rocks, and Proterozoic and Lower Palæozoic rocks. In the latter rocks the development has, of course, been partly influenced by the meridional graining of them, but not to any marked extent.

The drainage is still in a comparatively youthful stage of development.

(*c*) *Rejuvenation.*—Rejuvenation has probably occurred several times in the development of the present drainage system. The earliest rejuvenation took place when the peneplain or peneplains were uplifted to form the present plateau or plateaux. Little information exists in connection with the drainage systems of the peneplains, due solely to lack of investigation. The depths to which gorges have been cut in the plateaux bear witness to the amount of uplift and consequent rejuvenation. The streams draining the northern part of the Eastern Peneplain have cut gorges to depths of 1000 feet. Where the streams have cut through the edges of the Central Plateau, the gorges are much deeper, and attain a maximum of 3000 feet, e.g., Lake River, Mersey River, Forth River, &c. The Gordon and other streams have cut similar gorges in the South-western Highlands.

It cannot be stated whether the whole of the uplift occurred at once, or in a number of stages at different periods. It is certain, however, that the greatest portion of the uplift occurred between the Older and Newer basalt epochs, as in the Ringarooma Valley over 1000 feet of erosion occurred after the Older basalt epoch and before the pre-Newer basalt sedimentation (freshwater).

A later period of rejuvenation, but of less amount, followed the extrusion of the Newer basalts. This was probably the result of a slight uplift of the land, and not merely due to the filling of the valleys by basalt, because the present streams have cut their courses below the basalt and into the underlying freshwater sediments.

Lewis[7] reports considerable post-glacial river erosion at the southern end of the Central Plateau. This may represent rejuvenation due to a Pleistocene or post-Pleistocene uplift, or possibly the cutting of gorges by the headward erosion of the streams as a result of an earlier uplift.

There has been a rejuvenation of the west coast streams, as the streams crossing the Western Coastal Plain have dissected it to depths of at least 200 feet, and possibly greater in certain parts. This rejuvenation is not recognisable in other parts of the State, unless it be connected with the post-Pleistocene uplift, which at Smithton, Flinders Island, and probably Gladstone, raised the marine Pleistocene sediments to their present positions.

The rejuvenation following the recent uplift of 10 to 15 feet is only noticeable where the streams have cut through their alluvial flats near the coast.

(*d*) *Capture*.—There are only a few cases of stream capture known in Tasmania, which is due probably to the youthful nature of the drainage, and partly to the limited amount of physiographic investigation carried out.

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(7) Lewis, A. N., M.C., LL.D., M.H.A.: Note on the Origin of the Great Lake and Other Lakes on the Central Plateau. Proc. Roy. Soc. Tas., 1932, p. 15.

One possible capture that has been described is that of the upper portions of the former Henty River by the King River (Gregory).[8] It was considered that the head-waters of the present King River flowed westerly through the Sedgwick Gap, and continued as an ancient Henty River, before being captured by the lower portion of the King River. It must be pointed out, however, that the valley of the Comstock Creek flowing easterly from Sedgwick Gap into the King River was already in existence in Pleistocene time, as it is a typical glacial valley, and was filled with a considerable thickness of glacial deposits (morainal material, clays, &c.). The head-waters of the Queen River west of Sedgwick Gap contain no glacial deposits, and have been developed since the glacial epoch, thus proving a certain amount of erosion since Pleistocene time, which may have been partly responsible for the formation of the Sedgwick Gap. In any case, if the above capture did take place it must have occurred some time before the glacial epoch.

An obvious capture is that of the upper part of the Jordan River by the Coal River. Between Richmond and Colebrook the valley of the Coal River is fairly wide and open, but upstream from Colebrook it consists of a deep narrow gorge for a distance of 8 miles.

This gorge is 600 feet deep at its southern end, but approaching Baden its depth becomes less, until finally a much more mature valley is represented. Near the head of this gorge the river, which was flowing westerly, makes a right-angle bend, and flows southerly. This sharp bend occurs immediately east of Lake Tiberias and the head-waters of the present Jordan River. The explanation is that the Coal River, by head-water erosion along a fault, captured the head-waters of the west-flowing Jordan River, which was established in a fairly mature valley on the Eastern Peneplain.

Another probable capture is that of the Arthur River. There is a low gap at the head of the Duck River, which may indicate that the Arthur River

(8) Gregory, J. W.: Some Features in the Geography of North-Western Tasmania. Proc. Roy. Soc. Vic. Vol. XVI., Pt. 1, 1903.

flowed through it, and entered Bass Strait along the valley of either the present Duck River or Montagu River. The capture, if it occurred, was made by a small coastal stream now represented by the lower part of the Arthur River. Support is given to this view by the presence of blackfish *(Gadopsis marmoratus)* in the Arthur River, as it is stated that this is the only stream entering the west coast with these fish in it, and that the blackfish only occur in the southern rivers of Victoria and the northern ones of Tasmania, i.e., in streams entering Bass Strait.

An impending capture worthy of mention is that of the South Esk River by the North Esk River, near Evandale. The South Esk River, having been superimposed on the large body of diabase to the south-west of Launceston, has cut a steep and narrow course (the Launceston Gorge) through it, the grade of the stream being high. The North Esk, which flows mainly over soft Tertiary clays, &c., has naturally been able to excavate its valley with a lower grade. Thus near Evandale, where the streams are comparatively close, the valley of the North Esk is several hundred feet lower than that of the South Esk. The head-waters of a tributary stream (Rose Rivulet) have cut their valleys back to within a short distance of the South Esk near Evandale, and in the course of time will capture the latter stream. It is probable, however, that an extraordinarily large flood in the South Esk will bring this about. If the 1929 flood had risen several feet higher, the water would have flowed through a gap into the valley of Rose Rivulet, and thence into the North Esk.

It is probable that numerous captures have occurred in the drainage of the Central Plateau. Lewis[9] refers to the following captures: The Ouse and the Shannon capturing the drainage of adjacent streams, the Ouse having captured much of the drainage of the Nive River, and may shortly capture the Little Pine River; the Lake River capturing that of Arthur's Lakes, which was formerly part of the Derwent drainage system.

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(9) Lewis, A. N., M.C., LL.D., M.H.A.: Note on the Origin of the Great Lake and Other Lakes on the Central Plateau. Proc. Roy. Soc. Tas., 1932.

(*e*) *Relations of Valleys to Glacial Features.*—These relations cannot be definitely decided at present owing largely to lack of investigation. Moreover, the relations will probably be different in different parts of the State.

In the eastern, midland, and adjacent regions there is a general absence of features due to glaciation, and the streams apparently continued their development through the Pleistocene epoch without any noticeable change.

In the less elevated portions of the southern and western regions, the present valleys often contain glacial and fluvio-glacial deposits. This strongly suggests that the present valleys existed generally in their present form in pre-glacial times, and that the glaciers occupied these inherited valleys. Further, in general, the present valleys coincide with their pre-glacial ancestors, being modified only by the filling of glacial deposits and the subsequent erosion. However, valleys (chiefly small and tributary to the main ones) exist which contain no glacial deposits. These have undoubtedly been formed by vigorous post-glacial erosion, and for examples there may be quoted the upper part of the Ring River near Williamsford and Ringville, the Stitt River Valley, and the branch of Queen River rising near Comstock Gap, all of which are in close proximity to glacial-filled valleys.

The relations on the more elevated regions of the State are not definitely known. On the Central Plateau, Lewis[10] states: "I cannot at present throw any light on the pre-glacial drainage." He reports extensive post-glacial erosion, glacial-filled valleys, and the capture of the drainage of the main drainage course of pre-glacial times by streams in adjacent small valleys. Thus, in general, it may be stated that the present valleys may agree in some cases with their glacial-filled ancestors, while in other cases subsequent erosion, capture, &c., have considerably altered the valleys and the drainage compared with their pre-glacial ancestors.

(10) *Ibid.*, p. 32.

(4) LAKES.

A large number of lakes exist throughout the State, the majority being on the Central Plateau, and include the largest, such as Great Lake, Sorell and Crescent, St. Clair, Arthur's Lakes, Echo and Woods Lakes. In addition to those above mentioned there are innumerable smaller lakes, lagoons, &c. Lewis[11] has shown recently that practically the whole of the Central Plateau down to an altitude of 2700 feet was glaciated during the Pleistocene, and that the lakes are largely, if not wholly, of glacial origin. The innumerable lakes, &c, are indeed typical of the drainage of a glaciated area of fairly low relief. Of the larger lakes, only St. Clair (Clemes, 1924)[12] and (possibly) Arthur's Lakes[13] have been formed by damming due to terminal moraines. Lakes Sorell, Crescent, and the Great Lake are shallow, and occupy shallow depressions on the plateau, while dolerite ridges occupy the outlets from the lakes. In the case of the Great Lake, Lewis reports glacial deposits at other places than the outlet, and it appears that the glacial action may have produced the depression, and that the present outlet is due to later drainage capture. A similar origin for Lake Echo is possible, the subsequent erosion having removed the glacial deposits.

In the cases of the smaller lakes, and particularly the tarns on the plateau, there is usually terminal morainal material present, definitely establishing the glacial origin.

The lakes are smaller and less numerous on the western side of the Central Plateau and in the South-Western Highlands, which is probably to be explained by the greater amount of denudation which has occurred there. In every case where the lakes have been examined morainal material occurs and the glacial origin is established.

Only four lakes exist in the midlands and eastern districts. Lake Dulverton occupies a shallow depression in sandstone, with a sandstone bar at its outlet. Lake Tiberias occupies a shallow depression

(11) *Ibid.*

(12) Clemes, W. H.: Notes on a Geological Reconnaissance of the Lake St. Clair District. Proc. Roy. Soc. Tas., 1924.

(13) Lewis, A. N.: *Ibid.*

in felspathic sandstones, with dolerite at the outlet retarding the action of the Jordan River. The capture of the head of the Jordan by the Coal River has also affected the action of the Jordan River. Lake Tooms is an artificial lake formed by a dam, as is also Lake Leake.

In the case of the above four lakes evidence of glacial origin is absent, as is also evidence of glacial action in the vicinity.

(5) Glacial Physiographic Features.

The glaciation was most extensive on the Central Plateau, and ice covered a large portion of it, although nowhere was the ice thick. The mountains and hills protruded as nunataks, and the glaciers filled the valleys, and coalesced to form extensive glaciers. Valleys filled with morainal deposits were the chief land forms produced. Striated pavements are rare, but "*roches moutonnées*" are plentiful. At the head of the glaciers, and particularly during the last phase of the glaciation, cirques, tarns, and attendant phenomena were produced.

On the western side of the Central Plateau and in the South-Western Highlands the glaciers were of the mountain type, which entered inherited valleys. These produced the typical U-shaped glacial valleys, and filled them with morainal deposits. Piedmont glaciers may have been formed to a slight extent. Outwash fans were formed at a few places.

The most extensive glaciation of the cirque-cutting type progressed on some mountains until comb ridges, monuments, horns, &c., were produced.

Many of the button-grass plains in the valleys appear to be of fluvio-glacial origin, and to be formed by beds of gravel, &c.

(6) Evolution of the Topography.

(a) Geological Structure as Affecting the Evolution of the Topography.

As the evolution of the topography is determined by the geological structure, a brief description of the latter is necessary in considering the former.

General.—The basement consists of Proterozoic and Lower Palæozoic sedimentary rocks (metamorphosed in the case of the former) intruded by granite, the sedimentary rocks being folded and faulted. Upon this basement rest horizontal or slightly tilted sedimentary rocks of the Permo-Carboniferous and Triassic systems ranging in thickness up to 3500 feet. The latter two systems have been intruded on an extensive scale by Mesozoic dolerite in the forms of irregular sills and large dyke-like bodies. Large-scale faulting has occurred in Permo-Carboniferous and Triassic rocks.

Rocks.—From the viewpoint of evolution of the topography the rocks may be considered as follows:—

(i) Hard structures of the basement rocks: These include the Proterozoic schists and quartzites, the Lower Palæozoic conglomerates, quartzites, sandstones, slates, limestones, &c., and the Devonian granite and porphyries. These are strong structures, which have developed a more or less marked meridional "graining."

(ii) Soft: The relatively soft mudstones, &c., of the Permo-Carboniferous system occupy large areas in the south-eastern districts, and also occur in the north-eastern and north-central districts, and may underlie the eastern portion of the Central Plateau.

(iii) The hard structures (though not as hard as those of (i) above) of the Triassic Ross or Knocklofty sandstones, ranging up to 70 feet in thickness.

(iv) Mixed hard and soft: The Triassic or Jurassic felspathic sandstones, with coal-seams and mudstones, occur throughout the eastern districts, and range in thickness up to 1000 feet.

(v) Hard and very resistant: The irregular sills of dolerite range in thickness up to 1000 feet or more, and occur throughout the eastern and central regions.

As the dolerite intrusions are probably pre-Tertiary in age, the dismantling of them by natural forces of erosion must have commenced a very long way back in geological time, probably in at least a third cycle of erosion from the present.

[*Footnote:* It is not yet known at what date the dolerite sheets were injected, but it is clear that they have a wonderfully close analogue in the dolerite sills forming the kopjes of the Great Karroo in South Africa. They have also the closest possible resemblance to the huge dolerite sills first described by H. T. Ferrar, of the First Scott National Antarctic Expedition, in the Ross Sea area of Antarctica. The Antarctic Andes of Victoria Land are largely built up of similar great sheets of dolerite, which have thicknesses of considerably over 1000 feet in places. In South Africa these newer dolerites intersect the Stormberg volcanic series, of which latter the Drakenberg Range is so largely built. The Stormberg lavas and tuffs range from probably Rhætic into Jurassic. It is considered by Drs. A. W. Rogers and A. L. du Toit that the dolerite sills of South Africa are of pre-Cretaceous, and probably of late Jurassic, age.]

Faulting.—A consideration of the structure of the island reveals the extensive faulting in the Permo-Carboniferous and Triassic rocks. The Permo-Carboniferous rocks were deposited on a fairly level, if not a peneplained, surface of the older basement rocks, and as the former have not been folded and only slightly tilted, their base gives a fairly accurate estimate of the faulting of the basement. It is found that along sections in nearly every direction from the western part of the Central Plateau, downthrow faulting of the Permo-Carboniferous and the basement rocks occurs. One of the largest of such faults is that extending approximately from Ulverstone on the north coast to Catamaran on the south-east coast, with a downthrow of 2000-3000 feet to the east. A similar fault of like magnitude probably trends parallel west of the West Coast Range, and extends to the north coast. Similar faults probably surround the Ben Lomond Highlands.

In addition to the above faulting affecting the basement, there are numerous faults in the Permo-Carboniferous and Triassic rocks which are intimately associated with the dolerite intrusions, and which probably do not affect the basement, the displacement of the rocks being accounted for by the different thicknesses of the diabase sills.

(b) Cycles of Erosion.

The greater part of Tasmania has been a land surface since the close of the Triassic (or Trias-Jura) sedimentation, and the development of the present topography is therefore the result of the cycles of erosion which have operated since then, in conjunction with the various earth movements that have taken place. The evidence is not conclusive as to the number of cycles that have occurred during this development, but there is conspicuous evidence of two, or less conclusive evidence of a third and older cycle. In addition to these two or three, brief reference must be made to a still older one, viz., a pre-Permo-Carboniferous cycle.

(i) *Pre-Permo-Carboniferous Cycle.* — In the north-eastern portion of the State the basal Permo-Carboniferous beds overlie the basement of Cambro-Ordovician rocks and Devonian granite at a general elevation of approximately 2000 feet above sea-level. The surface of this basement is generally level, and strongly suggests a pre-Permo-Carboniferous peneplain. This plain is also observable in the faulted and tilted blocks surrounding the main highland block.

Similar conditions exist in the Cradle Mountain-Lake St. Clair region, but the old basement is now at a higher level than the portion in the north-eastern region.

In the north-eastern region portions of this old peneplain were re-exposed and incorporated in the later Miocene peneplain

(ii) *Pre-Tertiary (?) Cycle.*—Many of the higher mountains in the southern, western, north-western, and north-eastern districts have heights ranging from 3000 to 5000 feet above sea-level, some of the most prominent being Hartz Mountains (4000), Arthur Range (3363), Wilmot Range (3483), Mt. Wellington (4166), Mt. Field West (4721), Frenchman's Cap (4756), Mt. Eldon (4789), Cradle Mt. (5059), Ironstone Mt. (4736), and Ben Lomond (5160). It is possible that these and numerous other mountains and highlands represent the remnants of a former peneplain. The Central Plateau, South-Western Highlands, and Ben Lomond Highlands would represent more or less dissected portions of this peneplain. If this peneplain was formed, its formation must have been completed probably by the end of the Cretaceous period.

An alternative explanation is that these mountains, &c., represent hard residuals or monadnocks of the peneplain formed at a later period (Miocene) than that which would be necessary for the formation of the above supposed peneplain.

(iii) *Pre-Miocene Cycle.*—More than half of the surface of the State is situated at heights between 1000 and 3000 feet above sea-level. At many places in the western, north-western, north-eastern, eastern, and south-eastern districts there are plains or remnants of dissected plateaux, the surfaces of which are 2000 to 2200 feet above sea-level. These include the North-Western Peneplain and the Eastern Peneplain, and it is probable that they form parts of a former extensive peneplain. It is to be noted that this peneplain is arranged concentrically around the Central Plateau, Ben Lomond Highlands, and South-Western Highlands.

(iv) *Post-Miocene Cycle.*—Following the earth movements which affected the probable peneplain formed by Miocene time, another cycle of erosion commenced, and has continued with a considerable amount of interruption until the present time. The orderly development of this cycle has been interrupted by the outpourings of Newer basalt, earth movements of the Kosciusko epoch, transgression of the Werrikooian or Pleistocene sea, and numerous minor elevations and depressions of the land. Further, this cycle would include the very important glaciation of the Pleistocene epoch.

(c) Correlation of the Physiographic Units with the Cycles of Erosion.

The physiographic units naturally fall into several groups by virtue of their altitudes. The Central Plateau and its extension of the South-Western Highlands, together with the separated Ben Lomond Highlands, represent more or less dissected regions, ranging in height up to 5000 feet above sea-level. If the uniform height of the higher mountains in these units has any physiographic significance, it suggests an old peneplain. Such a peneplain would be the result of the first post-Triassic cycle of erosion referred to above.

The North-Western and the Eastern Peneplains, with altitudes of 2200 feet above the sea, form another group. These give definite evidence of peneplanation, which would be the result of the second Post-Triassic cycle of erosion referred to above.

The Western Coastal Plain and the Launceston Tertiary Basin appear to have no connection with each other or either of the above groups.

Several questions arise in connection with the above. In the first place, as the evidence of the older cycle and peneplain is not definite, it might be thought that this and the younger peneplain are faulted portions of one and the same peneplain. This cannot be the case, however, with the Eastern Peneplain and the Ben Lomond Highlands, as there are many mountains, e.g., Mt. Victoria, &c., rising to heights comparable with that of the Ben Lomond Highlands, which are clearly monadnocks rising above the Eastern Peneplain. Thus two definite cycles appear to be present.

Secondly, the Western Coastal Plain has been correlated by numerous writers with the North-Western Peneplain. However, this plain is essentially a coastal feature, and in places is distinct from the peneplain, so that it must be considered a separate feature.

There is a possibility, though small, that the coastal plain may form a warped or tilted portion of the peneplain, but there is no direct evidence of this.

Account can only be taken here of the second of the above two cycles, and so it and the peneplain produced will be discussed further, particularly from the point of view of age.

(d) Age of the North-Western and Eastern Peneplain.

The amount of direct evidence of the age of this peneplain is relatively small. The formations which would offer the best evidence are Tertiary marine rocks, Tertiary basalt flows, and Tertiary fresh-water sediments, and these will be briefly reviewed.

(i) *Tertiary Marine Rocks.*—These are very limited in extent, and are restricted to the north-western coastal districts. One isolated area occurs at Table Cape, and it is considered to be of Miocene age. The beds are overlain by basalt, which is therefore post-Miocene in age.

Other areas include Cape Grim, Marrawah, and Temma, and suggest a more extensive development. The beds in these areas are mainly polyzoal limestones, and their fossil content proves them to be Miocene in age. The limestone at Marrawah surrounds a low plateau of basalt, and includes pieces of the latter rock. This proves the age of the basalt to be pre-Miocene.

The Miocene marine beds are not extensive, and provide no direct evidence of the age of the peneplain, as they do not come in contact with the recognised parts of the latter. However, in providing proof of the age of the basalts they provide valuable evidence.

(ii) *Basalt Flows.*—Basalt flows occur throughout the island, but are most extensively developed in the north-western coastal districts. Until recently there was no evidence to suggest that there were basalts of more than one age, and they were regarded as being Upper Tertiary (the Table Cape section proved them to be post-Miocene) and probably the equivalents of the Newer basalt of Victoria.

The discovery in 1933 of the pre-Miocene basalt at Marrawah gave definite proof of an older basalt, probably equivalent to the Older basalts of Victoria.

In the present state of our knowledge the two basalts cannot always be separated, but certain factors indicate generally to which series any particular flow belongs. The Newer basalts occur generally as flows in valleys corresponding to those of the present streams, and subsequent dissection has been to shallow depths of only a few hundred feet. The Older basalts appear to occur mainly on elevated plateaux, and have been subjected to deeper weathering and to dissection amounting to 1000 feet.

The Newer basalts include those of the Ringarooma Valley, Launceston Basin, South Esk Valley, Derwent Valley (in part), and Smithton district.

The Older basalts include those of Marrawah, North-Western Peneplain (Waratah and Middlesex basalts), high-level basalts of the Midlands, those of Bulman Bluff near Branxholm, and of Weldborough.

(iii) *Freshwater Sediments.*—These occur under the basalt flows, and chiefly those of the Newer series. No recent age-determinations have been made as regards the fossil leaves and fruit found in them, but the sediments are regarded as being of Pliocene and possibly Miocene age. The subbasaltic beds at Waratah appear to be older than the others, and this coincides with the Waratah basalt occupying an elevated plateau and being probably of the Older series.

(iv) *Age of the Peneplain.*—Eastern: At Bulman Bluff, near Branxholm, Older basalt occurs at an elevation of 1700 feet or more, corresponding to the general level of the peneplain. The Ringarooma Valley has been eroded to depths of over 1000 feet below the peneplain and Older basalt level, and has been flooded with Newer basalt. Thus it would appear that the Older basalt was extruded on the peneplain, and that the peneplain was subsequently elevated (and perhaps faulted), and that it was dissected to a depth of at least 1000 feet before the freshwater beds were deposited and the Newer basalt extruded.

Similar dissection of the peneplain is evident in the upper portion of the South Esk Valley before the Newer basalt flows.

The above suggests that the peneplain was formed in pre-Older basalt time, and that it was elevated, and perhaps faulted, some considerable time before the Newer basalt series, and probably not long after the Older basalt flows.

North-Western Peneplain: This peneplain is covered with plateau basalts, apparently of the Older basalt series. Near Waratah the plateau has been dissected to depths of 1000 feet.

In the valley of the Forth River, on the road from Sheffield to the Shepperd and Murphy Mine, a valley-in-valley structure occurs.[14] The excavation of at least two sheets of lava, which had successively filled the valley of the Forth to depths of fully 500 feet below the level of the old peneplain, shows that the Forth River had already deepened its channel to very nearly its present level before the latest streams of basalt flowed.

The above evidence suggests that the peneplain was formed in pre-Older basalt time, and that the flows of this basalt were extruded over its surface. The peneplain was elevated and deformed between the Older and Newer basaltic flows, and probably not long after the Older basalt. Assuming, as occurs in other regions in Australia, that the Miocene marine beds were formed on the peneplain surface, the limited extent of them in the island suggests that the deformation of the peneplain occurred before this marine transgression, and that only small areas in the north-western districts (Temma, Marrawah, and Table Cape), and possibly larger ones in Bass Strait (King Island), were left near sea-level, and were covered by the Miocene sea. The

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(14) David, Prof. T. W. E., F.R.S.: Sketch Section in Geol. Surv. Tas. Bull. No. 14, 1913.

deformation of the peneplain therefore apparently occurred about the close of the Eocene or beginning of the Miocene period.

(e) *Bass Strait.*

It is not known at what particular epoch of geological time the east-west cross-warping occurred which defined the important lineament of Bass Strait.

As far as the evidence in Tasmania extends, the formation of Bass Strait was pre-Miocene. Marine sands, &c., of Pleistocene age occur at several places along the north coast, while marine sandstones, limestones, clays, &c., of Werrikooian age occur extensively on Flinders Island and other islands of the Furneaux group. A strait slightly more extensive than the present one was therefore in existence in Late Pliocene to Pleistocene time. Miocene deposits occur on the north-west coast of the State, on King Island, and most likely also on Flinders Island. It appears, therefore, that a strait similar to the present one was in existence in Miocene time.

In Victoria similar, but more extensive, evidence points to the existence of Bass Strait in Lower Tertiary times. The evidence at Port Phillip and at the Sorrento bore near the south-east entrance to Port Phillip shows that, even as far back as Oligocene time (Balcombian), there was already a marine trough where Bass Strait is now situated, and even to the north of it. This marine trough followed on either lacustrine or terrestrial conditions, inasmuch as in the Altona area, near Melbourne, extensive seams of brown coal are found underneath the marine Oligocene strata. Again, in early Miocene time there is evidence of an oscillatory movement, which converted the northern part, at any rate, of Bass Strait into a land or a freshwater lake, possibly a swampy plain area. Next we find that a widespread subsidence supervened, bringing the ocean waters not only over the original Oligocene freshwater and marine beds, as well as over the Miocene lacustrine beds, but it spread some considerable distance to the north of the old boundary of Bass

Strait. At this time the Great Valley of Victoria from East Gippsland to Robe (?) was more or less submerged, and formed a northern replica of Bass Strait.

As regards the Mesozoic rocks, there is in Tasmania the sandstones, felspathic sandstones, and mudstones assigned to the Triassic system, and in Victoria the felspathic sandstones, shales, mudstones, &c., assigned to the Jurassic system, coal-seams being present in both States. Though assigned to different systems, the felspathic sandstones are identical lithologically, and, being of rather unusual types, it is by no means improbable that the two should be assigned to the one system. Moreover, the fact that both are freshwater sedimentary series rather tends to suggest a land connection between Tasmania and Victoria. If this is the case, then the formation of Bass Strait would be late Jurassic or post-Jurassic and (as shown above) pre-Oligocene.

Support is given to this veiw as the Jurassic strata of Victoria (excluding those of the Great Valley) have been tilted so that, on the whole, they tend to dip towards Bass Strait. In Tasmania it cannot be said that the Triassic strata have a similar relation, but the underlying Permo-Carboniferous strata (from above which the Triassic have been removed by erosion) along the north coast, and especially in the north-eastern districts, show a general dip towards Bass Strait. This indicates tilting towards the Strait, while faulting is also prevalent with the down-faulted blocks on the Bass Strait side. It will be noticed, on reference to the section, that Bass Strait is, on the whole, defined by very definite heavy, marginal faults. If these faults and the tilting are connected, as seems likely from the above, with the formation of the Strait, then they are probably connected with the late Jurassic widespread intrusions of dolerite into the Jurassic and older rocks. This does not necessarily imply that all the faults are of this age, and it is quite possible that many, including even the main faults, are of newer origin. Some may be connected with the uplift and deformation of the North-Western and Eastern Peneplains, which occurred in late

Eocene or early Miocene time. Others may be connected with the important tectonic movements of the Kosciusko epoch.

As regards the date of origin of Bass Strait, the evidence is fairly definite that it is Lower Miocene or pre-Miocene, but is not conclusive as to whether it is late Eocene (or early Miocene) or late Jurassic.

(f) *General Sequence of Events in the Evolution of the Present Physiography.*

Without going into unnecessary details, the following table gives the events (elevations and depressions of land, sedimentation, basalt flows, erosion cycles, &c.) responsible for the present physiography of the State:—

Triassic (or Jurassic) sedimentation ends.
Extensive intrusions of dolerite (probably late Jurassic).
Large-scale faulting accompanying dolerite intrusions in the Permo-Carboniferous and Triassic rocks.
Pre-Miocene cycle of erosion and formation of peneplain.
Older basalt extrusions.
Deformation of North-Western and Eastern Peneplain by uplift, faulting, and warping.
Miocene marine transgression on north-west coast, King Island, and possibly Flinders Island.
Erosion with dissection of North-Western and Eastern Peneplains to depths of over 1000 feet.
Present drainage system established.
Depression of land of at least 350 feet.
Accumulation of freshwater sediments (possibly Pliocene) in valleys coincident with, or differing little from, present ones.
Newer basalt extrusions.
Formation of Western Coastal Plain.
Pleistocene glacial epoch.
Werrikooian transgression on north-west and north-east coasts, Flinders Island, &c.

Elevation of land of at least 250 feet and withdrawal of Werrikooian seas.

Rejuvenation of streams and slight gorge-cutting.

Depression of land of possibly 150 feet.

Formation of flooded valleys near coast, coastal islands, &c.

Recent elevation of land of 10 to 15 feet with formation of raised beaches, tied islands, &c.

III.—GEOLOGY.

(1) ARCHÆOZOIC.

No rocks assignable to this era are known to occur in the State.

(2) PROTEROZOIC.

The most ancient rocks of the island belong to the Proterozoic era. With the exception of a few disconnected outcrops along the north coast, they are restricted to the western half of the State, and more particularly to the south-western part thereof. The largest belt has a general north-and-south trend, with a length of 130 miles and a width ranging from 20 to 30 miles. Six smaller and detached areas occur outside this main belt.

The principal rock types present are quartz mica schists, quartz schists, argillaceous schists, quartzites, and numerous intermediate varieties of schists. Smaller amounts of conglomerates, quartz breccias, phyllites, dolomites, and limestones also occur. The above types form over 90 per cent. of the pre-Cambrian rocks of the State.

The mica, quartz, and argillaceous schists are present in every district where the pre-Cambrian outcrop. Hard quartzitic conglomerates occur at Port Davey, while at Jane River siliceous conglomerates and quartz breccias outcrop to a small extent. At Goat Island, on the north-west coast, schistose conglomerates are noted for the splendid examples of stretched pebbles contained in the rocks.

Dolomites and limestones conformably underlie a thick series of quartzites, quartz schists, argillaceous schists, and phyllites in Jane River Valley. Magnesium limestones, interbedded with schists, occur along the Arthur River, and similar rocks have also been recorded from south of Macquarie Harbour.

All the above types have almost certainly been derived from sedimentary beds consisting originally of gravels, sands, clays, and limestones.

In addition to the above, subsidiary amounts of altered basic igneous rocks are referred to this era.

The largest area of these types occurs in the Rocky River district. Other occurrences are at Collingwood River, Hamilton-on-Forth, Quamby Brook, &c. The prevailing type is an amphibolite, the principal varieties being zoisite and garnet-zoisite-amphibolites. The original rock was apparently a gabbro.

The Proterozoic schists have been highly folded or tilted; they show regional metamorphism to a marked degree, and recorded dips are usually at high angles. Actual folding (anticlines and synclines) is seldom detected, but the rocks appear to represent a conformable series, generally dipping in one direction. This may represent the presence of tilting without folding, or, what is more probable, the truncation of overfolds.

The strikes are variable, due to crumpling, but they may be taken generally to have a meridional direction. The structural details of these rocks have not been worked out in any detail. It is impossible to give even an approximation of their thickness, but it is apparent that it must amount to many thousands of feet.

These rocks were originally referred to as pre-Cambrian, but later they were given the more correct term of Algonkian. In conformity with usage throughout the world, they are now spoken of as Proterozoic.

(3) PALÆOZOIC.

(*a*) *Cambrian.*

Fossils described as Cambrian have been obtained from beds at the following localities:—

- Sandstones of Caroline Creek: These beds contain *Dikelocephalus tasmanicus, Asaphus* (sp.), *Ophilita* (sp.), *Ptychoparia stephensi.*
- Slates of Florentine Valley: These contain *Dikelocephalus florentinensis, Niobe, Bellerophon, Tentaculites, Orthis, Olenticularis.*
- Slates, occurring at Hatfield Plains, on Emu Bay Railway, from which *Hurdia davidi* has been described.
- Slates at Arthur River containing *Tasmanadia twelvetreesi.*

(*b*) *Ordovician.*

Ordovician fossils have been discovered in two localities only, viz., the North-East Dundas Tram, where graptolites occur in dark slates, and at Railton, where the limestone has yielded a few fossils which suggest a correlation with the Larapintine series of South Australia.

(*c*) *Cambro-Ordovician.*

Between the Proterozoic schists and the basal Silurian series there exists a large thickness of sedimentary rocks, which occupy a considerable portion of the surface in North-Western, North-Eastern, and Southern Tasmania. At only one locality—Frankford—has there been observed a relationship between the base of these rocks and the Proterozoic schists, and here basal conglomerates are unconformable to the schists. The basal Silurian rocks overlie the Dundas and other series with a marked unconformity.

Apart from the few fossiliferous localities referred to above, and yielding Cambrian and Ordovician fossils, the rocks appear unfossiliferous. The determination of the stratigraphy has proceeded only to the extent of the recognition of a few series.

In Western Tasmania the Dundas series of slates, breccias, cherts, quartzites, &c., is the most prominent and widespread of the Cambro-Ordovician rocks. Generally it is found that this series is in faulted relationship to the Silurian rocks, and in a few cases it is overlain unconformably by the basal Silurian series (West Coast Range). This is suggestive that the Dundas series forms the upper part of the Cambro-Ordovician system. Support is given to this view by the evidence of the graptolites on the North-East Dundas Tram, the graptolite bed being interbedded with the Dundas series, and the graptolites suggesting that the age is either at the summit of the Lower, or at the base of the Upper, Ordovician. The Dundas series is therefore now regarded as being of Ordovician age.

In North-Western Tasmania the Balfour series of slates, quartzites, and conglomerates has been referred to the Cambro-Ordovician system; but there is, however, a lithological resemblance to the Silurian rocks, though not fossiliferous.

In North-Eastern Tasmania only one series—the Mathinna slates and sandstones—has been recognised. It is a highly folded series, and bears a close lithological resemblance to the Ordovician rocks of Victoria. It has previously been compared with the Balfour and the Dundas series. Field work in Warrentinna district in 1934 disclosed several poorly preserved fossil plant remains in weathered slates of the Mathinna series, near the railway-station. The fossils were considered to be remarkably like psilophytales as found in Silurian rocks in Victoria, and which have never been found in any part of the world lower than the Silurian. Although no fossils have previously been identified in the Mathinna series, it has been the practice of late years to refer the rocks to the Cambro-Ordovician period. When better preserved fossils, which can be definitely identified, are obtained it may be necessary to place the Mathinna series of rocks in the Silurian system; but in the absence of further evidence this cannot be attempted.

The rocks below the Dundas series in Western and North-Western Tasmania consist of a thick series of dark and light coloured slates, quartzites, thin beds of conglomerate, &c. This series would therefore represent either a part or the whole of the Cambrian system. Its base has not yet been recognised, nor has its relations with the Proterozoic rocks been determined. It includes the pre-Dundas rocks of Rosebery; the pre-Dundas rocks between Irishtown and Sisters' Hills; probably the Farrell slates; and probably the Balfour slates and sandstones. The presence of such a series of Cambrian rocks in other regions is proved by the occurrence of fossiliferous Cambrian rocks along the Arthur River; at Caroline Creek; on the eastern margin of Florentine Valley; and probably at Hatfield Plains.

It is thus evident that a satisfactory division of the Cambro-Ordovician rocks is beginning to become apparent. The lower part consists of a system assignable to the Cambrian, and consisting of dark and light coloured slates and quartzites. The upper part is the Dundas series, assignable to the Ordovician, and consisting of the typical purple or red slates, cherts, breccias (composed of igneous material), lavas, and tuffs, with lesser amounts of dark slates, quartzites, dolomites, and limestone.

The Read-Rosebery schists and the Lyell schists, which were previously considered to be thin series of schistose sedimentary rocks, have now proved to be sheared igneous rocks, so that these series are not regarded as forming portion of the Cambro-Ordovician sedimentary system.

In former years the porphyroid series, including pyroclastic sediments, acid lava flows, and plutonic and hypabyssal igneous rocks, was recognised in Western Tasmania. Recent work by the Geological Survey staff has tended to prove that the series does not exist as such. The sediments belong either to the Dundas or pre-Dundas series, and the lavas, pyroclastics, &c., are really massive and sheared intrusive rocks. (See Devonian.)

(*d*) *Silurian.*

Rocks of the Silurian system are confined to the western half of the State of Tasmania. They occur in a number of irregular areas in association with the Proterozoic and Cambro-Ordovician rocks of the western districts. The general distribution may be described as follows:—

- A number of more or less connected areas in a general north-south belt in South Central Tasmania.
- A number of similar areas in a north-south tract parallel to the central part of the west coast.
- A number of areas forming an east-west tract in North Central Tasmania.

(i) *West Coast Range Conglomerate Series.*—As its name implies, this series is prominent on the West Coast Range (Mts. Owen, Lyell, Sedgwick). It is also prominent on many other mountains in the State, e.g., Clear Hill, The Thumbs, and Denison Range in the south, Mts. Osmund, Zeehan, Pearse in the west, and Mts. Claude, Roland, and The Badgers in the north. Its prominence on mountains is due to the resistant nature of the conglomerates which compose the greater part of it.

The conglomerates occur in massive beds, and are of a very coarse-grained type. They contain water-worn pebbles of an average size of 2 to 4 inches. The pebbles consist mainly of two rock types—reef quartz and quartz schist. The matrix was originally sandy, but has been altered to quartzitic material.

Finer-grained rocks, ranging down to grits and sandstones (subsequently altered to quartzites), are interbedded with the conglomerates. These finer beds are more plentiful towards the upper portion of the series.

The conglomerate series uncomformably overlies the Dundas and other Cambro-Ordovician series, and underlies the fossiliferous Silurian rocks. It is therefore regarded as forming the basal series of the Silurian system.

It contains a few fossils in the upper parts, but these consist of the "pipe-stems" (to be described below) and a few indefinite specimens of brachiopods.

(ii) *Pipe-stem or Tubicolar Series.*—This series includes sandstones, quartzites, grits, and conglomerates which are much finer in grain than those of the West Coast Range conglomerates series. The rock types are also different in colour, being either white or pink, as compared with the darker pink or red colour of the conglomerate series. The pebbles are similar in nature, but are smaller and fewer in number. The characteristic feature of this series is the presence of cylindrical casts, which may represent some organism.

A few of these casts occur in the upper portion of the conglomerate series.

The tubicolar series is most highly developed in the northern parts of the State, particularly in the Middlesex district, at localities such as Black Bluff, Stormont, Five-Mile Rise, Oliver's Hill, Tin Spur, Lemon Thyme Hill, and Round Hill. They are also present, but to a much less extent, near Zeehan, and in the valleys of the Loddon and South Loddon Rivers, in the western district.

At Zeehan the tubicolar series conformably overlies the conglomerate series, and is in turn conformably overlain by the fossiliferous limestone, slates, and sandstones.

The exact origin of the forms represented by the " pipe-stems " is very indefinite, and they may represent either tracks or dwelling-tubes of worms. Other organic remains are rare; the only fossil recorded is a *Rhynchonella borealis*.

(iii) *Quartzite Series.*—As already stated, the tubicolar series is not developed in the southern districts. In the Adamsfield district the conglomerate series is succeeded by one of dense white quartzites. Tubicolar casts have not been discovered, but the quartzites have been found to contain numerous specimens of apparently one species of an euomphaloid gasteropod.

It is considered that these are the southern equivalent of the tubicolar series. At Adamsfield this series conformably underlies the Gordon River limestone series.

(iv) *Discoidal Series.*—In the South Loddon Valley the tubicolar series is overlaid conformably by a series of white sandstones containing peculiar discoidal impressions. Similar forms occur in the sandstones at Zeehan, and have also been reported in the Cambrian sandstones at Caroline Creek.

The available evidence does not seem to warrant the establishment of a special series for these rocks. In fact, the evidence rather indicates the occurrence of the above forms in widely separated series.

(v) *Gordon River Limestone Series.*—As its name implies, this series is well developed on the Gordon River, in Western Tasmania. It is exposed along the Gordon at several localities between Macquarie Harbour and the Great Bend. From the head of the Gordon to the south coast there is a N.N.W.-E.S.E. tract of Lower Palæozoic rocks, in which many areas of limestone occur. It does not seem so prominently developed in the western districts, but is present in numerous places in the northern districts, e.g., Vale of Belvoir, Moina, Chudleigh, Gunn's Plains, &c. (There is a certain amount of evidence which rather suggests that the limestones at Railton, Flowery Gully, and Beaconsfield are older than the Silurian, and they are therefore not included in the Gordon River series.)

This series consists almost entirely of limestone of a dense dark-grey or blue type. The limestones are massively bedded and highly fossiliferous. Shales or slates occur as thin beds, but in no great quantity.

The limestone series is a thick one, and ranges in thickness up to 4000 feet. At Adamsfield a good section of the series is exposed, and the width of the outcrop of limestones from the quartzite series on the west to the Queen River sandstones on the east is 4000 feet, the limestones dipping at 70° to 80°.

Collections of fossils from the Gordon River yielded the following:—

Favosites
Halysites
Stenopora
Syringopora
Orthis
Retzia mima
Rhynchonella
Cryodonta auriculata
C. compressa
C. distarto
C. gibbosula
C. inflata
C. obliquata
C. pinguis
C. reversa
Modiolopsis
Gordonensis
Tellinomya amygdale
T. antiposa
T. jonesii
Eunema æmula
Bellerophon pugnus
Eumophalus
Helicotoma milligani
H. pusilla
Holopæa mumia
Hormotoma nerinoea
H. usitata
Hoxonema
Murchisonia franklini
M. mimetica
Pleuotomaria
Raphistoma
Tasmanicus
Scalites australis
S. salteri
S. gouldi
Straparollus tasmanicus
Trochonema bigsbyana
T. etheridgei
T. montgomerii lituites
Orthoceras antilope
O. murchisoni
O. theca
O. youngii
Phragmoceras

At Adamsfield this series conformably overlies the quartzite series, and is itself conformably overlain by the Queen River slates and sandstones.

(vi) *Queen River Slate and Sandstone Series.*—At the Queen River, Zeehan, Dundas, Heazlewood, and Middlesex, fossiliferous Silurian rocks occur. These consist of sandstones, quartzites, shales, slates, and limestones. The sandstones are the most common rocks, and consist of soft, friable types, the colouration usually being white, while at Adamsfield it is generally green. Quartzites or indurated sandstones are present only in the Zeehan district. The shales and slates are light-coloured, thinly bedded types subordinate in amount to the sandstones. Thin beds of grey limestone are interbedded with the above.

Numerous fossil collections have been obtained from this series, and the following list includes the principal fossils determined:—

Favosites grandipara
Halysites
Pleurodictyum
Crinoids
Cornulites tasmanicus
Fenestella
Atrypa hemispherica
A. cuneata
Camarotechia
Conchidium
Dalmanella
Lingula
Meristidoe
Orthis elegantula
O. flabellum
O. lata
Cardiola
Leptodomus (?)
Muciformis
Palæoneilo
Tellinomya jonesi
Helicotoma johnstoni
Harmotoma
Lothospira
Murchisonia
Loxonema
Trochonema montgomerii
Tentaculites
Pentamerus tasmaniensis
P. knightii
P. galeatus
Rhynchonella antinasula
R. borealis
R. capox
R. cuneata
R. decimflicata
R. nasuata
Spirifera crispa
S. elvata
S. lyellensis
Strophodonta
Strophomena
Strophonella
Trematospira tasmaniensis
Actinoceras

Orthoceras	*Hansmannia*
Amphion (?) brevispinus	*(Dalmanites) meridionalis*
Asaphus	*Homalonotus*
Bromus murchisoni	*Illoenus johnstoni*
Calymene blumenbachii	*Phacops*

The principal determinations were made by Gould (1860), Johnston (1888), Etheridge (1896), Etheridge (correspondence, 1909), and Dun (correspondence, 1910). The general opinion expressed was that the species had Ordovician and Silurian facies, but generally were of Silurian age.

As far as the present knowledge extends, the Queen River series represents the uppermost series of the Silurian system. At Adamsfield the series conformably overlies the Gordon River limestone series.

(*e*) *Devonian.*

No sedimentary rocks which can be ascribed to the Devonian system have so far been located, and the State was apparently a land surface during this period.

The next younger rocks—the Permo-Carboniferous—overlie the Lower Palæozoic rocks, with an unconformity. The Silurian sedimentation was followed by a diastrophic epoch of considerable intensity, during which the Lower Palæozoic rocks were invaded by extensive bodies of magma. Considerable differentiation occurred, and the resulting rocks include many plutonic types of the ultrabasic (peridotites, pyroxenites, serpentines), basic (gabbros), and acid (granite) divisions. The acid rocks predominate, and the large bodies in North-Eastern, North-Western, and Western Tasmania represent one or more granitic batholiths.

It has been indicated above that the Porphyroid series of rocks (see Cambro-Ordovician) are now regarded as being massive and sheared intrusive igneous rocks. The unaltered rocks are generally porphyritic, and include quartz porphyries, felspar porphyries, and porphyrites. Non-porphyritic rocks approaching felsitic types and dolerites are also present. The altered types include the Read-Rosebery and Lyell schists and sheared porphyries which were derived from the massive prophyries. The alteration of the porphyries to schists was caused mainly by earth movements, but the final and most complete alteration was due to the action of mineralising solutions.

The porphyries are found to be intrusive into all the rock systems up to and including the Silurian. The best evidence of their intrusion into Silurian sedimentary rocks is found at Queenstown, Lynchford, South Dundas, and Mt. Claude.

These rocks are therefore now regarded as belonging to the Devonian intrusions. The granites are the plutonic, and the porphyries the hypabyssal, representatives.

(*f*) *Permo-Carboniferous.*

The Permo-Carboniferous sedimentation must have taken place over the whole of what is now the State of Tasmania, with the possible exception of the extreme south-western portion. The basement upon which the basal members were deposited consists of highly folded Proterozoic and Lower Palæozoic sedimentary rocks and associated igneous intrusions. In many parts of the State the surface of the basement had been worn down to a peneplain before the deposition of the basal members of the Permo-Carboniferous system.

The total thickness of the system has a considerable range. It has a minimum thickness of 400 feet in the north-eastern part of the State, but the thickness apparently increases rapidly to the south and west, the greatest thicknesses being in the eastern, south-eastern, and portions of the north-western districts. The maximum thickness has a range of 2000 to 3000 feet. The thickness of the different series also has a considerable range in the different parts of the State.

The structure of the rocks of this system is uniform throughout the State. Folding is absent, but block tilting has occurred to a large extent. The amount of tilting, however, is not great, and the dips of the beds range from 0° to 10°, and very seldom exceed the latter, a few dips up to 25° being recorded. The system has been largely faulted, with the result that it occurs in the form of horizontal or slightly tilted blocks, as described above. The faulting and tilting was, for the most part, associated with the intrusions of the Mesozoic diabase (dolerite) at the close of the Triassic sedimentation.

The summit of the system is marked by pebbly grits forming the basal members of the Ross series of the Triassic system.

The following series have been recognised in Tasmania:—

(i) *Basal Series.*—The basal members consist of conglomerates, pebbly grits, or pebbly sandstones. In most districts these are definitely of glacial origin, and consist of glacial conglomerates and tillites. In the Wynyard and Preolenna districts this series of glacial beds is 1200 feet in thickness. In the north-eastern districts, where the thickness of the system is not great, the basal beds consist of pebbly grits and sandstones not definitely of glacial origin.

(ii) *Lower Marine Series.*—The basal conglomerates, tillites, &c., pass up into the Lower Marine series without any break. This series consists of highly fossiliferous marine mudstones, limestones, and mudstone conglomerates. The thickness ranges from 30 feet at Barn Bluff to approximately 1000 to 2000 feet in the southern districts.

The following genera are among the most prominent:—*Stenopera, Fenestella, Protoretepora, Productus, Strophalosia, Spirifera, Aviculopecten, Eurydesma, Pachydomus, Platyschisma, Pleurtomaria, and Conularia.*

The limestone member of this series is prominent throughout the State, and ranges in thickness from 50 feet in the north-east to a maximum thickness of several hundred feet on Bruny Island.

(iii) *Greta Series.*—At many localities the Lower Marine series is succeeded by a freshwater coal-bearing series of sandstones and shales. It occurs particularly at Barn Bluff, Preolenna, Mersey Valley, and Lilydale in the north, and Bruny Island and Port Cygnet in the south. The series is characterised by *Glossopteris* and *Gangamopteris* flora.

At several localities (Quamby Bluff, Mersey Valley, Chudleigh, and Oonah) in the north central districts, the Greta freshwater series is replaced by a Marine series containing beds of tasmanite oil shale. In these areas it would appear that freshwater conditions did not exist, but the marine (probably estuarine) conditions continued from the Lower Marine series.

In some districts in the south the Greta series has not been definitely proved to exist, and it is probable that the Lower and Upper Marine sedimentations were continuous.

(iv) *Upper Marine Series.*—The Greta series is conformably overlain by the Upper Marine series. This series consists mainly of white siliceous mudstones and impure sandstones, and it is not so fossiliferous as the Lower Marine, the upper portion being only sparingly fossiliferous. It is thickest in the south, and reaches 1000 to 2000 feet in the vicinity of Hobart.

The fossils are generally similar to those in the Lower Marine, the most plentiful being *Fenestella, Spirifer,* and *Strophalosia.*

In many districts the Upper Marine series is overlain apparently conformably by the basal grits of the Triassic system.

(v) *Tomago Series.*—In several districts (Barn Bluff, Preolenna, Sandfly, Cygnet) the Upper Marine series is overlain by a thin freshwater series, with a *Glossopteris* flora. It has been correlated with the Tomago series of New South Wales.

The above subdivisions give the general section of the system as at present recognised in Tasmania, but there are features in some localities of which the correct stratigraphic positions have not been determined.

At Cape Paul Lamanon, A. N. Lewis has described a glacial series containing blocks of fossiliferous Permo-Carboniferous limestone. If the limestone is from the Lower Marine, then there must be a glacial series above it in some localities at least.

In the ordinary section the usual coal-bearing series (the Greta) is, of course, above the Lower Marine series (including the limestones). At Mt. Elephant, near St. Marys, however, two thin coal-seams occur below limestones, which apparently are the usual Lower Marine limestones. It will appear, therefore, that either another freshwater series will have to be recognised below the Lower Marine, or else a new limestone horizon will have to be recognised below the Lower Marine.

(4) Mesozoic.

(a) *Triassic.*

The basal beds of this system succeed the Permo-Carboniferous without any apparent break, although it is probable that a disconformity exists. They are not so widespread as the Permo-Carboniferous, and are restricted to the eastern half of the island. The Triassic contain no rocks definitely of marine origin, though some may be of estuarine origin. The remainder are of freshwater origin. Folding is absent, but block faulting has caused tilting, the resultant dips being seldom over 10°, and usually ranging from 0° to 10°. Large-scale faulting and huge intrusions of doleritic magma accompanied earth movements at the close of the Triassic period.

Four sedimentary series have been recognised, as follows:—

(i) *Basal Grit Series.*—The basal series of the Triassic consists of fine conglomerates and grits. The pebbles are composed of quartz and quartzitic types, and rarely exceed a few inches in size. The matrix consists almost wholly of quartz grains. The thickness of the series is small, ranging from 50 to 100 feet.

This series is apparently restricted to the midland, eastern, and south-eastern districts, and is not present in certain parts, e.g., St. Marys, of the north-eastern districts.

When visible this series overlies the uppermost beds of the Permo-Carboniferous system, with an apparent conformity. The uppermost beds of the Permo-Carboniferous system consist of very fine-grained marine rocks resembling mudstones, but composed principally of silica.

The change in nature of the rocks from the Upper Permo-Carboniferous beds (marine siliceous mudstones) to the basal Triassic (freshwater or estuarine conglomerates and grits) indicates a change of conditions of sedimentation, and perhaps an interval of time. The junction of the two systems is therefore regarded as a disconformable one.

No fossil plants or animals have been found in this series.

(ii) *Ross or Lower Sandstone Series.*—This series occurs throughout the south-eastern, midland, and eastern districts, but is absent in certain parts of the north-eastern districts, e.g., St. Marys and Dalmayne. When this series and the basal grits are absent, the Middle or Felspathic Sandstone series (see below) directly overlies the Permo-Carboniferous system.

In the midland and south-eastern districts this series attains a maximum thickness of 800 feet, but apparently is thinner to the north-east.

The rock types are quartzose sandstones, with interbedded shales and mudstones. The sandstones are of medium grain size, the grains often having glistening faces (crystal or fracture). Mica (both biotite and muscovite) is plentiful, being particularly developed along the bedding-planes. False or current bedding is common, and while generally it is referable to the action of currents in shallow water, it may sometimes be due to wind action in the formation of dunes. Clay pellets (flat and ellipsoidal) are common in the sandstones, and also in the mudstones, and in extreme cases form mudstone or "clay-pellet" conglomerates.

The mudstones and shales are generally present in thin beds, and present a considerable diversity of types. The mudstones are unstratified, and range from white to grey in colour. There is, however, a more or less complete gradation to the thinly stratified shales. Carbonaceous types are present, but no seams of good coal occur.

Certain zones of the sandstones are slightly saliferous, and solutions percolating them deposit halite and epsomite.

The basal grits pass by gradual reduction of grain size into the Ross series, and the relation is undoubtedly a conformable one. The Ross series is overlain apparently conformably by the Felspathic Sandstone series.

The Ross series has the following fossil animals and fish:—

Two humeri of labyrinthodonts (Hobart).
Acrolepis Hamiltoni (Hobart).
Acrolepis tasmanicus (Tinder Box Bay).

Fossil plants have also been found, especially in the shales and mudstones, but they are not nearly as plentiful as in the overlying Felspathic Sandstone series. A complete record of the fossil plants in this series is not possible, as the fossils from this and the overlying series have not been kept separate. It can be said that the fossils include the more common genera of those occurring in the Felspathic Sandstone series. Such would include *Phyllotheca, Cladophlebis, Thinnfeldia, Phœnicopsis,* and a cone described as *Lepidostrobus mulleri* (of which the generic determination is apparently wrong).

The false bedding, saliferous nature, and nature of the fossils (plants, fish, and animals) point to origin in shallow waters (estuarine and/or lacustrine), with possible terrestrial conditions at intervals, under possibly sub-arid conditions.

(iii) *The Middle or Felspathic Sandstone Series.*—This series is more extensively developed than the underlying series, and occurs throughout the south-eastern, midland, and north-eastern regions of the State.

The rock types include felspathic sandstone, mudstones, shales, quartzose sandstones, and coal-seams. The most common type is the felspathic sandstone, which is medium to coarse in grain, and consists of felspar (more or less decomposed), quartz, and mica (biotite and muscovite), with clay pellets similar to those in the Ross sandstones. The mudstones and shales are white to grey in colour, and are highly fossiliferous. Sandstones similar to the Ross are interbedded, but are subordinate in amount. Carbonaceous shales are common, and coal-seams ranging in number to eight have been found to occur.

The following thirty-four species have been determined:—

Equisetales:

Neocalamites carrerei (Zeiller).
Neocalamites hœrensis (found later).
Phyllotheca australis (Brongn).

Filicales:

Cladophlebis australis (Morris).
Cladophlebis tasmanica (Johnston).
Cladophlebis Johnstoni (Walkom).
(?) Phlebopteris alethopteroides (Eth., Jr.).
Thinnfeldia Feistmanteli (Johnston).
Thinnfeldia odontopteroides (Morris).
Thinnfeldia lancifolia (Morris).
Thinnfeldia acuta (Walkom).
Thinnfeldia cf. *talbragarensis* (Walkom).
Johnstonia coriacea (Johnston).
Johnstonia dentata (Walkom).
Johnstonia trilobita (Johnston).
Linguifolium diemenense (Walkom).
Linguifolium Lillieanum (Arber).
Sphenopteris Morrisiana (Johnston).
Pecopteris (cf. *Hillæ*, Walkom).
Tæniopteris Morrisiana (Johnston).
Tæniopteris Carruthersi (Tenison-Woods).
Sagenopteris moribunda (Johnston).
Chiropteris tasmanica (Walkom).

Cycadophyta:

Pterophyllum Strahani (Johnston).
Pterophyllum Risdonensis (Johnston).
Pterophyllum (Anomozamites) inconstans (Braun).
Pseudoctenis sp.
Sphenozamites Feistmantelii (Johnston).

Ginkgoales:

Ginkgoites digitata (Brongn).
Ginkgoites salisburioides (Johnston).
Baiera tenuifolia (Johnston).
(?) Baiera bidens (Tenison-Woods).
(?) Czekanowskia sp.
Phoenicopsis elongatus.

These have been examined and determined by Dr. Walkom, who considers the beds to be Upper Triassic.

The series are conformable with the underlying Ross series, but the change in the conditions of sedimentation from those of the latter to the lacustrine or swampy conditions of the former indicates a slight break. The Felspathic Sandstone series pass up conformably into an overlying series of sandstone similar to the Ross series.

(iv) *Upper Sandstone Series.*—This series has been reported from one district only, viz., St. Marys, where 200 feet of sandstone, similar to the Ross, overlies it. No fossils have been discovered.

(v) *Igneous Intrusions.*—The Permo-Carboniferous and Triassic rocks have been block-faulted and intruded by dolerite (diabase) on a large scale, the faulting and intrusions being contemporaneous. The intrusions are in the form of large sills, with transgressive bodies and dykes arising from the sills into the overlying strata. The intrusions are pre-Tertiary, and probably occurred at the close of the Triassic sedimentation, which would conform to similar dolerite intrusions in South Africa, &c.

The rock attains its greatest development throughout the eastern half of the State, but appears as isolated cappings of some of the mountains in the western portion.

(*b*) *Jurassic; Cretaceous.*

Rocks referable to these periods have not been located in Tasmania. These periods are represented by an interval of erosion continuing into the Tertiary era.

(5) Tertiary.

(*a*) *Oligocene.*

The occurrence of basalt at Marrawah is the only rock which can be placed in this division. The basalt forms a small plateau, round which Miocene limestones (containing pebbles of the basalt) have been deposited. As the limestones yielded fossils determined to be Lower Miocene, the basalt is of pre-Miocene age, and is comparable in age with the Older basalts of Victoria.

(*b*) *Miocene.*

Small thicknesses of marine limestones, calcareous sandstones, and brownish mudstones occur in the far north-western districts. The beds, before partial removal by erosion, were probably most extensive in the Marrawah-Cape Grim-Welcome River district. At Table Cape, near Wynyard, fossiliferous limestones and calcareous sandstones of marine origin, with exposed thickness of 100 feet, are regarded as of Miocene age.

The determination of fossils from Temma, Marrawah, and Cape Grim prove the rocks in which they are contained to be of Lower Miocene age, so that they can be correlated with the Table Cape beds further east.

(*c*) *Pliocene.*

(i) *Lower.*—Freshwater clays, sands, and gravels occur at scattered localities throughout the State, the largest development being in the Launceston Tertiary basin, where they obtain a thickness of several hundred feet. Other localities are Ringarooma Valley (400 to 500 feet), Waratah (100 to 150 feet), Tamar Valley, St. Helens, Macquarie Harbour, Henty River, and Derwent Valley.

The sediments contain seams of brown coal and fossil leaves and fruit, &c. Generally they are overlain by basalt.

The alkaline intrusive rocks of the Cygnet district are referred to the Tertiary era, but their exact position in it is doubtful. They include alkali syenite porphyries, solvsbergite, &c.

(ii) *Upper.*—In general, the Lower Tertiary sediments are covered by basalt flows ranging in thickness up to 300 feet. The normal types are basalt and olivine basalt, but at Sandy Bay, Shannon Tier, and Stanley nepheline basanite occurs. Basaltic lavas were outpoured over the greater part of the north coastal districts, and along many of the midland and southern valleys. At Smithton, in the north-west of the State, four distinct flows of basalt have been recognised, each flow being separated by beds of freshwater sediments.

The only direct evidence of the age of these basalts is at Table Cape, where the basalt overlies the Lower Miocene marine sediments.

In most of the other localities the rock overlies freshwater beds, the leaf remains in which suggest a Lower Tertiary age for the beds. The basalts are therefore regarded as being post-Miocene, and probably the equivalents of the Victorian Newer basalts.

Small thicknesses of sands, gravels, &c., were deposited above the basalt in several localities. The largest area occurs in the midlands, where 30 feet of sands have been formed.

The Werrikooian series is represented at Wingaroo, Flinders Island, where fossiliferous marine sands have been penetrated to a depth of 80 feet by boring. This represents the first record of marine beds of Werrikooian age in Tasmania.

(6) QUATERNARY.

(*a*) *Pleistocene.*

The Tasmanian glaciation is assigned to this period, so that the morainal and fluvio-glacial deposits of the western highlands are referred to as Pleistocene.

The Mowbray Swamp deposits of marine and freshwater beds, in which *Nototherium* remains have been found, are of this age from the evidence of the contained molluscs and ostracoda. The sands, gravels, &c., of the Great Northern Plain, Gladstone, may also be of this age.

(*b*) *Recent.*

The recent deposits include gravels and alluvium accumulating along the courses of numerous streams, and raised beaches, sand dunes, and kitchen middens appearing at intervals along the coast-line.

IV.—THE MINING INDUSTRY.

(1) History.

The mining industry of Tasmania began with the discovery and mining of coal early in the nineteenth century (probably about 1820). Coal was found at many localities, and numerous mines were opened in the thirties and forties. Work has ceased in these districts, and coal is now being mined in others more favourable for the economic production of coal.

Another product which was also largely mined in the early history of the State was the sandstones for building purposes, as witnessed by the large number of old houses and buildings, bridges, &c., throughout Tasmania.

The next important event was the discovery of gold near Mangana in 1852, which was followed by the location of the principal alluvial and reef goldfields during the sixties and seventies.

During and following the gold boom a large area of the State was prospected, and attention was also given to other metallic mineral deposits.

An epoch-making event was the discovery of the world-famous Mt. Bischoff Tin Mine in 1871. This led to extensive prospecting in North-Western and Western Tasmania, and the discovery of numerous other mineral fields. The discovery of the Heemskirk tinfield was made in 1876 or 1877, followed by that of the Zeehan silver-lead field in 1882, and the Mt. Lyell deposit in 1883.

In the late eighties and the nineties the remaining important fields of the West Coast, such as Read-Rosebery, Mt. Farrell, and Dundas, were discovered.

During the same period the important tinfields of North-Eastern Tasmania and further goldfields were found.

Thus by the year 1880 the mining industry was firmly established, and became an important factor in the development of the State. The further development of the industry is indicated by the statistics which will be given below.

(2) Annual Production.

The following table (No. 1) shows the total annual production of the mining industry from 1880 till 1936:—

Table No. 1.

Year.	Value.	Year.	Value.
	£		£
1880	554,031	1912	1,493,502
1881	602,723	1913	1,415,700
1882	556,306	1914	1,007,038
1883	560,873	1915	1,225,575
1884	468,302	1916	1,521,050
1885	518,885	1917	1,582,322
1886	489,966	1918	1,597,694
1887	593,256	1919	1,301,090
1888	616,733	1920	1,421,104
1889	504,718	1921	822,851
1890	444,210	1922	1,013,415
1891	528,388	1923	1,219,456
1892	526,909	1924	1,496,804
1893	627,909	1925	1,700,861
1894	732,764	1926	1,808,847
1895	575,692	1927	1,621,027
1896	662,058	1928	1,593,828
1897	1,006,140	1929	1,790,653
1898	1,071,084	1930	1,270,114
1899	1,660,622	1931	894,986
1900	1,888,695	1932	897,168
1901	1,763,896	1933	1,053,373
1902	1,378,406	1934	1,037,351
1903	1,354,044	1935	1,387,511
1904	1,379,204	1936	1,979,637
1905	1,729,129	Unenumerated prior to 1894	31,988
1906	2,257,147		
1907	2,277,159		
1908	1,650,027		
1909	1,574,995	Total sterling	£67,520,906
1910	1,432,193		
1911	1,349,497		

The production reached a maximum of £2,277,159 in 1907, and then decreased almost continuously until 1921. It increased from 1922 to 1929, but showed a decline during the world depression years, 1930-1932. In the following years, 1933-1936, a marked improvement in value took place, and it will be noted that production in 1936 was the third greatest in the history of the State.

(3) DETAILED PRODUCTION OF MINERALS AND METALS.

The following table (No. 2) gives the total production of the various minerals, metals, &c., that have been produced between 1880 and 1936:—

Table No. 2.

Mineral or Metal.	Value.
	£
Asbestos	7,105
Barytes	7,014
Bismuth	25,934
Cadmium	31,713
Carbide	1,212,207
Cement	2,004,014
Coal	2,731,881
Copper (blister) to 1918 (now shown under Silver and Copper)	13,778,527
Copper matte	133,734
Copper ore to 1918 (now under Copper)	577,873
Copper (from 1919)	8,341,003
Gold	7,996,700
Granite	3,209
Ilmenite	1,256
Iron ore	25,701
Iron pyrites	167,113
Lead (from 1919)	1,738,787
Limestone	1,240,194
Nickel	35,246
Ochre	375
Osmiridium	613,681
Scheelite	112,468
Shale (oil)	23,908
Silica	3,231
Silver-lead to 1918 (now shown as Silver and Lead)	6,429,291
Silver (since 1919)	1,435,925
Talc	315

Table No. 2—contd.

Mineral or Metal.	Value.
	£
Tin	17,207,046
Wolfram	347,089
Zinc	1,256,306
Unenumerated	31,988
Total sterling	67,520,906

It is to be noted that, from the point of view of total production to date, the order of importance is copper, tin, silver-lead, gold, coal, cement, zinc, limestone, carbide, osmiridium, tungsten, pyrite, cadmium, bismuth, iron ore, oil shale, asbestos, and barytes.

The annual production of each of the minerals or metals for the year 1936 was as follows:—

Mineral.	Quantity.	Value.
		£
Barytes (tons)	33	66
Coal (tons)	132,264	92,269
Carbide (tons)	6,855	137,100
Cement (tons)	73,285	210,489
Copper (tons)	13,030	556,734
Cadmium (tons)	33·64	10,799
Gold (ozs. f.)	17,600·47	123,383
Granite, red (tons)	568	3,209
Lead (tons)	7,563·04	134,413
Limestone (tons)	262,301	71,243
Osmiridium (ozs.)	280·6	3,862
Pyrites (tons)	33,711	33,711
Silver (ozs. f.)	906,458	81,036
Silica (tons)	6,463	3,231
Tin (tons)	1,004·06	206,656
Talc (tons)	3	8
Wolfram (tons)	207·13	28,323
Zinc (tons)	18,769	283,105
Total Sterling	.... £	1,979,637

Total Sterling Australian Currency £2,331,783

From the present production the order of importance is therefore copper, zinc, cement, tin, carbide, lead, gold, coal, silver, limestone, pyrites, tungsten, cadmium, osmiridium, silica, granite, barytes, and talc.

(4) Geographical Distribution of the Mineral Fields.

The principal metallic mineral fields are situated in the western, north-western, and north-eastern parts of the State. The western and north-western districts include the copper, silver-lead, zinc-lead-silver, iron, tin (partly), nickel, osmiridium, barite, and asbestos deposits.

The north-eastern district contains the gold, tin (lode and alluvial), and tungsten deposits.

The coal deposits occur throughout the south-eastern, eastern, and northern districts, while the sandstones for building purposes are restricted to the two former.

The oil shales are restricted to the northern and north-western portions.

Limestone deposits of excellent quality are distributed throughout the island.

(5) Relation Between Geological Structure and Mining Fields.

The above geographical distribution is a direct result of the geological structure and history of Tasmania. The whole of the primary deposits of the metallic minerals and certain non-metallic minerals (barite, &c.) are generally connected with the granite, porphyries, &c., of Devonian age. The granite and porphyries intrude Proterozoic and Lower Palæozoic sedimentary rocks, and the above deposits occur both in the sedimentary and igneous rocks. As these rock systems are practically restricted to the western, north-western, and north-eastern districts, the geographical distribution is readily understandable.

The coal seams occur in the Permo-Carboniferous and Triassic systems, while the oil shales are restricted to the former, and the building sandstones to the latter.

These two systems are restricted, with a few minor exceptions, to the eastern parts of the State, so that the coal, shale, and sandstone deposits are similarly restricted.

(6) The Future of the Industry.

The future of the mining industry depends upon the following factors:—

(*a*) *Continued Working of the Present Mines, &c.*—This factor is dependent upon many others, such as price of the products, extent and value of the deposits, cost of working, &c. Though mines are not inexhaustible, it may be stated generally that is no reason to expect the present mines, industries, &c., to do other than continue operations in the near future on the same scale as at present.

(*b*) *Exploitation of Known Deposits at Present Unexploited.*—There are in Tasmania mineral deposits of considerable magnitude and value which are at present either not being worked, or are being worked on a scale incompatible with their importance. This applies especially to the deposits of limestone, oil shale, iron ore, building-stones, and partly to those of tin in the north-eastern and western districts. As an illustration, the zinc-lead deposits of the Read-Rosebery district may be cited. Until a few years ago these deposits would have been included in this group, but owing to the commencement of operations by the Electrolytic Zinc Company they now form one of the most valuable of our deposits being exploited, and during 1936 yielded zinc, lead, silver, gold, and cadmium to the value of £501,175.

The limestone deposits are large, of good grade, and generally convenient for quarrying, so that there is scope for the development of numerous industries, such as cement manufacture, &c.

The oil shale deposits are extensive (at least 31,000,000 tons reserve) and of fair grade (assumed to average 27 gallons of crude oil per ton). The particular problem associated with them is the best type of plant for treating them and the general factors associated with the commercial exploitation of them.

(*c*) *Discovery of New Mineral Deposits and Fields.*—The discovery of new deposits is, of course, the factor upon which the ultimate future of the industry depends. In those parts, such as the western, north-western, and north-eastern districts, where the geological conditions are extremely favourable for the occurrence of primary mineral deposits, it is highly improbable that no further discoveries will be made.

Surface prospecting may not reveal as many as it has done in the past, because naturally the most easily found have already been discovered. Nevertheless it is very probable that search in the least prospected areas and heavily timbered ones will reveal new ore-bodies. The ordinary underground exploratory work of mining companies should also reveal new bodies of ores. The greatest results are likely to be obtained, however, from scientific prospecting by geophysical methods in the known mineralised zones and their extensions.

(7) General Conditions Affecting the Mining and Metallurgical Industries.

(*a*) *Water-supply.*—The mining districts are situated in regions having annual rainfall ranging from 40 to 160 inches. The resulting water-supply in the lakes and streams is therefore an abundant one for mining purposes, especially aided by conservation schemes. In some cases the mines have individual hydro-electric power schemes, proving that there is sufficient water for this as well as the ordinary mining and metallurgical purposes.

(*b*) *Power.*—As already mentioned, some of the mines have individual hydro-electric power schemes. In addition the State Hydro-Electric Department has already installed schemes totalling 144,000 h.p., which represents a mere fraction of the State's hydro-electric power resources.

The power is available at low rates, especially if taken in large blocks. The conditions are extremely favourable for large mining and metallurgical companies requiring large blocks of power.

(*c*) *Timber.*—The mining fields embrace large areas of timbered country, containing forests of eucalypts, beeches, &c., which are suitable for general mining and constructional work, both as regards quantity and quality.

(*d*) *Transportation.*—The coast contains many harbours suitable for large ships. The interior is traversed by convenient railways and roads connecting it with one or more of the ports. Any lines needed to open up any field would be short in length.

(8) Importance of the Mining Industry.

The importance of the industry may be judged from the figures quoted above. The total production during the past 56 years has amounted to £67,520,906, or an average production of £1,205,730. The production for 1936 was £1,979,637, which is well above the average.

The State owes much to the mining industry, which has enabled the development of large parts of its territory, and it may be said that a large amount of its prosperity is due to this industry.

From an investor's point of view it is interesting to note that approximately £10,000,000 has been paid in dividends by mining companies operating in Tasmania. In addition to actual dividends many mines have been partly equipped out of profits, while the profits made by small syndicates, individuals, &c., cannot be included, due to lack of information.

The importance of the industry is also emphasised by the numerous minerals, metals, and other products which have been produced in the past, while it is possible that even a greater number may be produced in the future.

V.—THE MINERAL DEPOSITS.

(1) Metallic Minerals.

The metallic mineral deposits are present in the north-eastern, north-western, and western districts. The north-eastern district contains deposits of gold, tin, and tungsten. The north-western district contains those of tin, silver-lead, tungsten, copper, iron, gold, and osmiridium. The western district contains those of copper, silver-lead, zinc-lead-silver, iron, nickel, and osmiridium. Osmiridium occurs in the south central, and small deposits of tin in the south-western district. The geographical distribution of each metal or mineral will be described separately under its own heading.

(a) *Distribution Throughout the Rock Systems.*

(i) Primary Deposits.

The primary metallic (and certain non-metallic) mineral deposits are distributed throughout the various rock systems as follows:—

Proterozoic.—The Proterozoic rocks contain no important mineral deposits, but only a few small and not very important ones. This is due probably to non-development of large intrusions of granite or porphyry in these rocks. Near Cox Bight and Ray River small veins of tin ore are present, while near Port Davey small veins of stibnite occur. Near Mt. Remus pyritic and other veins carry molybdenite and cobalt (in the pyrite), while in the Pelion district lodes containing ores of tin, tungsten, and copper occur. Basic igneous rocks at Quamby Bluff contain copper ores.

Cambro-Ordovician.—The pre-Dundas or Rosebery series is not extensively developed on the West Coast, but possibly the Farrell slates belong to this series, and contain the North Mt. Farrell silver-lead ore-body. The Balfour series may also be the equivalent, and this series contains the copper lodes and some of the tin lodes of the Balfour district.

The Dundas series contains some of the silver-lead lodes at Zeehan and Dundas, tin and silver-lead lodes of North Dundas, tin lodes at Renison Bell and Mt. Lindsay, copper lodes at Colebrook Hill, some of the unimportant silver-lead lodes of the Waratah district, and the unimportant copper and silver-lead lodes of the Leven River district.

The Mathinna series of the north-eastern districts contains the auriferous quartz reefs, the tin-tungsten lodes of the Storey's Creek district, and the copper, tin, and tungsten lodes of the Scamander district.

Silurian.—The rocks of this system contain some of the silver-lead lodes of Zeehan, barite lodes on Howard's Plain, possibly a small part of the Mt. Lyell copper deposits, some of the tin lodes of Mt. Bischoff, unimportant galena lodes of the Waratah district, the silver-lead, the tin, and tungsten lodes of the Moina district, and the iron deposits of the Dial Range and Blythe River districts.

Devonian Igneous Rocks.—The granite of the north-eastern and western districts in almost every case contains numerous tin deposits.

The porphyries at Mt. Bischoff contain some of the tin deposits, while the sheared porphyries of the West Coast mineral belt contain the copper deposits of Mt. Lyell and Jukes-Darwin and the zinc-lead-silver deposits of Mt. Read, Rosebery, &c.

The basic and ultra-basic rocks contain the osmiridium lodes of Bald Hill, Mt. Stewart, and Adamsfield, the copper-nickel lodes of the Five-Mile (Zeehan), the nickel deposits of Trial Harbour, &c., the iron deposits of Zeehan, Long Plains, and Anderson's Creek, and the silver-lead deposits of Magnet, &c., in the Waratah district.

Permo-Carboniferous.—The only deposits in these rocks are the unimportant gold ones in the Cygnet district.

(ii) Detrital Deposits.

The detrital deposits are restricted to the younger rocks, especially the Tertiary and Recent ones.

Permo-Carboniferous.—In a few places in the north-eastern districts, e.g., Roy's Hill, the basal conglomerates contain detrital tin ore derived from lode formations in the underlying granite.

Tertiary.—The Tertiary freshwater sediments in mineral districts often contain minerals such as gold, tin ore, and osmiridium. In many cases they are overlain by Pliocene basalt, and form sub-basaltic systems of deep leads. The most important system is that of the Ringarooma Valley, which contains the important tin deposits worked in the Arba, Briseis, Echo, Pioneer, and other mines. The leads of the George and Mussel Roe Rivers and the St. Dizier lead are also tin-bearing. The deep leads at Lefroy and Back Creek contain gold, while those at Bald Hill contain osmiridium.

Recent.—The numerous alluvial deposits along the present streams often contain valuable metals and minerals. Those of the north-eastern districts, and of Heemskirk, Stanley River, Waratah River, Cox Bight, &c., have been worked for their tin ore. At Lisle, Mangana, Mathinna, Alberton, Lefroy, Corinna, and Queenstown districts they have been worked for gold. Practically the whole of the osmiridium won has been obtained from the Recent deposits at Bald Hill, Nineteen-Mile Creek, Savage River, Wilson River, and Adamsfield districts.

(*b*) *Metallogenetic Periods.*

It will be realised from the above descriptions that the primary metallic (and certain non-metallic) mineral deposits are almost entirely restricted to Lower Palæozoic sedimentary rocks and Devonian igneous rocks. This means, in other words, that the Devonian intrusions of igneous rocks represent the most important metallogenetic periods. Other periods occur, and will be referred to below, but are relatively unimportant.

(i) Proterozoic.

The only ores definitely referable to this period are some copper ones in the Quamby Brook district, which A. M. Reid found to be associated with a certain band of basic igneous rocks of Proterozoic age.

(ii) Cambro-Ordovician (Porphyroid).

Certain ore-bodies, such as the iron ores of Jukes-Darwin, some of the copper ores of the same region, the iron ores of Long Plains, the barite deposits, and other unimportant ones, were formerly referred to this period, but are now regarded as belonging to the Devonian period, as the igneous rocks with which they were associated are referable to the Devonian intrusions.

(iii) Devonian.

This is the most important metallogenetic period in the State, and resulted in the formation of the important primary mineral deposits. Several phases are recognised.

Basic.—The serpentinised peridotites of the Bald Hill, Mt. Stewart, Wilson River, and Adamsfield districts have been the source of the osmiridium which rendered the detrital deposits of such importance. Similar rocks contain the nickel deposits at Trial Harbour, Heazlewood, &c., and the more important ones at Five-Mile district, Zeehan. The magnetite of Long Plains, and possibly that of Zeehan, is also associated with the basic rocks.

Acidic.—The whole of the tin deposits are associated with the granitic rocks and the porphyries connected therewith. The auriferous quartz reefs of the north-eastern regions are also associated with the granitic rocks, and occur in the adjacent intruded sedimentary rocks.

The copper, silver-lead, zinc-lead-silver, barite, and gold deposits of the western and north-western regions appear to be associated with the porphyry offshoots from the granitic intrusions.

(iv) Tertiary.

This is an unimportant period, and has given rise to only one set of deposits, viz., the gold deposits of the Cygnet district. Gold occurs at and near the contact of alkali porphyry with Permo-Carboniferous mudstones, &c.

(c) *Gold.*

Gold was the first metallic mineral found in Tasmania in payable quantities, the first discovery being at the Nook, near Fingal, in 1852, and the first quartz mine started in the same district. Since then a number of fields have been discovered, chiefly in the north-eastern districts.

The total production of gold to date has been 1,963,890 oz., with a value of £7,996,700. This has been obtained from quartz reefs, copper ores, alluvial deposits, &c.

The primary deposits are, with one exception, all of the same age, and occur in Lower Palæozoic rocks intruded by Devonian granites and porphyries. In the north-eastern districts the quartz reefs occur in Cambro-Ordovician slates and quartzites intruded by granite. The main belt is that through Mangana, Mathinna, Mt. Victoria, Alberton, Warrentinna, Forester, and Waterhouse. This belt occupies a trough between two cupolas of the granite batholith. The fields of Lisle, Lefroy, and Beaconsfield occur outside this belt, but may occupy analogous positions with regard to the western side of the batholith.

In the north-western and western districts quartz reefs are not numerous, but those that do exist, and also small alluvial districts, occur near Devonian porphyries which are intrusive into Lower Palæozoic rocks, and particularly those belonging to the Silurian system.

The deposits of the north-eastern districts are the normal quartz reefs. In addition to the gold they carry small quantities of sulphides, such as arsenopyrite, pyrite, galena, sphalerite, stibnite, &c. In the Alberton and other fields in the far north-east, arsenopyrite is the predominant sulphide, and, in conjunction with the proximity to granite, indicates a higher temperature of formation. At Mathinna pyrite was the predominant sulphide, while galena was more closely associated with the gold than the other sulphides. At Lefroy pyrite and stibnite were the most plentiful sulphides.

The Mathinna field is occupied by slates and quartzites, with strikes of 20° to 30° west of north. In general, the reefs show no relationship to the rock structures, but the most important reefs occur in a narrow zone of close folding. The Golden Gate was the most important mine, and produced 246,000 oz. of gold from 290,000 tons of ore. This mine was remarkable, in that only one reef (Western) really outcropped. Loane and Main reefs were discovered at shallow depths, and worked to a depth of 800 feet. Two other reefs (East and West) were worked from 800 to 1800 feet. A "slide" bearing 30° W. of N. exists in the south of the mine, and the reefs appear to terminate at it; but it is probable that the slide is prior in age to the reefs, and that it acted as a channel for the solutions which formed the reefs.

The Alberton, or North Mt. Victoria, field contains more than 100 reefs (not all of commercial importance) in a belt $4\frac{3}{4}$ miles long and $1\frac{1}{2}$ miles wide, and trending in a N.N.W. direction. The reef-bearing belt comprises a closely folded (and faulted) zone in slates and quartzites, which otherwise represent a westerly-dipping series. The reefs have strikes which divide them into two groups striking at 30° and 330°, the former representing fault-fissures, and the latter fissures coincident with the bedding in strike but not always in dip. The strike of 30° (and a dip to the south-east) is the most common, and is the prevailing one in the northern half of the field. In the southern half three zones are recognisable—the eastern, with strikes of 330° and north-easterly dip; a central one, with strikes of 30° and south-easterly dips; and an unimportant western one, with strikes of 330°. About £100,000 has been the value of the production, the most important mines being the Ringarooma and Mt. Victoria.

The Lefroy goldfield is occupied by Cambro-Ordovician slates and sandstones, which show signs of alteration, chiefly by the development of mica in the latter. These rocks have a strike between 320° and 340°, and dip to the west at angles from 30° to 50°; folding being absent. The rocks at Back Creek, 6 miles to the north-east of Lefroy, dip to the east, showing that folding exists in adjacent regions. Faulting is the dominant structural feature of the district, and the auriferous reefs have been injected along a parallel series of faults which have bearings of approximately 80°. Subsequent movements along some of the fault planes have broken the reefs into a rubbly mass of quartz and mullock, and finally into a soft pug. All the reefs in this field owe their values to surface enrichment, and below the 400-feet level all the mines have become unpayable. The New Pinafore Company sank its shaft to 1200 feet, and did very extensive crosscutting and driving at this and other levels; but it was on unpayable ore practically all the time below the 400-feet level.

The Beaconsfield field is occupied by slates, sandstones, grits, conglomerates, limestones, &c., forming a conformable series, with a strike of 350° and a dip of 45° to the north-east. Several small folds occur at the north-western end of Cabbage Tree Hill. Faulting is common, but is earlier than the mineralisation. The principal reef worked was the Tasmania reef, from which 854,600 oz. of gold were obtained from 1,022,692 tons of quartz. The Tasmania reef has a general strike from north-east to south-west, but has a distinct curve at its western end, the strike finally approaching a north-westerly one. The reef dips to the south-east, and had a maximum length of 1500 feet. At the eastern end the reef has a natural ending, and breaks up into a series of veins in a clay bed adjacent to limestone. At the west end two faults occur, and there have been differences of opinion as to whether these were pre-reef in age or post-reef (and displaced the reef). The reef was, however, picked up west of the main fault, and possibly west of the other one. The reef was worked to a depth of 1500 feet, but the shoot became shorter and of lower value in depth.

The Mt. Lyell Mine was originally worked as a gold mine, the hematite adjacent to the pyritic body carrying good gold values. Since copper-smelting started the mine has been a consistent producer of gold, and a total of 430,491 oz. (fine) has been obtained.

Detrital deposits are restricted to Tertiary to Recent river gravels, &c. Sub-basaltic deep leads exist at Lefroy and Back Creek, but have not been proved payable. Small quantities of alluvial gold were won in all the goldfields of north-eastern and western districts, but the most important alluvial field was that of Lisle, from which at least 250,000 oz. were obtained.

(*d*) *Silver.*

Deposits composed chiefly of silver minerals do not occur, but small quantities are contained in the copper, silver-lead, and zinc-lead-silver ores, the treatment of which has yielded considerable quantities of silver. The total production is estimated at 55,500,000 oz. The Mt. Lyell Company has produced 14,470,902 oz. (fine) from its copper ores, and the remainder (41,000,000 oz.) has been derived from the lead and zinc-lead deposits of Zeehan, Dundas, Magnet, North Mt. Farrell, Rosebery, Mt. Read, &c. These ore-bodies will be described under their respective headings.

(*e*) *Copper.*

Copper deposits are restricted almost entirely to the western and north-western districts. The most important field is that at Mt. Lyell, while others occur at Jukes Darwin, Heazlewood, Balfour, and Scamander. The copper-nickel deposits at the Five-Mile district, Zeehan, are discussed under " Nickel."

The Mt. Lyell District is occupied by three important rock systems and formations, viz.:

Silurian Sedimentary Rocks.
Queen River Syenites or Porphyries.
Mt. Lyell Schists.

The Silurian rocks include the West Coast Range conglomerate series and the Queen River series.

The former series is at least 2000 feet thick, and consists of conglomerates, quartzites, and shales. Conglomerates predominate in the lower portion, and quartzites (with shales) in the upper portion. The Queen River series consists of limestones, sandstones, and shales, the sandstones being fossiliferous and often of a friable nature. The conglomerate series is the basal one, and is overlain by the Queen River series.

The Queen River porphyries occur in a belt along the east side of the Queen River, the belt having a width of 1 to 2 miles and a general north-and-south trend. The rocks include numerous types of intermediate and acid porphyries, such as quartz porphyry, felspar porphyry, syenite porphyry, &c. Gregory regarded these rocks as older than the Silurian, but it is not clear as to whether he regarded them as intrusive or extrusive. Loftus Hills regarded them as pre-Silurian lava flows. In recent years the Geological Survey has examined these rocks at many localities along the west and north-west coastal districts, and has found them to be intrusive into all rocks up to and including the Silurian. They are therefore now regarded as intrusive porphyritic rocks of Devonian age.

The Mt. Lyell schists represent a belt of schistose rocks occurring in the vicinity of the ore-bodies, and occupying a position between the Queen River porphyries on the west and the Silurian rocks on the east. They were regarded by Gregory as altered porphyrites and tuffs of pre-Silurian age. Loftus Hills considered them to be metamorphosed tuffs of pre-Silurian age. The Geological Survey is now regarding them (in conformity with similar schists at Rosebery, &c.) as sheared porphyries of Devonian age, i.e., sheared representatives of the Queen River porphyries.

The structure of the district is rather complicated. Gregory considered the boundary of the schists on the west and the conglomerates on the east to be a faulted junction, with a general north-south trend. He also mapped numerous east-west faults branching off the main one and extending into the conglomerates on the east side. Hills' conceptions of the structure were similar to the above, but he showed more cross-faults, and emphasised the folding, overthrusting, and faulting. If the more recently adopted views with regard to the porphyries are correct, the main schist-conglomerate contact will be partly, if not wholly, an intrusive one.

The ore-bodies are associated with the eastern side of the schists, and occur at or near the schist-conglomerate contact. Hills considered the location of individual ore-bodies to be due to the presence of the cross-faults or thrust-planes, the North Lyell and Blow thrust-planes having been responsible for the North Lyell and Mt. Lyell ore-bodies respectively. There are two main types of deposits, viz.:

(*a*) Lenticular Bodies of Pyrite.
(*b*) Mineralised Bands of Schists, &c.

The pyritic bodies include the Mt. Lyell and South Lyell deposits. The Mt. Lyell body was elliptical, being 800 feet long and 200 feet wide at the outcrop, and tapered gradually downward to a rounded base, the probable depth being 730 feet. The South Lyell body probably represents the parallel body to the Mt. Lyell body. The pyritic bodies are very pure, consisting essentially of pyrite, with some chalcopyrite galena, and less sphalerite, while the gangue (chiefly quartz and barite) is present in only small amounts. At first ore containing 2·35 per cent. copper was mined, but the grade decreased, and the average content became 0·5 per cent. copper, with 1·5 oz. silver and 0·4 oz. of gold, per ton.

The outcrop of the Mt. Lyell body was represented by hematite, rich in gold, and the mine was originally operated as a gold mine until the hematite was depleted.

The mineralised bands of schist, &c., include the ore-bodies of the North Lyell (and adjacent Crown Lyell, Lyell Blocks, Royal Tharsis) Mine and the Lyell Comstock Mine. They form large ore-bodies of considerable length and vertical extent, but irregular in shape, and with a considerable range in width. The North Lyell body has been mined to a depth of 1300 feet from the surface, while the Tharsis has been proved to a depth of 1000 feet. The ore consists of schists or quartzite, &c., with bornite, chalcopyrite, pyrite, &c.

All the above ore-bodies are owned by the Mt. Lyell Mining and Railway Company, and the following figures for the reserves were supplied by the General Manager (Mr. R. M. Murray) :—

	Tons.	Copper Content.
		%
North Mt. Lyell Mine	260,000	4·5
Lyell Comstock Mine	534,000	2·75
Crown Lyell Mine	230,000	2·00
Royal Tharsis Mine	2,300,000	2·00
Prince Lyell Mine	1,000,000	1·25
Lyell Tharsis Mine	201,000	1·50
West Lyell Mine	4,300,000	1·75

Since its inception until the 31st December, 1936, the Mt. Lyell Company has produced from 9,722,933 tons of ore, 303,099 tons of copper, 14,924,551 oz. (fine) of silver, and 430,716 oz. (fine) of gold, and paid £5,484,069 in dividends.

The present scale of operations is illustrated by the figures for 1936, during which year 665,422 tons were treated. Of this, 7289 tons of North Lyell ore were sent direct to the smelter, and the remainder was concentrated, to yield 51,675 tons of concentrates. Including a small amount of purchased ore, 58,966 tons of copper-bearing material were smelted, for a production of 13,136 tons of blister copper, containing 13,040 tons of copper, 103,189 oz. of silver, and 7046 oz. of gold, with an approximate value of £617,232.

The Jukes Darwin Field is situated to the south of Mt. Lyell field, and possesses the same geological features. The ore-bodies are similar, and occur under similar geological conditions and structural relations. The field has not been exploited owing to transport difficulties and absence of high-grade deposits.

The Mt. Balfour Field is occupied by Cambro-Ordovician sedimentary rocks intruded by Devonian (?) granite and amphibolites. The copper lodes are enclosed in the sedimentary rocks and the amphibolites. The metallic minerals are chalcopyrite and pyrite in a gangue of quartz, chlorite, sericite, and dolomite. Very little production has taken place.

The Heazlewood Field is occupied by intermediate, basic, and ultra-basic igneous rocks intruded in Cambro-Ordovician and Silurian sedimentary rocks. The copper deposits consist of bornite and chalcopyrite in the ultra-basic rocks, probably as segregations. The deposits are small, and the production has been very limited.

The Scamander Field is occupied by Cambro-Ordovician slates and quartzites intruded by granite. The rocks strike N.W.-S.E., and the lodes agree with them in strike. The primary ore consists of quartz, chalcopyrite, and arsenopyrite. The lodes appear to be low-grade, and have only been worked where secondary enrichment occurs at and near water-level.

The statistics of the Mines Department show the total production from Tasmania as follows (up till December, 1936) :—

	£
Copper and silver in blister copper to 1918	13,778,527
Copper ore to 1918	577,873
Copper matte	133,734
Copper (from 1919)	8,341,003
	£22,831,137

(*f*) *Silver-Lead and Zinc.*

Silver-lead and zinc-lead-silver deposits are restricted to western and north-western districts, the most important fields being those of Zeehan, Dundas, Read-Rosebery, Tullah, Magnet, and Moina.

The ores are of two types, viz., the silver-lead ores of Zeehan, Tullah, and Magnet, and the zinc-lead-silver of Read-Rosebery. The silver-lead ores consist generally of coarse-grained galena and sphalerite (usually high in iron and of the marmatite variety), the most common and characteristic gangue being manganiferous siderite. The Round Hill ore was somewhat different, in that sphalerite was not present to any great extent, but chalcopyrite was plentiful.

The zinc-lead-silver ores of Read-Rosebery are fine-grained mixtures of sphalerite, galena, and pyrite, and are important on account of their zinc content, whereas the others were worked for their galena content, the sphalerite being discarded.

The Zeehan Field is occupied by rocks of two sedimentary systems (pre-Silurian and Silurian) and numerous types of igneous rocks. The pre-Silurian system consists of slates, quartzites, and breccias, with spilite lavas and tuffs and keratophyre tuffs, and though not identical with the rocks of the Dundas series, they are sufficiently similar to be correlated with that series. The Silurian system comprises conglomerates, quartzites, slates, sandstones, and limestones, with Silurian fossils and includes the West Coast Range conglomerate series and the Queen River (or Zeehan) slate and sandstone series.

The igneous rocks include dykes of granite porphyry, aplite, and mica gabbro, while to the west serpentine, gabbro-amphibolite, and granite occur. These rocks all belong to the Devonian intrusions. The two sedimentary systems occupy their present positions by virtue of faulting. In the northern part of the field there appears to be one main fault, with a trend from N.N.W. to S.S.E., which separates the Dundas series on the west from the Silurian to the east, the latter being on the down-thrown side.

The greater number of the reefs have strikes parallel to the main fault, and the earth-movements apparently caused the formation of the fractures or fissures along which the lodes formed. There is an earlier set of fractures and fault zones which cross the lode fissures.

The vein types are numerous, and include pyrite-cassiterite, magnetite, magnetite-pyrite-chalcopyrite-sphalerite-galena, pyrite-blende-galena, pyrite-galena, siderite-galena, pyrite-stannite-chalcopyrite, and pyrite-stannite-galena. The siderite-galena type has been the most important type from the economic aspect. The siderite is manganiferous, and the galena argentiferous, while tetrahedrite and bournonite also contribute to the silver value of the ore. The proportion of silver was usually 1 oz. per unit or less.

Numerous mines were worked in the past, the most important being the Western, Montana, Spray, Queen, &c. The total production of the field was approximately £5,000,000. Most of the lodes were worked to shallow depths only, but the important ones were payable to 600 feet, and though tested to 1000 feet were found unprofitable.

The Magnet Ore-Body occurs near the foot-wall of a composite dyke of basic and ultra-basic rocks. The dyke was intruded along the northern side of a block of Silurian slates and sandstones faulted down into Dundas slates and breccias. The bounding faults intersect at Magnet, and form the western end of the faulted block, which extends easterly as far as Waratah. At the intersection of the faults the dyke extends to the west along the line of the southern bounding fault. The dyke was later than the faulting, and is Devonian in age. The dyke is 5 miles in length, with a width of 5 to 10 chains, and generally appears to be a medium to coarse dolerite (much weathered and altered). In the vicinity of the Magnet Mine the dyke is 20 chains wide, and dips to the north-west. The south-eastern, or footwall, side consists of 360 feet of ultra-basic rock, described by Rosenbusch as Websterite porphyrite. The central part is occupied by 300 to 400 feet of basic rock, described by Rosenbusch as diabase porphyrite, with which is associated some variolite. The western part is composed of spheroidal websterite or bronzitite.

The ore-body occurs in the hanging-wall part of the websterite porphyrite adjacent to the diabase porphyrite. The junction between these rocks is represented by the dolomite hanging-wall of the ore-body, this wall having a strike of 25° and a dip of 55° to the north-west. The wall is polished and slickensided, indicating movement along it. The dimensions and form of the ore-body have altered as depth was attained. At the surface, and down some distance, the ore-body had a strike of 20° to 30°, and occurred under the dolomite hanging-wall. At depth a branch made off to the south on the eastern side of, and approximately midway along, the ore-body. The southern part of the main portion diminished in length and importance, as did also the northern part, but at a less rate, while the branch (with a strike of north and south) became more important, and a large body of ore came in between the branch and the southern portion. The latter body in the apex became the most important at depth. Another change was also found at depth, when a narrow lode was revealed some 10 feet west of the dolomite hanging-wall. The country between the new lode and the main one was composed of dolomite and dolomitised diabase porphyrite, but at No. 16 level the country between the two lodes was occupied by ore over a considerable distance.

The ore consists of coarse-grained galena, sphalerite (marmatite), and pyrite, with the gangue minerals mangano-siderite or manganiferous siderite and ankerite, and partly replaced country rock. The ankerite is sometimes stained green, apparently by a chromiferous mineral. The first four minerals belong to one period of mineralisation, but the ankerite is distinctly later, and replaces all other minerals. The ore on the footwall is banded, but the remainder has no banding, and the deposit appears to have been formed by replacement.

The ore-body has been worked to a depth of approximately 1200 feet below the outcrop by the Magnet Company. The mine has yielded ore containing 35,000 tons of lead and 7,000,000 oz. of silver.

The Tullah or Mt. Farrell Field is occupied by Silurian sedimentary rocks and Devonian igneous rocks. The Silurian rocks include most of the members of the system from the West Coast Range conglomerates of Mt. Farrell to the slates, sandstones, and limestones of the Queen River and Zeehan series. The slates, &c., of the mineralised belt have been referred to as the Farrell slates, and possibly of Cambro-Ordovician age, but it is by no means impossible that they are members of the Silurian system, and will be regarded as such. The igneous rocks are those typical of the West Coast mineral fields from Mt. Lyell, through Mt. Read and Rosebery, to Tullah. They have been described as being chiefly volcanic rocks, with small bodies of intrusive rocks, but are now regarded as being wholly instrusive. They include quartz porphyry and felspar porphyry, syenite, granite porphyry, &c., while granite occurs at Granite Tor to the east. In places the igneous rocks are schistose, and have probably been rendered so by shearing.

The ore-bodies occur in a zone with a general north-and-south strike. They are not confined to any one rock, but exist in the porphyries, and also the slates near porphyry contacts. They are generally of the fissure lode type, but unimportant disseminated deposits also occur. The economically important lodes are those of silver-lead, and both carbonate-lead and pyritic-lead types are present.

The North Mt. Farrell has been the most successful mine. The lode has a strike of 9°, and dips westerly at 60° to 70°. It is contained in slates, a short distance east of their contact with porphyry. The ore consists essentially of galena, sphalerite, and siderite, with smaller amounts of chalcopyrite, pyrite, and carbonate minerals other than siderite. The mine was worked to a depth of 900 feet from the surface, but work at that depth ceased during 1932. The North Mt. Farrell Company produced ore containing over 40,000 tons of lead and 4,000,000 oz. of silver.

The Round Hill Field is occupied by Silurian conglomerates, quartzites, sandstones, limestones, &c., and Palæozoic igneous rocks. The latter have been described as Cambro-Ordovician felsites, keratophyres, &c., but are now regarded as porphyries and sheared porphyries of Devonian age. Several parallel lodes occur in a belt of folded tubicolar quartzite 800 feet wide, and are associated with the crests of anticlinal folds, the strike being W.N.W. The ore consists of galena, with abundant chalcopyrite, and some pyrite, sphalerite, and siderite, while bismuthinite, pinite, and quartz are also present.

The Read-Rosebery Field is occupied by Lower Palæozoic sedimentary rocks and Devonian intrusive igneous rocks. The former include those of a pre-Dundas or Rosebery series, the Dundas series, and the Silurian system. The Rosebery series occupies the central portion of the field, and has a general north-and-south trend, the rocks being dark slates and quartzite. The Dundas series forms a parallel belt of westerly-dipping rocks overlying the Rosebery series, the rocks being the typical grey, green, and red slates and breccias. The Silurian rocks (conglomerates) occupy the mountains to the east of the field.

The igneous rocks include ultra-basic (serpentine), basic (gabbro), and acid types. The latter are the most extensive and important rocks, and occupy the eastern half of the field. They include quartz porphyries and felspar porphyries, certain zones of which have been rendered schistose by shearing, and referred to as the Read-Rosebery schists. These rocks were formerly regarded as acid lava flows (keratophyres, &c.), interbedded with the Lower Palæozoic sedimentary rocks, but on evidence in this field and numerous other localities in Tasmania they are now regarded as intrusive porphyries of Devonian age.

The zone of sheared porphyries occurs along the western margin of the main porphyry intrusions, and the most important lodes occur in this zone. The planes of schistosity strike 340°. Isolated blocks of sedimentary rocks (possibly roof pendants) occur in the porphyries, and the shearing forces apparently reached their maximum in the vicinity of such blocks. The lodes occur at intervals over a length of 6 miles, the most important being the Rosebery lode at the north end, and the Hercules and Mt. Read groups at the south end. The Rosebery lode is a tabular one, 4000 feet in length, containing five more or less distinct lenses of payable ore. It occurs at the eastern boundary of the schistose porphyry, and adjacent to an included block of slates, &c., the latter determining in a general way the length of the lode. The lode, schistosity, and slates all dip to the east. The Hercules group includes up to eight lodes, some of which are irregular in outline. Schistose porphyries and slates are also in evidence here, but the structure has not been worked out in detail.

The ore is a fine-grained one of massive sulphides, composed chiefly of sphalerite, pyrite, and galena, with a small amount of carbonates and quartz as gangue. The Rosebery ore contains 35 per cent. of sphalerite, 31 per cent. of pyrite, and 7·3 per cent. of galena, with 24 per cent. of gangue, the assay being Zn 21·3 per cent., Pb 6·4 per cent., Cu 0·5 per cent., Ag 8·5 oz. per ton, and Au 2·12 dwt. per ton. The Rosebery lode may have been formed by replacement of the sheared porphyries or as simple fissure veins, while the Hercules ores appear to be replacement deposits.

The Electrolytic Zinc Company of Australasia leases all the important deposits. The mines are opened up and a modern treatment plant has been erected at Rosebery.

(*g*) *Tin.*

Tin ore is one of the most important mineral products of the State, the present annual production being 1004 tons (metallic), with a value of £206,656, while the total recorded production has been 143,426 tons (oxide and metallic), with a value of £17,207,046. It occurs in the north-eastern, north-western, western, and south-western districts. In the north-eastern district both primary and detrital deposits occur, the greater production being from the detrital deposits. In the north-western and western districts both types occur, but the production has been chiefly from the primary deposits.

Cassiterite is the common tin mineral produced, but from the Oonah Mine, Zeehan, small quantities of stannite were won in the past.

(i) Primary.

The North-Eastern District includes many fields and an extraordinary number of types of deposits. One of the principal groups of fields is that extending from Branxholm on the west to Blue Tier on the east. This group occupies the summit of a range, with a general trend from W.N.W. to E.S.E., and has supplied the greater part of the tin ore to the Ringarooma deep leads and to deposits in other streams. The deposits occur in Devonian granite, which has intruded Cambro-Ordovician slates and quartzites. In the western portion, in particular, numerous remnants of the slates, &c., which formed the roof of this part of the granite batholith occur. The tin deposits extend right up to the slates, and, as a general rule, do not penetrate the latter, although in a few cases veins of nearly pure cassiterite of dark colour extend upwards into the slates. The above conditions, viz., the top of the granitic intrusion, are the most favourable to occurrence of tin deposits, especially if the granite rises as a cupola above the top of the batholith. Other favourable conditions are around the sides of the cupolas. The deposits include veins of quartz greisen, quartz-mica greisen, and mica greisen, and irregular deposits of altered porphyritic granite (apparently ramified with extremely narrow veins of cassiterite), altered aplitic rocks, and "tin granites." The greisen veins were formed by pneumatolytic or hydrothermal actions along fissures in the granite. The altered granites clearly received their context of tin ore, and were subjected to the alteration (kaolinisation of the felspars, &c.) by pneumatolytic action on the already crystallised granite. The origin of the altered aplites and the "tin granites" has been considered to be due to either alteration of the granite, or to separate intrusions following the normal granite. The latter is probably the correct explanation, the intrusions, however, being accompanied by pneumatolytic action along their sides and summits. The "tin granites" differ little, if any, from the altered aplites, and consist essentially of fine to medium grained, non-porphyritic, granite rocks composed essentially of quartz, white felspar (more or less altered), and mica (either muscovite or what appears to be a bleached biotite). Pinite (used in Dana's sense of a massive mineral with the composition of muscovite) almost invariably accompanies the aplites and tin granites, and is particularly abundant where the rocks are richer in cassiterite. The tin granites and the ore-shoots in them contain other minerals in small quantities, such as fluorspar, tourmaline, topaz, molybdenite, &c. The tin granites are the most plentiful in the Blue Tier district in the vicinity of Lottah and Poimena. Numerous mines were worked in them, the Anchor Mine at Lottah having been the largest.

The Ben Lomond District is occupied by Cambro-Ordovician slates and quartzites intruded by Devonian granite. Permo-Carboniferous sedimentary rocks overlie the above, and have been intruded by Mesozoic dolerite. The tin ore deposits occur in the Cambro-Ordovician rocks and the granite, and were formed as a result of the granitic intrusions. The deposits consist chiefly of quartz veins and greisen veins, the "tin granite" type being absent, but the tin-bearing graphic granites, pegmatites, and porphyries are present. The quartz veins consist of ordinary reef quartz, and occur in the granite (but to a less extent), as well as in the slates and quartz-mica varieties, while quartz-tourmaline veins and pipe-like bodies also occur.

The Gipps Creek field includes quartz veins and quartz-mica greisen veins in granite, the general strike being 340° to 350°, and the dips easterly. Both cassiterite and wolfram occur, cassiterite predominating in the northern, and wolfram in the southern, part of the field.

The Story Creek field consists of slates and sandstones, the chief mineral deposits being quartz veins containing cassiterite and wolfram. The Story Creek Mine has opened up two veins, striking 350° and 335° respectively, and dipping westerly at 20° and

and 37° respectively. The veins were over 130 feet apart at the surface, but met at a depth of 480 feet on the dip. At this depth they diverged along their strike, but it appears that they are continuing in depth as one vein. The minerals present are cassiterite, wolfram, pyrite, and martite, in coarse and separate aggregates, usually near the walls. The ore contains 0·75 to 1·75 per cent. tin oxide and 0·75 to 2·0 per cent. wolfram, and slightly over £300,000 worth of these minerals has been produced.

The Aberfoyle Mine has opened up a series of narrow quartz veins, striking 10°, in slates and quartzites, striking 315° and dipping south-westerly. A fault striking at 350° crosses the vein system at an acute angle. The downthrow is to the west, and the throw is at least 50 feet, and may be considerably greater. This fault has lowered the Permo-Carboniferous basal beds which unconformably overlie the Cambro-Ordovician rocks, and the fault at the surface is marked by the contact of the two rock systems. Up to 50 feet of the Permo-Carboniferous rocks overlie part of the vein system, thus concealing the outcrop of many of the veins. The veins range in width up to 3 feet, and have lengths of several hundred feet. The veins consist of white reef quartz, and contain veinlets and blebs of cassiterite, wolfram, pyrite, sphalerite, &c., with pinite (finely crystalline to massive muscovite) and some fluorspar. The cassiterite is generally associated with the pinite, and both occur along the walls of the veins. From 1932 to 1936, 769 tons of tin (metallic) and 85 tons of wolfram were produced, with a value of £172,062.

The Gipps Creek field includes veins of greisen (with cassiterite and wolfram) in the granite, and, what is unusual in this part of the State, veins of reef quartz in the same rock. The Rex Hill ore-body is associated with graphic granite, and a portion of it consists of a mixture of cassiterite, chalcopyrite, sphalerite, galena, quartz, &c.

The St. Paul River field contains veins and bodies of quartz greisen, quartz-mica greisen, and quartz tourmaline in the granite. The Royal George Mine was the most successful, and opened up a quartz-greisen ore-body and produced at least 900 tons of tin ore.

The tinfields in north-western districts include those of Moina, Housetop, and Waratah, the Housetop field being relatively unimportant. The Moina field is occupied by rocks of the Silurian system (including nearly all series), overlying the so-called porphyroid series of pyroclastics, extrusive and intrusive igneous rocks, and intruded by Devonian granites, porphyries, &c. The ore-bodies are of two types—firstly, pegmatite and greisen veins in the granite; and, secondly, quartz veins in the metamorphosed sedimentary rocks and (to a less extent) in the granite. The most important mine was the S. & M., at Moina.

The country rocks are quartzites and garnet rocks, representing metamorphosed sandstones and limestones. The garnet rock consists of garnet (andradite and grossularite), with epidote, pyroxene, magnetite, vesuvianite, fluorite, &c. The rocks strike north and south, and dip westerly at 30° to 45°. Seven parallel lodes exist, with general east-west strikes, and consist of quartz fillings of fissures traversing at right angles the beds of quartzite and garnet rock. The lodes are remarkably straight, and have lengths up to 1200 feet. They are more uniform, and contain the best values in the garnet rock. The mineral components of economic value are cassiterite, wolfram, bismutite, and bismuthinite, in the proportion of: cassiterite, 20; wolfram, 12; and bismuthinite, 3; concentrates of the three being obtained and marketed.

The Mt. Bischoff field is occupied by Silurian sandstones and slates faulted down into Dundas slates and breccias, both systems being intruded by Devonian granite and porphyries. The ore-bodies of Mt. Bischoff are restricted to portion of the down-faulted Silurian block, which is ramified by porphyry dykes. The ore-bodies are of four types, viz.—

(1) Fillings of joints in, and impregnation of, slates and quartzites.
(2) Mineralised porphyry.

(3) Quartz fissure veins traversing the slates and sandstones, and the porphyries.

(4) Replacement deposits at intersections of fault and lode fissures.

The first three types need no description, but the fourth includes the largest and most interesting type. These replacement ore-bodies occur at the intersection of the fault and lode fissures, and consist, according to A. M. Reid, of pyrite and pyrrhotite replacements of dolomite, the latter being a hydrothermal alteration of peridotites and pyroxenites. They include the Gossan Face, Happy Valley, White Face, Slaughter-yard, and Brown Face ore-bodies.

The Mt. Bischoff Tin Mining Company worked nearly all the ore-bodies on the mountain, and has produced until the end of 1936 some 80,070 tons of cassiterite. The adjacent West Bischoff Mine mined the Wheal or Giblin lode, one of the quartz reef type.

A number of fields exist to the south-west of Mt. Bischoff, and are connected with the granite of the Mt. Ramsay, Meredith Range, Parson's Hood, and Stanley River districts. At Luina the Cleveland Mine workings have exposed a number of replacement-fissure lodes of two types, viz., pyrrhotite-chalcopyrite, and pyrite-quartz, with cassiterite as the economically important mineral. In the Mt. Ramsay district the primary deposits are mainly quartz-tourmaline bodies. In the Stanley River district the deposits are of the quartz-tourmaline and the contact metamorphic types. The latter has been opened up in the Mt. Lindsay Mine, and consists essentially of magnetite, pyrrhotite, and other sulphides, and typical contact metamorphic minerals, such as garnet, vesuvianite, epidote, hornblende, &c.

The Renison Bell field is occupied by Dundas slates, &c., in which are intruded quartz-porphyries, gabbros, and serpentines, probably of Devonian age. The ore-bodies include the following types, with gradations between them: quartz, quartz-tourmaline, pyritic (including pyrrhotitic), and dolomitic.

The pyritic deposits, with pyrite, marcasite, and pyrrhotite, are the most important, the tin being present as cassiterite.

In the Heemskirk field the tin deposits are largely restricted to the granite, few occurring in the intruded slates, &c. The deposits comprise a number of types, including quartz greisen, quartz-mica greisen, quartz-tourmaline, pyritic, and pinitoid veins.

Mention must be made of the stannite deposits of Zeehan in the Oonah and Silver Queen Mines. The Oonah lode is the most important, and besides stannite contains cassiterite and pyrite, chalcopyrite, and other sulphide minerals.

(ii) Secondary.

Alluvial deposits of recent age, and containing cassiterite, occur along most of the streams in the tinfields described above, and have yielded considerable quantities of tin ore.

In addition to the above, there are deeper and older deposits, ranging back into the Tertiary era. Some of these have been covered by basalt flows, and represent typical sub-basaltic deep leads.

The most important system of leads is that of the Ringarooma River and its tributaries. The tributaries are mainly north-flowing ones, and derived their tin-ore content from the numerous greisen lodes, &c., on the high country between Branxholm and the Blue Tier. All mine workings have been carried out on the tributary leads, which include those of Branxholm Creek (Arba Mine), Valley Creek, Cascade River (Briseis Mine), Weld River, and Wyniford River (Pioneer Mine). At the Briseis Mine 200 feet of basalt (in three flows) overlies 310 feet of gravels, clays, grits, &c., and the workings yielded over 13,000 tons of tin ore. At the Pioneer Mine the basalt had been removed by denudation, and only 110 feet of "drifts" remain; and the workings have yielded approximately 9000 tons of tin ore.

At Gladstone the alluvial deposits are probably younger, Werrikooian or Pleistocene sands, clays, &c., having been deposited in an estuary and covered by later river gravels, which in places contain tin ore.

Near St. Helens the conditions are similar, the deep lead containing little or no tin ore, while the surface layers, possibly of later origin, contain in places profitable amounts.

In the North Heemskirk field basalt-covered deep leads also exist.

(*h*) *Tungsten.*

Both wolfram and scheelite have been mined, the production to the end of 1936 being 3002 tons of wolfram and 589 tons of scheelite.

The wolfram is associated with the tin deposits, and has been produced chiefly from the Story's Creek, Aberfoyle, and S. and M. Mines, which have been described above. In the Story Creek Mine the lodes contain approximately equal percentages (1·0 to 1·4) of cassiterite and wolfram, but in the more recent mining the wolfram content has been slightly the greater. In the Aberfoyle Mine the amount of wolfram is small compared with the cassiterite produced. In the Gipps Creek district wolfram is present in some of the quartz veins in granite, to the exclusion of cassiterite. In the quartz veins of the S. and M. Mine, Moina, wolfram was subordinate to the cassiterite. Wolfram is the predominant mineral in other mines in the Moina district, and in one (All Nations) cassiterite is entirely absent.

Scheelite occurs in small quantities in the S. and M. Mine, but the only deposit of commercial importance is that at Grassy, King Island. The King Island Mine was worked between 1917 and 1920, for a production of 589 tons of scheelite. The ore-bodies occur in a series of slates and quartzites, which at the mine strike east and west, and dip south at 20° to 40°. These are intruded by narrow veins of aplite, while granite outcrops to the south. The ore-bodies are probably five in number, and conform in strike and dip with the enclosing rocks. They consist of garnet (andradite), with subsidiary amounts of quartz, and about 1 per cent. of scheelite. Associated garnet pyroxene rocks, and the aplite, are also reported to contain scheelite. The garnet rock represents altered and replaced beds in the slates. The ore-bearing zone has a general westerly trend, and is probably bounded on the northern side by a fault.

(*i*) *Molybdenum.*

Molybdenite occurs at a number of localities within the State, and more particularly on the tin-fields, but not in sufficient quantity to warrant mining. In the north-eastern districts it occurs in small amounts in some of the tin deposits. At Mt. Stronach it occurs in apparently unaltered granite, but veins of pegmatite, and possibly oxidised sulphides, suggest mineralisation.

Molybdenite is present in small quantities in the King Island scheelite mine and some of those in the Moina district. At Mt. Remus molybdenite occurs in pyritic bodies containing also cobalt and vanadium, the former being contained in some of the pyrite and the latter in chlorite present in the ore.

(*j*) *Bismuth.*

Bismuth ores have been mined to a small extent, the total production to date being 77·7 tons. The Moina district has supplied almost the whole of the output, the S. and M. Mine being the largest producer. The ores do not, as a general rule, occur in bismuth lodes, but as accessory minerals in the tin and wolfram lodes already described above. Native bismuth occurs in the S. and M. and All Nations Mines; bismuthinite and bismutite in the S. and M., Princess, Squib, and Premier Mines.

At the Stormont Mine, to the south-west of Moina, a bismuth ore-body free from other metallic minerals was discovered in recent years. Bismuthinite is the principal mineral, with small amounts of bismutite and bismite also present. The ore-body is composed of garnet (almandine) rock formed by contact metamorphism from shales, &c.,

of Silurian age, interbedded with tubicolar sandstones and intruded by quartz porphyry. Areas of less-altered rocks containing tremolite occur, as do also bodies of garnet-magnetite rock. The garnet rock occurs in bodies of two types, one being more or less horizontal and the other vertical. The former represent replacements of flat dipping beds and the latter appears to be related to faulting. The best values are close to the fractures which allowed the ascent of the mineralising solutions. The concentrates contain high gold values, the gold being present in the free state. Sulphide minerals occur in quartz veins in the vicinity.

(*k*) *Iron.*

Iron ores occur at a number of localities on the north, north-west, and west coasts, both hematite and magnetite deposits being present.

At Anderson's Creek (Beaconsfield district) superficial deposits of limonite, with some hematite and magnetite, exist. The deposits have formed from the iron content of underlying Devonian serpentine, the magnetite being, however, derived from veins in the serpentine. The principal deposits are at Mt. Scott, Mt. Vulcan, and Barnes Hill.

The ore is a low-grade ore, and contains small amounts of chromium and nickel, the following table showing the average composition as determined by bore samples:—

	SiO_2	Fe_2O_3	FeO	Cr_2O_3	Al_2O_3	H_2O
Mt. Vulcan ...	12·28	59·10	2·20	5·18	10·11	9·07
Mt. Scott	17·72	51·50	2·93	5·63	13·39	7·89
Barnes Hill ...	14·17	51·74	2·31	7·80	11·39	9·75

Attempts were made to smelt the ore (chiefly from Mt. Vulcan) in 1872 and 1876, but were not successful, due largely to the difficulty in working the cast-iron.

The Blythe River field contains one or more parallel lodes of hematite, with strikes of 30° and high dips to the south-east. The country rocks are Silurian conglomerates, quartzites, sandstones, and slates, while Devonian granite outcrops some distance to the south. Tertiary basalt overlies the Silurian rocks and covers parts of the iron lodes. The lodes agree in strikes and dip with the enclosing rocks. The ore occurs as a number of lenses, along the general line of the lodes, over a length of 70 chains. The width ranges from 30 to 100 feet, and estimates of amount of ore range from 9 to 30 million tons. The lenses have been opened up by a number of adits and the quality of the ore tested. Some parts are siliceous, and it has been stated that the ore, as a whole, was too siliceous. Average results indicate an iron content of 63 per cent. and a silica content of 7 per cent., though these are probably from the better-grade ore.

Similar deposits occur on the Dial Range and along Penguin Creek. The former have a north-and-south trend, and consist of red hematite replacing Silurian conglomerates over a maximum width of 200 feet. The Penguin Creek deposits consist of red hematite in association with Silurian conglomerates, sandstones, and slates. They occur along a length of 1¼ miles, and have a strike of 30°. The Iron Cliffs lode has a north-south trend, and consists of limonite, derived apparently from the oxidation of iron sulphides.

The Long Plains deposits consist of disconnected bodies of magnetite along a tract of country 25 miles long and half a mile wide. This tract has a general north-and-south trend, and is occupied by altered basic igneous rocks. The ore is contained in a gabbro-amphibolite, with which is associated in places almost unaltered gabbro. The gabbro-amphibolite is contained in, and apparently merges into, talc, hornblende, and serpentinous schists. Metamorphosed sandstones and slates are also present. The trend of the planes of schistosity is northerly, while the schist zone strikes north-westerly. The schists have been referred to as Proterozoic, but may represent younger metamorphosed rocks. The deposits consist of numerous large and disconnected lenticular bodies of magnetite, and are regarded as magmatic segregations. Some hematite is associated with the magnetite, and at places small amounts of pyrite, pyrrhotite, and chalcopyrite are also present. The latter also occur as separate parallel bands, and have possibly contributed much of the alluvial gold to the streams. The largest lens is 2000 feet long and 100 feet wide, and it has been estimated that the field contains 20,000,000 tons of ore. The ore is high-grade, and samples indicate an iron content of 63 to 69 per cent.

The Zeehan ironfield is situated 5 miles to the west of the Zeehan township, and at the foot of Mt. Agnew. The Heemskirk Range, to the west and north of the district, consists of Devonian granite, while basic and ultra-basic igneous rocks (gabbros, serpentines, &c.), in the forms of dykes, fringe its southern and eastern sides. The granite, gabbro, &c., intrude Cambro-Ordovician slates, sandstones, breccias, &c., the basic and ultra-basic rocks being also of Devonian age, but intruded prior to the granite. The gabbros have been altered by saussuritisation of the felspars and alteration of the pyroxenes to amphiboles. Other changes have taken place, particularly near the margin of the dykes and in the vicinity of the ore-bodies, the mineralisation having been apparently the main factor in the metamorphism. Bodies of massive diopside and of crystalline dolomite occur, while tremolite, actinolite, epidote, chlorite, serpentine, quartz, calcite, &c., are also present. The iron ore exists as discontinuous lenticular bodies of magnetite along the margins of the basic dykes. A number of these bodies (up to eight in number) have been discovered, but have not been opened up by development work to any extent. The general strike is from north of west to south of east. The largest body is the Tenth Legion, with a length of 1400 feet at the outcrop, and a width of 50 feet. The ore is of high grade, with an iron content between 60 per cent. and 70 per cent. The reserves have been estimated at 2,900,000 tons.

(*l*) *Manganese.*

No deposits of commercial importance exist, but two unimportant ones are known in the Dial Range and Penguin districts. The ores range from low-grade manganese ore to manganiferous iron ore. The Dial Range deposit is the more important, and occurs under conditions similar to those of the iron deposits of the district, viz., replacements of Silurian sedimentary rocks, the ore consisting of a mixture of various oxides of manganese (manganite, &c.) and manganiferous iron ore.

The Penguin deposit consists of boulders on the beach, possibly representing the partial replacement of a siliceous rock. Some of the ore contains psilomelane.

(*m*) *Nickel.*

Nickel minerals occur at several localities in the western districts, but only one deposit (Five-Mile district) is of commercial importance. The deposits are intimately associated with the Devonian basic and ultra-basic igneous rocks.

At Heazlewood narrow veins of pentlandite and its oxidation product—zaratite—occur in the serpentine. Near Trial Harbour pentlandite and magnetite occur as grains throughout the serpentine, which is veined with deweylite and secondary minerals.

Five-Mile District.—This field is situated 5 miles north of Zeehan and adjacent to the Emu Bay Railway. Purple and grey slates and breccias of the Dundas series occupy the greater part of the field. They are intruded by two narrow basic dykes, with a general north-and-south trend and easterly dip. The basic rock is a dolerite or fine gabbro, the augite of which is largely altered to chlorite.

The ore-bodies are associated mainly with the eastern dyke, and occur in it or at its footwall, and conform to it in strike and dip. This dyke is 1½ miles in length, and the ore-bodies extend over 1¾ miles, apparently continuing further south than the dyke. The ore-bodies are not continuous, but occur at intervals along the dyke, the total number being eight.

The ore is a massive sulphide, and consists essentially of pyrrhotite, pentlandite, and chalcopyrite, with smaller amounts of pyrite, marcasite, &c. It is fine in grain, and while pyrrhotite and chalcopyrite sometimes occur as blebs, the pentlandite does not do so, and is difficult to distinguish from the pyrrhotite. The ore is therefore a nickel-copper ore, the pentlandite supplying the nickel content and the chalcopyrite the copper content. The average metal contents are: nickel, 9 to 12 per cent.; copper, 5 to 6 per cent. In the case of the Devereaux ore-body, the relative proportions are reversed, while an analysis also revealed silver (1·1 to 1·4 oz. per ton), gold (0·02 to 0·03 oz. per ton), and platinum (0·10 to 0·16 oz. per ton).

The available information about the ore-bodies is summarised in the following table:—

	Length. (Feet.)	Width. (Feet.)	Depth. (Feet.)	Remarks.
Devereaux	Not known	1·0-1·5	...	Exposed in shallow shafts and trenches
Nickel Reward	30	2·0-8·0	...	Proved by shallow shafts
Vaudeau	79 at 70-ft. level 30 at 122-ft. level	Up to 10 3 at 122-ft. level	122	Worked down to 122-feet level, with 1500 tons above this level
Blowfly	60	(?)	Small	Worked out
Dundas Cuni South (Eastern)	90	(?)	75	Worked down to 75-feet level
Dundas Cuni South (Western)	Possible maximum 150	2¼	Not known	Indicated by geophysical survey Outcrop proved by two trenches; metal contents not known
Dundas Cuni North or Copper-Nickel South	80 at 70-ft. level Possible maximum 200-300	2	70	Zone 300 feet long indicated by geophysical survey, with concentration over 200 ft.; partly worked out above 70 feet
Copper-Nickel North	Possible maximum 350	3	110	Indicated by geophysical survey; several trenches and two bore-holes have intersected it

Ore has been produced mainly from the Vaudeau (2849 tons), Dundas Cuni South (1189 tons), and Copper Nickel South ore-bodies (2000 tons approximately).

The ore as mined was marketed overseas before the Great War, but no market has been available since.

(*n*) *Chromium.*

Chromite occurs in association with the serpentine of western and north-western districts, but no important primary deposit exists. It, however, occurs plentifully in some of the alluvial deposits adjacent to the serpentine. The alluvial deposits of the Adamsfield osmiridium field contain chromite, with an almost complete absence of any other heavy mineral. Chromite is also plentiful in the alluvial deposits north and west of Renison Bell.

The chromiferous iron ore of the Anderson's Creek district has been discussed under "Iron."

(*o*) *Osmiridium.*

Tasmania is one of the largest producers of osmiridium in the world, the production being derived almost entirely from alluvial deposits. Primary deposits have been discovered in three of the fields. In the alluvial fields the source of the osmiridium can be traced to bodies of serpentine. The original rock is in all cases completly serpentinised, and it is difficult to determine its type. Both Twelvetrees and Reid have considered the rock to have been a peridotite containing bronzite. Reid also considered that serpentines derived from pyroxenites and gabbros did not contain osmiridium, and that the presence of bronzite rich in alumina in the peridotites was an essential feature for the occurrence of osmiridium in the serpentinised peridotites.

As a general rule, the osmiridium-bearing serpentines contain irregular veins and patches of coarsely crystalline enstatite or bronzite, and these are apparently just as characteristic as the probable peridotite containing an orthorhombic pyroxene.

The metallic oxide minerals which occur in the serpentine and accompany the osmiridium are not the same for all fields. At Bald Hill they comprise magnetite, picotite, ilmenite, &c., while at Adamsfield chromite is present to the exclusion of the others.

The first primary deposit discovered was the Caudry prospect, on the north-western slopes of Bald Hill. Osmiridium was found along a line with a S.S.E.-N.N.W. trend, and excavations revealed a foliated zone with vertical walls 4 to 6 feet apart. The excavation was 200 feet long, but osmiridium-bearing rock occurred at three places only. At depths of 15 to 25 feet the bounding walls were not so definite, and the foliation became less prominent and more irregular. It was also found that the osmiridium was not confined to the rock between the walls, but was present in dark-bluish unfoliated rock to the east of the eastern wall. The production from this deposit was approximately 250 oz.

Near Mt. Stewart three structural planes were located, and osmiridium found as " schlieren " in the planes, but not in the serpentine adjacent to the planes.

The most important primary deposit is that at Adamsfield. The serpentine occurs as a dyke over 3 miles long, with a width of 20 chains at the southern end and increasing to 40 chains to the north, and ending in a knob or bulge 80 chains wide at its north end. The primary deposit or lode occurs within a few chains of the eastern boundary of this bulge. It has a general north-and-south trend, but conforms to the boundary of the dyke, and is curved to the west at its northern and southern ends. Towards the southern end the lode consists of serpentine between two well-defined vertical walls 8 feet apart, the osmiridium-bearing portion consisting, however, of one, two, or three narrow veins of somewhat foliated serpentine.

Immediately west of the lode is a 10-feet band of massive talc, dirty-white in colour, and representing altered serpentine. Short, narrow, and irregular quartz veins accompany the talc in some places, and also occur in the lode, but to only a small extent.

The lode has been traced for 15 chains, but becomes narrower and not so well defined at both ends, but particularly to the north. In this direction, also, the lode, owing to the narrowing of the dyke, intersects, and to the north occupies, the contact between the serpentine and Silurian shales. Nuggets of chromite up to 4 inches diameter occur in the lode, while the serpentine and the talc contain innumerable small octahedral crystals of the same mineral. Towards the south end a narrow branch of the lode trends to the west and traverses the talc for a short distance.

The lode has been mined to a depth of approximately 50 feet at several places, and is still osmiridium-bearing at that depth.

The osmiridium is dark-coloured, due to adhering serpentine, &c. It is obtainable in nuggets ranging up to an ounce and over in weight. The production has probably been between 200 and 400 oz.

While the above deposits are the best known, it is probable that other similar, though smaller, ones exist. This must be the case in order to account for the osmiridium in the alluvial deposits on the various fields. These will probably be similar to those described above, but the possibility of the osmiridium being in some cases disseminated through the serpentine cannot be disregarded.

Alluvial.—The production of osmiridium has been derived almost entirely from the alluvial deposits. The principal fields are five in number, and include Bald Hill, Savage River, Mt. Stewart, Wilson River, and Adamsfield.

The Bald Hill field is situated some 15 miles west of Waratah. It includes all the alluvial workings around Bald Hill and in the valleys of Nineteen-Mile Creek and Heazlewood River. The osmiridium has been shed from a small body of serpentinised peridotite on Bald Hill, including Caudry Prospect, already described above. The deposits consist of Recent gravels along the streams, detrital material on the slopes of Bald Hill, and Tertiary gravels.

The Savage River field is really an extension of the Bald Hill field, and derived its osmiridium from

Bald Hill by way of Nineteen-Mile Creek. The stream gravels and terraces have been worked over a length of 15 miles.

The Mt. Stewart field is 13 miles south-west of Waratah. The deposits include the stream gravels of Loughnan Creek and Castra River. The osmiridium is derived chiefly from the serpentinised peridotite in Loughnan Creek.

The Wilson River field lies to the north of Renison Bell. The deposits include the recent stream gravels and also detritus on the serpentine. The osmiridium has been derived from serpentinised bronzitite and peridotite, and a few short "schlieren" have been found.

Adamsfield is situated 50 miles W.N.W. of Hobart. A long dyke of serpentine intrudes folded and faulted Silurian rocks. The serpentine has shed osmiridium mainly from the eastern margin, and particularly from the vicinity of the lode at the head of Main Creek. The deposits are of many types, and osmiridium has been obtained from stream gravels, surface soil, subsoil, clay, detritus from serpentine, &c.

The recorded production of osmiridium since 1910 is 28,227 oz., with a value of £683,681; and of this Adamsfield since 1925 had produced 19,991 oz., with a value of £256,988.

(*p*) *Titanium.*

Both rutile and ilmenite exist in the State, the known deposits being alluvial ones.

The most important deposits of rutile are situated in the Lewis River district, between Macquarie Harbour and Port Davey. The rutile occurs in the deposits along the present streams and in the gravels on a dissected plain. It is associated with cyanite (clear blades, with brown centres) and small amounts of garnet. The source has not been discovered.

Rutile also occurs in the Ulverstone district in deposits along the present streams, and also in sandstones probably of Tertiary age.

Ilmenite occurs in small quantities throughout the State, being derived from the Tertiary basalt, Mesozoic dolerite, and some of the Devonian ultrabasic rocks. The only important deposit is a raised beach along the coast near Narracoopa, King Island. A small amount of cassiterite is associated with the deposit, which was formerly worked for that mineral, but without success. The deposit also contains garnet, zircon, and possibly rutile. The ilmenite is the most plentiful mineral, and the deposit was recently exploited for the extraction of that mineral, which was used to manufacture titanium dioxide for white paint.

(q) *Antimony.*

Stibnite is known to occur near Cox Bight, Southern Tasmania, and a parcel of many tons has been reported as having been obtained. No deposit of large size is known, but very little attention has been paid to this part of the island. Antimony is a very common associate of lead in the sulphide bodies of Zeehan and Ringville.

(r) *Monazite.*

Monazite occurs in alluvial sands on the Stanley River and on the East Coast; at Yellow Band Plains and other places on the West Coast; and at Fraser River, King Island.

(s) *Arsenic.*

Arsenopyrite occurs plentifully in the ore-deposits of Tasmania, but not in sufficient quantity to warrant its extraction. Larger deposits are known to exist at Dundas, Mt. Horror, and Scamander, but have not yet been proved to be of economic importance. Cassiterite is associated with the Dundas deposit. This is likely to prove the most important of the known deposits. Gold and tin ore are common associates of arsenopyrite deposits.

(t) *Sulphur (Iron Pyrites).*

No deposits of native sulphur are known in Tasmania, but pyrite has been mined at several localities for its sulphur content. The largest deposit occurs at the Mt. Lyell Mine, where it is smelted for its copper, silver, and gold contents, and also shipped to Victoria for utilisation in the company's superphosphate works. Cupriferous pyrite has also been mined at the Chester Mine, in the North Pieman district. Other producers have been the Susanite and Kynance Mines, Comstock. All the pyrites produced has been exported to the superphosphate works in Victoria. There is also the possibility in the future of the low-grade pyritic-cassiterite deposits being utilised for their tin and sulphur contents. Pyrrhotite and marcasite in enormous quantities occur with cassiterite at Renison Bell and Mt. Bischoff.

The production is recorded from 1915 to 1936 as 141,868 tons, of a value of £167,133, but the total production probably greatly exceeds this figure.

(2) Non-Metallic Minerals.

(a) *Barite.*

Barite deposits are restricted to western and north-western districts. It has been mined at a number of places, but only on a small scale, the total production being 1883 tons.

The barite occurs in Lower Palæozoic sedimentary rocks and schistose porphyries of either the same or Devonian age, but particularly in the sedimentary rocks near the porphyries. Barite also occurs as a gangue mineral in the copper deposits of Mt. Lyell, the zinc-lead deposits of Mt. Read and Rosebery, &c. These deposits are now considered to be genetically associated with the Devonian intrusives (porphyries, &c.), and it is probable that the barite ore-bodies are similarly associated.

On the Intercolonial Spur, at Mt. Jukes, an east-west vein of barite has a length of 26 chains and a width ranging from 1 to 8 feet. Both samples have assayed up to 86 per cent. of $BaSO_4$. At Madam Howard Plains, near Queenstown, a main lode with a strike of 250° traverses Silurian sandstones, while to the north a zone containing veins and small lodes has a general north-easterly strike.

A number of ore-bodies occur at Murchison River, Lynch Creek, Pinnacles, and Mt. Block between

Tullah and Mt. Block. Porphyries and schistose porphyries are common in these districts, but the deposits have not been opened up.

At Beulah a number of lodes and veins conform in strike with the enclosing slates, with which are associated schistose basic porphyries.

The Riana deposit is a small lode striking north, and enclosed in slates and breccias probably of the Cambro-Ordovician system.

The Alma deposit occurs in dark slates and quartzites, probably belonging to the Cambro-Ordovician system. On the Paradise Range, north-north-westerly trending veins traverse sandstones, with which are associated schistose porphyries.

The Harford lode traverses quartzites and slates of the Cambro-Ordovician system. No outcrops of Palæozoic igneous rocks are known in this district.

(*b*) *Asbestos.*

Asbestos occurs at two localities, viz., Anderson's Creek, in the Beaconsfield district, and at Asbestos Point, on the south side of Macquarie Harbour. The former is the more important deposit, and was worked during 1917, 1918, and 1919 for the production of 440 tons of asbestos fibre. The asbestos is of the chrysotile type, and generally of the cross-grain variety. It occurs as narrow veins in serpentine or serpentinised ultra-basic rocks.

At Anderson's Creek the country rocks include Cambro-Ordovician conglomerates, quartzites, and sandstones, intrusive into which are Devonian peridotites and pyroxenites. The latter have been intruded by small dykes of granite aplite, &c., and have been almost completely converted into serpentine, though small portions escaped serpentinisation.

The serpentinisation of the ultra-basic rocks, and particularly the formation of the asbestos veins, was associated with the intrusion of the granite and aplite dykes. The asbestos occurs in veins up to 4 inches wide, but the usual width is below half an inch, though a number of these narrow veins may be parallel and closely spaced over a wider zone. The fibres are generally arranged across the vein (cross-fibre), but the slip-fibre variety is also present. In addition to chrysotile asbestos, picrolite and amphilbole-asbestos are also present in the serpentine in the form of veins. Magnetite also occurs as veins of cross-fibre type.

At Asbestos Point the country rocks include schistose basic igneous rocks, possibly of Proterozoic or Lower Palæozoic age. A long narrow dyke of pyroxenite intrudes the above, and has been partly serpentinised. Narrow veins of chrysotile asbestos are present at several places along the dyke, and are of the cross-fibre type. Only a small amount of development work has been carried out, and no production has taken place.

In both the above districts the cross-fibre asbestos is pale-green in colour and often with a bronze sheen, but yields, when teased, a white fibre with a soft and silky feel.

(*c*) *Talc.*

The talc deposits are not of any great extent or commercial importance, the total production being 110 tons.

At Gawler, near Ulverstone, a narrow vein up to 2 feet in width occurs in Proterozoic mica schists, and appears to conform to the planes of schistosity. It is fine in grain and nearly pure white in colour. This is the only deposit that has been worked.

At Mt. Stewart, west of Waratah, a 2-feet vein of coarse-grained talc traverses the altered pyroxenites of the district.

At the Razorback Mine, Dundas, a large body of talc occurs adjacent to the pyritic tin ore-body. It is fine-grained and of a dirty-white colour, and was formed by alteration, during mineralisation, of a serpentine.

(*d*) *Limestone.*

Limestone exists in the Lower Palæozoic, Permo-Carboniferous, and Tertiary rock systems. The Lower Palæozoic limestones are dark-grey types of high grade, and occur in beds many hundreds of feet thick, generally dipping at high angles. They are found in western and north-western and southern districts, and are used for various purposes.

The Ida Bay deposits are used in the manufacture of carbide at Electrona; for making lime-sulphur sprays; and in the metallurgical process of the Electrolytic Zinc Company at Risdon. The Melrose stone is shipped to Newcastle for fluxing purposes in the iron-smelting industry. The Beaconsfield, Railton, and Mole Creek deposits are burnt for lime for agricultural and building purposes. The Railton deposit is also used in the manufacture of cement by the Goliath Portland Cement Company. The Queenstown deposits are used as flux in the copper-smelting operations of the Mt. Lyell Mining and Railway Company, and the Zeehan deposits were formerly used as flux in the lead-smelting industry.

The Permo-Carboniferous limestones are light-grey in colour, and generally of low grade, with a silica content ranging up to 20 per cent. They occur as horizontal or slightly inclined beds, ranging in thickness up to 100 feet. They are burnt for lime at Bridgewater, and were formerly used for cement manufacture at Maria Island.

The Tertiary limestones are of no great extent, and are little utilised. Marine limestones occur at Marrawah and King Island, and freshwater ones at Flinders Island and Risdon.

(e) Dolomite.

The most important and extensive deposits of dolomite are the sedimentary beds in the Smithton district. Similar beds, but probably of less extent, occur in adjacent districts, such as Montagu, Black River, &c., but have not been geologically surveyed. These rocks are interbedded with the Dundas series of slates and breccias, and are probably near the base of the series.

Another type of deposit results from the alteration of the Devonian ultra-basic and basic rocks by mineralising solutions. One such deposit on the Arthur River consists of a mixture of dolomite and magnesite. In the Magnet Silver-lead Mine the basic and ultra-basic rocks on the hanging-wall of, and in, the lode-channel were altered to ferriferous dolomite, or ankerite.

The Smithton deposits are in the form of a large syncline, but are largely covered by Pleistocene and recent marls, peats, sands, &c. The eastern limb is the better known, and the beds outcrop along the Duck River and dip west at 45°. The dolomite is generally of a very fine-grained type, with a dirty-white to cream colour. Near Smithton a coarser-grained crystalline type occurs over considerable areas. It is generally white in colour and very high in grade, containing only a very small percentage of impurities. The dolomite was formed by the dolomiterisation of limestone, and the conversion was complete, as the calcium and magnesium carbonates are present in the theoretical proportions for dolomite. Calcite appears to be absent, except in a few spots, where it is present as small veins or coarse crystals. An interesting feature is that a bed of limestone 300 feet stratigraphically below the dolomite, has not been dolomitised to any extent.

The purity of the deposit is such that a company is undertaking tests with a view to manufacturing magnesium compounds and metallic magnesium.

(f) Diatomaceous Earth.

Only one deposit is known, and is situated several miles east of Andover, in the midlands.

The material occupies one or two basin-like depressions in the dolerite bedrock. It is not of high grade, as it contains a proportion of clay, but is suitable for some purposes.

(g) Coal.

Coal-seams exist in many localities in Tasmania, and occur in strata belonging to the Permo-Carboniferous, Triassic, and Tertiary systems. The Permo-Carboniferous strata form the lower coal measures of Tasmania, and coal-seams occur in these strata at the Barn Bluff-Pelion, Preolenna, and Mersey fields in the north, and at Mt. Cygnet and Bruny Island in the south.

The Triassic strata form the upper coal measures, and coal-seams are extensively developed in the eastern, midland, and south-eastern portions of Tasmania. These seams constitute by far the greatest coal reserve of the State.

The Tertiary strata also contain coal-seams, but so far they have proved of no importance.

The following statement explains the variation in character and composition of the coal found in the above systems:—

Permo-Carboniferous—

Greta Coal Measures: Kerogenites and humic-kerogenites.

Tomago Coal Measures: Sub-anthracites and non-caking humic.

Triassic—

Sub-anthracites and non-caking humic.

Tertiary—

Brown coals and lignites.

The total production of coal is somewhat in excess of 3,500,000 tons, with a value of approximately £2,700,000. The present annual production is 92,269 tons, valued at £132,264. The greatest development has taken place in the Mt. Nicholas area, on the East Coast, where the principal mines are the Mt. Nicholas and the Cornwall Coal Mines. The Cornwall Coal Mine has contributed one-third, and with the Mt. Nicholas Mine one-half, of the total production.

The coal reserves, calculated on the basis of existing economic conditions, amount to 134,398,000 tons. On the basis adopted by the International Geological Congress, the "actual" reserve is 124,980,000 tons, and the "probable" reserve 123,013,000 tons, with a still further, unknown, "possible" reserve.

The following figures show the analysis, evaporative power, and calorific value of the average Tasmanian coal (Triassic) :—

	Per Cent.
Moisture	4·36
Volatile hydro-carbons	21·27
Fixed carbon	51·84
Ash	22·64
Sulphur	0·60
Evaporative power	10·49
Calorific value	5,636 Calories. / 10,145 B.T.U.

(h) Oil Shale.

Extensive deposits of oil shale occur in the northern and north-western parts of Tasmania, as beds on the horizon of the Greta coal measures of the Permo-Carboniferous system. Tasmanite shale forms the greater part of these deposits, and an estimate of the reserves of this shale is as follows:—

	Tons
Latrobe-Railton-Kimberley area	17,895,000
Beulah area	2,346,750
Quamby Bluff area	3,750,000
Nook area	1,050,000
Chudleigh area	6,000,000
	31,041,000

The average yield of crude oil from these shales is estimated at 27 gallons per ton, and the oil reserve therefore amounts to 838,107,000 gallons. Only a small amount of development work has been performed in connection with these shales, and it has been mainly in the direction of experimental tests in connection with various types of retorts for distillation purposes.

Kerosene shales and cannel coals occur at Preolenna, and pelionite in the Barn Bluff-Pelion area, but the reserves of these materials are very small compared with those of tasmanite.

(i) Clay.

Many deposits of clay are known to exist, but no investigation of these has been made. They are mainly of Tertiary to Recent age, but beds also occur in the Trias-Jura system. Bricks are manufactured from local clays in both Hobart and Launceston; tiles are made in both cities; and coloured earthenware is also produced in Launceston. Apart from these, the best known deposits are those at George's Bay, Rosevale, and Kingston.

(j) Cement Materials.

The essential materials for making cement—limestone, clay, and fuel—have been described above.

These often occur in close proximity to each other, and the conditions are therefore suitable for cement manufacture. A plant for this purpose is operated at Railton by the Goliath Portland Cement Company.

(k) Slates.

Slates of commercial value occur in the Cambro-Ordovician system in at least two localities in Tasmania—Bangor and Arthur River. Bangor is situate 15 miles to the north of Launceston, and slates were obtained both by open-cut methods and also underground mining, and considerable quantities placed on the market. The other locality is on the east bank of the Arthur River, 12 miles north of Waratah, where slates of value were reported, but have not yet been developed, owing to the lack of transportation.

(l) Sandstones.

Sandstones suitable for many purposes occur in the Ross series of the Triassic system, which are largely developed in the north-eastern, eastern, midland, and south-eastern parts of the State. These sandstones are specially suitable for building, constructional, and monumental purposes, grindstones, &c. They have been extensively quarried throughout the above districts for the building of houses, particularly in the earlier days of the settlement. In the cities of Hobart and Launceston and the townships throughout the country the public and other large buildings are chiefly constructed of these sandstones.

They have also been used for bridges, as at Ross, Richmond, and Pontville. At Ross these sandstones are specially adapted for grindstones, and large numbers of these are exported to Australia. In addition these sandstones are the principal rocks used for tombstones, headstones, monuments, &c.

(m) Granite.

Granite outcrops at many localities in Tasmania, chiefly in the north-east, east, and western districts, but in the past it has not been utilised to any great extent. Numerous varieties occur, particularly with regard to textures, but colours are confined to black and white (grey), and red or pink. The only granite being exploited for commercial purposes occurs at Cole's Bay, on the East Coast. This granite is a red, coarse-grained type, and has been opened in quarries along the water-front. The red colour and the polishing qualities of the rock render it an attractive stone for building and monumental purposes. The present production of red granite is 568 tons, valued at £3209.

(n) Zircon.

Zircon occurs in alluvial deposits, the most important being those at Sisters' Creek and near Penguin, North-Western Tasmania, and near the mouth of the Arthur River.

(o) Gem Stones.

Topaz is found in the alluvial tin deposits and also on Flinders Island, the stones from the latter locality being particularly large ones. Sapphires are also found at the former locality, but not in any great number. A few diamonds have been found in the western districts, but no deposits of value have been proved to exist.

The large and good-grade zircons are used for gems.

P. B. NYE, Government Geologist.

F. BLAKE, Field Geologist.

Hobart, 14th May, 1937.

APPENDIX

DEPARTMENT OF MINES INFORMATION

I.—STAFF.

Secretary for Mines: J. B. Scott. *Chief Clerk and Accountant*: A. B. Bryan. *Registrar*: W. A. Smith. *Clerks*: C. A. H. Woods, C. B. Askey, I. E. Corby, J. I. Murtagh. *Typists*: Miss A. Kelso, Miss H. Killick.

Government Geologist: P. B. Nye, M.Sc., B.M.E. Field Geologist: F. Blake. Assistant Geologist and Draftsman: Q. J. Henderson. Draftsman: T. D. Hughes. South-Western District Warden of Mines: J. B. Scott.

North-Eastern Division, Launceston.—Warden of Mines: F. N. Stops. Registrar: A. R. Parkes. Chemists: W. Manson, C. J. Penman. Messenger: J. Beams.

Eastern Mining Division, St. Helens.—Registrar: Thomas Haley.

North-Eastern Mining Division, Derby.—Registrar: B. W. Turner.

Western Mining District, Devonport.—Warden of Mines: J. P. Clark. Registrar: A. D. Soutar. Registrar of Mines, Zeehan: J. R. Falconer.

Southern Mining District.—Warden of Mines: W. Hutchins.

Inspectors of Mines.—Chief Inspector: James O. Hudson, Hobart. W. H. Williams, office, Launceston. H. A. Vaudeau, office, Upper Burnie. J. F. Shaw, office, Queenstown.

Magazines and Explosives Branch.—Chief Inspector of Magazines and Explosives, J. O. Hudson. Southern District: Magazine-keeper and Inspector, E. W. J. Dean. Launceston District: Magazine-keeper and Inspector, B. L. Murphy. Inspectors—North and North-Western District: H. A. Vaudeau. Western District: J. F. Shaw. North and Eastern District: W. H. Williams.

District and Mining Surveyors: F. E. Windsor, C. S. Wilson, D. Frazer, H. F. Miles, G. C. Smith, C. M. Archer, K. M. Harrisson, C. E. Radcliff, R. B. Montgomery, Joseph Wilks, J. H. Hinsby, C. A. Goddard, E. D. Blackwood, D. Fraser, C. K. Goddard, J. H. E. Howell, H. H. Lennox, R. G. C. Smith.

Board of Examiners for the issue of Certificates of Competency for the Office of Mining Manager, under Provisions of the Mines and Works Regulation Act, 1915: Chief Inspector of Mines, Chief Inspector of Machinery, and the Government Geologist.

Persons Authorised to Issue Prospectors' Licences and Miners' Rights.—The Wardens and Registrars: J. E. Gough, Fingal; Mrs. P. Guy, Mathinna; M. A. Summers, Wynyard; H. E. T. Spotswood, Scottsdale; T. A. Canning, Queenstown; Miss Kitto, Lefroy; Mrs. Annie White, Lottah; A. W. Freiboth, Sheffield; Mrs. M. Flight, Gladstone; Mrs. J. A. Lee, Mole Creek; Miss V. Hetherington, Renison Bell; C. J. Newman, Avoca; W. F. Devitt, Smithton; M. T. Donovan, Waratah; C. Berryman, Whitemark, Flinders Island; John Byrne, Adamsfield; Mrs. R. Bryce, Weldborough; G. H. Smythe, Cape Barren Island.

II.—MINES DEPARTMENT LABORATORY, LAUNCESTON.

The Scales of Charges is as follows:—

	s.	d.
Tin sale assays	5	0
(Lots of 10 bags and over, 7s. 6d.)		
Sale assays	5	0
Determination of gold and silver in any sample	2	0
For each additional sample	1	0
Determination of silver and lead in any sample	3	0
For each additional sample	1	6
Determination of any single mineral or metal, one sample	2	0
For each additional sample	1	0
Complete analysis of rocks, ores, &c., each constituent determined	2	0
Analysis of coal	7	6
Determination of calorific value	5	0
Determination of furnace temperatures	10	0
Examination of any mineral involving only simple tests	Free	

Postage stamps will not be received in payment of charges.

Where the assayer is satisfied that the assay is made for a genuine prospector, a rebate of 25 per cent. is made.

In special cases, upon good cause being shown, the Secretary for Mines may authorise a free assay.

III.—REGULATIONS UNDER THE MINING ACT.

The mineral lands of the State are dealt with under special laws and regulations distinct from the Crown Lands Acts. The Department is controlled by the Minister for Mines, through the direct supervision of the Secretary for Mines, under whom are appointed Wardens of Mines for each division of the State, who act judicially in the settlement of disputes and conduct of all business matters connected with the mining industry.

The Mining Regulations provide for the issue of:—

1. *Prospectors' Licences,* under which, at the annual cost of 10s. (or 5s. if issued after June), the holder is authorised to take possession of and hold for prospecting purposes: 100 acres for coal, shale, slate, or oil, or 50 acres for any other mineral. Provision is also made for authorising increased areas under special authority, where the nature of the prospecting operations renders such desirable, and for the issue of special licences to search for coal or oil.

2. *Miners' Rights* under which, at the annual cost of 5s. (or 2s. 6d. if issued after June), the holder is authorised to take possession of a claim, and to mine and work such claim and take and remove minerals therefrom.

Any number of persons (not exceeding ten) being the holders of miners' rights may surrender same, and upon payment of an amount equal to the sum of the fees payable in respect of as many individual miners' rights as there are persons in the party, obtain a consolidated miner's right conferring upon the holders thereof the same rights and powers as are conferred by a miner's right held by one person.

The respective areas which may be held under miners' rights are as follows:—

Miner's Right Claims:

Single Claim.—One man, ½-acre, 50 yards x 50 yards. (Crown land only.)

Consolidated Claims.—For every man up to ten, ½-acre each.

3. *Mineral Leases* are granted in areas not exceeding 80 acres for a term of 21 years, at a rental of 5s. per acre per annum, with statutory right to renewal. *For coal,* in areas not exceeding 640 acres, or for *slate, freestone, or limestone,* in areas not exceeding 320 acres, for a term of 21 years, at a rental of 2s. 6d. per acre per annum, with statutory right to renewal. *For any mineral other than the above,* in areas not exceeding 80 acres, for a term of 21 years, at a rental of 5s. an acre per annum, with statutory right to renewal. *For oil,* area 640 acres, at a rental of 1s. per acre per annum and a royalty.

Any person, with the consent of the owner and/or occupier of any private land, or a permit from the Warden of Mines, may enter therein and search for any mining product, and may mark off and apply for a lease of such area as if the same were Crown land.

Special provision is made to secure to the owner compensation for surface damage.

No lease of any private land shall include or apply to the surface thereof which is used as a garden or orchard, or a cultivated field under crop, or has upon it any dwelling or other substantial building, or any natural or artificial, lake, dam, reservoir, or pond, or within 100 yards on the surface from any of the abovementioned things.

4. *Machinery Sites.*—Sites for machinery, at an annual rental of 5s. per acre of areas not exceeding 10 acres, and for a term of 21 years, for mineral or gold, with right of renewal.

5. *Licences for Water Rights* for a term or 21 years, renewable, at an annual rental of £1 per head, carrying the right to construct races, dams, and reservoirs.

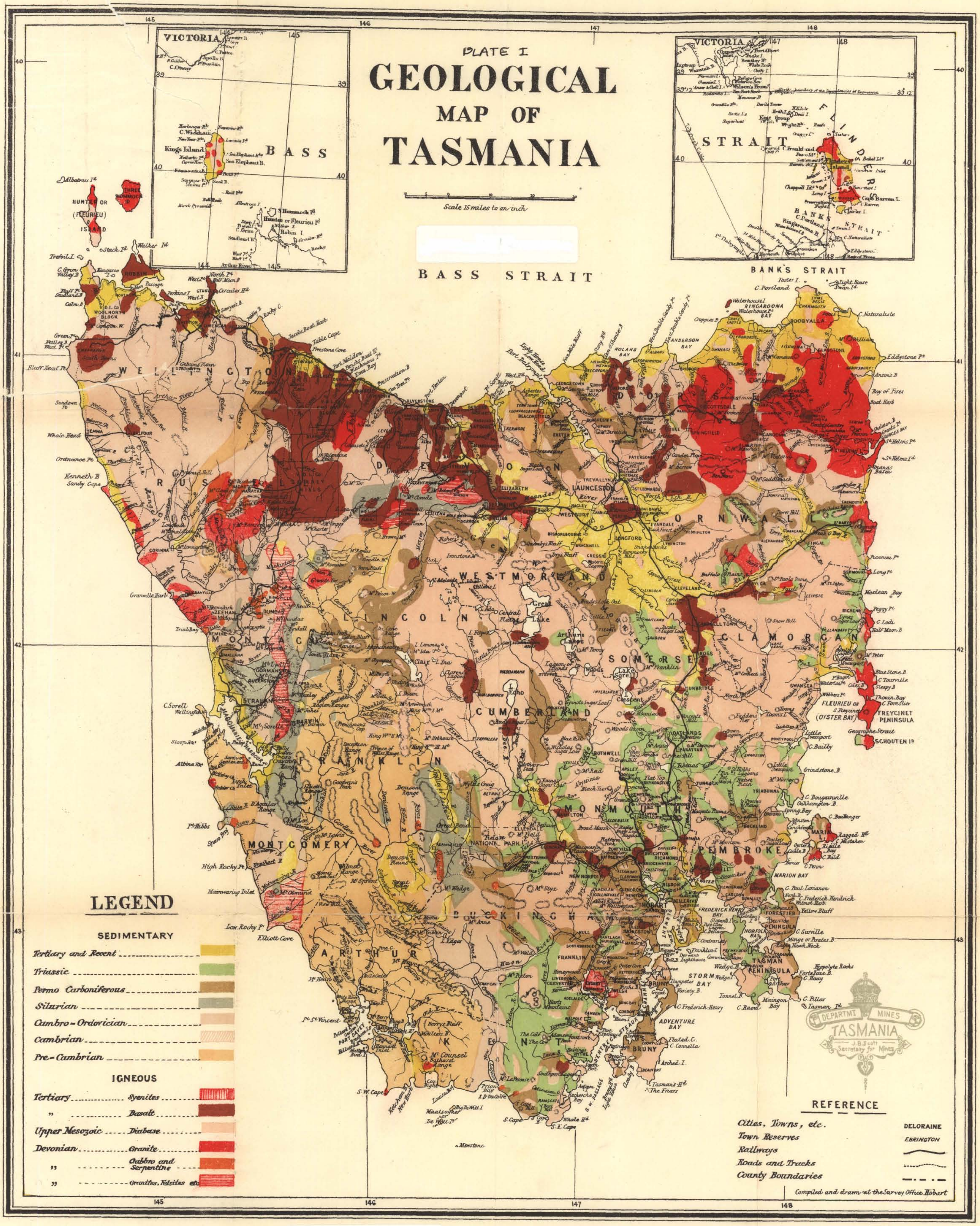
6. *Easement Licences* are granted to lessees at a rental of 5s. per acre per annum for the conveyance of tailings and *debris*, and the construction of roads, tramways, tunnels, shafts, and subways.

7. *Leases to Work River Beds.*—Provision is made for the issue of leases to work the beds and banks of rivers at an annual rental of 5s. per acre per annum.

Provisions are made for the settlement of disputes and partnership questions, regulating the mode of marking and applying for claims and areas, the shape and survey of claims, priority of rights, conditions of working, mode of forfeiture, regulating appeals to the Supreme Court, regulation and inspection of mines, acquisition of water rights and easements through private lands, &c., and under separate Acts for the incorporation and winding-up of mining companies, the working and inspection of mines, and the granting of certificates of competency to managers of mines.

FEES AND RENTS.

The particulars of fees and rents mav be ascertained upon application to the Head Office or any branch office.



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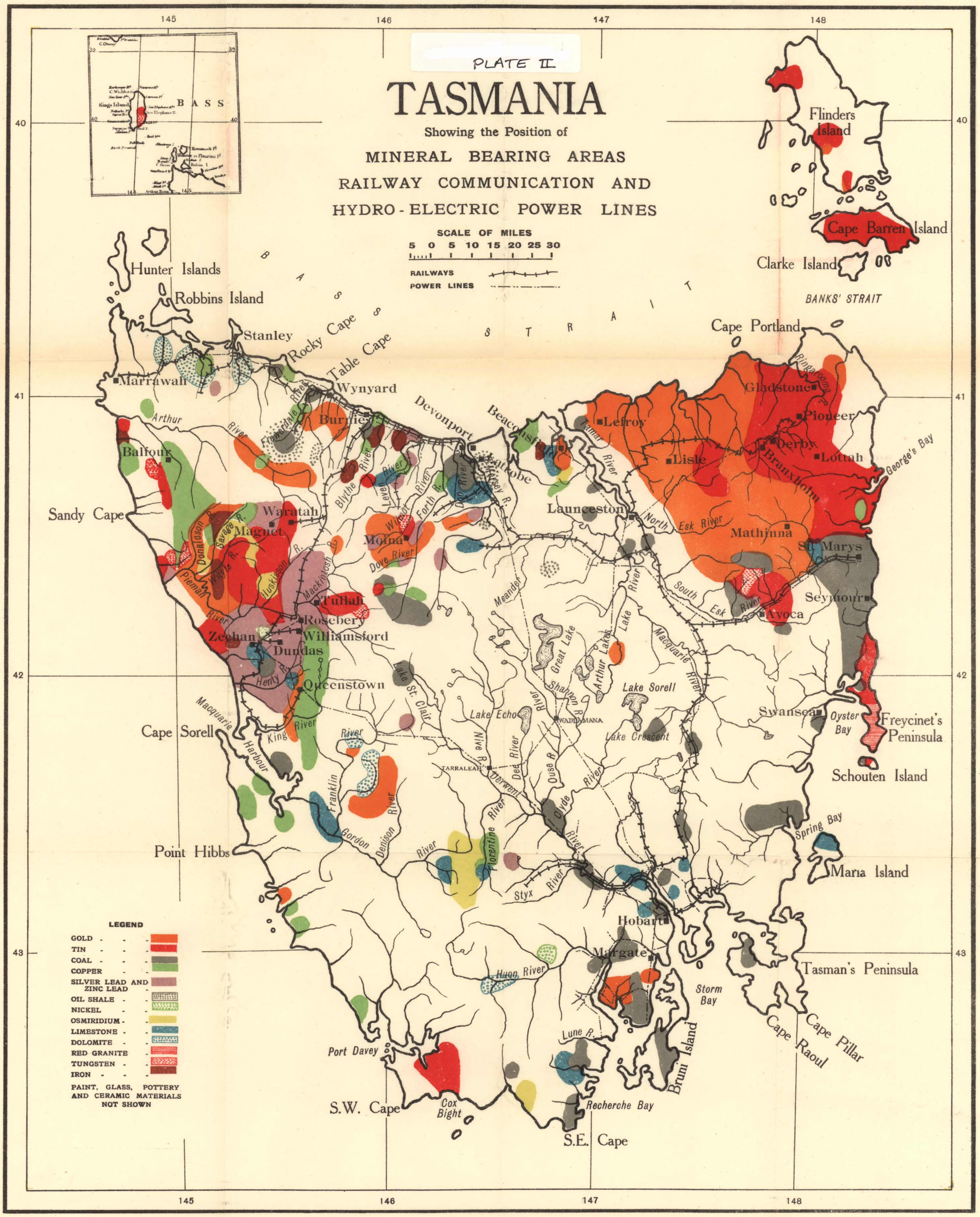

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