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No. 34

The Mount Bischoff Tin Field

BY

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The Mount Bischoff Tin Field.

SUMMARY.

For thirty years Mt. Bischoff held pride of place as the foremost tin-producing field in Australia. This position has been vacated of late owing to the cessation of active operations at the parent mine, but a return to its former greatness is not unlikely to follow as a result of the development work at present in progress. It is interesting to note that of the £6,000,000 worth of tin ore produced from this field, only £100,000 worth was obtained from mines outside the small area enclosing Mt. Bischoff. This fact is particularly striking, because a great deal of attention has been given to neighbouring areas, especially those occupied by granitic rocks. Of these, the country in the vicinity of the Cleveland and South Bischoff Mines, lying ten miles to the south-west and south respectively, offers the only opportunities for productive development. Five main types of tin deposits occur in the district, namely:—

(a) Fissure veins;
(b) Replacement-fissure deposits;
(c) Greisen veins;
(d) Aplite dykes;
(e) Alluvial and detrital deposits.

Of these, the fissure veins and replacement-fissure deposits have proved the most important, and both have been extensively worked in the Mt. Bischoff and Cleveland Mines. The fissure veins are narrow, rich, and remarkably persistent, both in length and depth. Deposits of the replacement-fissure type, which constitute the chief sources of tin ore at the Mt. Bischoff Mine, are large, irregularly-shaped pyritic bodies containing occasional rich bonanzas. Probably, as large masses, their maximum depth below the surface nowhere exceeds 300 feet; but in the channels through which the ore-bearing solutions found their way rich tabular deposits will be discovered in faulted position near the pyritic bodies. Greisen veins represent the local alteration of the wall-rock of fractures in granite. Like the quartz-vein type

these are remarkably persistent, but the rich ore-shoots in them are invariably short and erratic in their distribution. Types of this kind occur at Moore and Campbell's Prospects. The ore-bodies in the South Bischoff area are contained in aplite dykes intrusive into normal granite. They are comparatively small bodies, in the form of short lenses, and are invariably associated with fluorine-bearing mica. This association is so pronounced that the presence of the mica may be taken as an indication of the occurrence of tin ore. Alluvial deposits of both Tertiary and Recent ages are found here. The former are represented by sub-basaltic gravels exposed in the Don and Bischoff-Taylor workings, and the latter by accumulations in existing streams. The Tertiary gravels show little sign of attrition, having been deposited in slowly moving waters. There is, accordingly, no prospect of finding rich concentrations of tin ore in them. The only deposits of recent age that have proved of any considerable value are found in the valley of Waratah River.

From the foregoing it will be seen that the prosperity of the field is still largely dependent upon the results of operations at the Mt. Bischoff and Cleveland Mines. Within the area enclosed by the geological map accompanying this report, the country to the south-east of Cleveland Mine appears the most favourable for future exploration.

II.—INTRODUCTION.

(1)—Preliminary Statement.

The discovery of tin ore at Mt. Bischoff in 1871 marked a new era in the history of Tasmania. Coming at a time of extraordinary trade depression, no event before or since has produced such a far-reaching effect in the industrial development of this country. At the time agriculture, the chief industry of the people, had been checked by a variety of circumstances. The Victorian markets were closed to produce from Tasmania because of large shipments from South Australia and New Zealand and the imposition of a protective tariff. Very little produce found a market in New South Wales, and the export of foodstuffs beyond Australia was impracticable owing to the remoteness of this country from centres of population and the slow rate of transportation.

Mining, also, was almost at a standstill. The coal mines of the Eastern district, and the silver-lead prospects of the North-Western, failed to reach expectations, and only two gold mines were in operation.

It was at this critical period in our history that the richest lode-tin deposit in the world was discovered. Although years passed before the significance of this discovery was fully realised, the results of development works were very encouraging, and gradually an important settlement became established in the heart of the unexplored western region, providing a convenient base for explorers desiring to operate farther afield. The incentive thus given to exploration led to a succession of mineral discoveries of great importance in neighbouring districts. During the following decade silver-lead was found at Magnet and Heazlewood, gold at Corinna, tin at Heemskirk, and copper and iron at the Rocky and Savage Rivers. These in turn led to the discovery of silver-lead at Zeehan, zinc-lead at Rosebery and Mt. Read, copper at Mt. Lyell, and tin at Renison Bell. Although the offspring, as it were, grew to become great producers of wealth, they never at any time wholly eclipsed the parent mine.

After paying dividends without intermission for forty years from the profits of production, the company operating this mine has used up the reserve of rich ore, and in consequence active operations have been temporarily suspended. Unfortunately, the depletion of the rich deposits synchronised with the collapse of the market at the time of the outbreak of the Great War, and at present rates for tin the low-grade deposits, which are very extensive, cannot be profitably mined. The future prosperity of the company from its Mt. Bischoff operations depends upon one of two factors: an appreciable rise in the tin market, or the location of richer ore-bodies. As the former cannot be anticipated, the latter phase of the question only can be considered.

It was with the object of assisting the company in this connection that the writer was detailed to make a thorough investigation of the ore-deposits. In the following pages an endeavour is made to present as lucidly as possible an explanation of the origin and nature of these deposits. In addition, a complete account is given of the various activities of the company. Depending upon the results of these researches certain recommendations concerning the future policy of exploration and development are made, and it is considered that if these recommendations are carried into effect the results will inaugurate a new era of prosperity for the company.

Advantage was taken of the occasion of this visit to extend the investigation in order to include all the known tin lodes in the district, and an examination was made also of those areas that were considered likely to contain deposits of this metal. Although the Mt. Bischoff overshadowed in importance all other tin mines in the district, each received careful attention, and detailed descriptions are given in this report of the various kinds of ore-deposit exposed in the several workings. With one exception, the smaller mines also are closed, and many of the poorer prospects have been abandoned. There is, however, the likelihood that some of the richer mines will soon be reopened.

(2)—General Statement.

This bulletin is based on the results of investigations made during the period extending from 23rd January to 5th June, 1922. A considerable portion of the field-mapping was performed by H. G. W. Keid, Government Geologist, who acted also as assistant to the writer in connection with the examination of the Cleveland and Mt. Bischoff Mines.

Owing to the rugged nature of the country, the heavy vegetable cover, and the difficulty of access, the work of investigation was arduous and slow. The study of details was confined to the more easily accessible areas where mining development was in operation. However, a reconnaissance survey of the whole district was made, and sufficient information was obtained concerning the geology of the outlying areas to serve as a foundation for future exploration. A considerable portion of the area is covered with beds of Tertiary age, and stratigraphic sections of the older Palæozoic mineral-bearing rocks are not well exposed. The mountain sides are clothed with forests, and the plains are covered with peat and button-rush, and natural outcrops of strata, except in the beds of streams, are few. Road, ditch, and tramway excavations, in addition to mine-openings, provide facilities for examination unobtainable in the undeveloped areas, and on the sections thus exposed this investigation is based.

(3)—Acknowledgments.

The writer takes this opportunity of expressing his gratitude to residents of every part of the district for their hospitality. It would be out of place in this publication to mention by name all those who extended these courtesies, and thereby helped to lighten the labour incidental to the investigation. The writer will therefore be pardoned if he refers by name to those only who furnished valuable information bearing upon the subject of this report. In this respect his thanks are due in particular to Dr. L. Grey Thompson, chairman of directors of the Mt. Bischoff Tin Mining Company, for the use of the annual reports of the operations of the company, and for several manuscript reports by mining engineers and geologists, and to Mr. John Luck for information of a similar character relating to the Cleveland Mine.

To Messrs. C. W. Gudgeon and A. Tilley, general manager and mine superintendent respectively of the Mt. Bischoff Mine, he is indebted for information relating to the ore-deposits and the mining operations of the company. In addition to this, Mr. Gudgeon provided plans and notes descriptive of the processes employed in the concentration and calcination of the ores.

It is a pleasure to acknowledge the great assistance rendered by Mr. A. D. Mackay, consulting mining engineer, who was for many years an officer on the staff

of the Mt. Bischoff Company. From Mr. Mackay the author received many helpful suggestions in connection with the study of the origin of the ore-deposits. To this gentleman he is indebted also for copies of analyses of rocks and minerals, and the use of a large number of microscope slides of rocks occurring at Mt. Bischoff.

In addition to the aforementioned, Messrs. R. R. Moore, J. Quinton, Geo. Warner, M. Falkiner, W. Pryde, and A. Palmer contributed valuable information.

(4)—Previous Literature.

(a) *Official Records.*

Official records of the tin-ore deposits of the Waratah district are very meagre. Literature from other sources, however, especially that relating to the Mt. Bischoff Mine, is considerable. It is not customary to review unofficial publications, but, as reference will be made to some of the works of private investigators, it has been considered expedient to present the complete bibliography. In these works, it will be noted, there is a wide divergence of opinion as to the origin of the deposits, no two investigators arriving at complete agreement in any important particular. The work of Weston-Dunn(1) is the most important of these contributions to the geology of Mt. Bischoff.

Differences of opinion are expressed also in the writings of Government geologists. It should be mentioned, however, that no detailed investigation has been attempted since 1884.

In view of the information obtained lately, a summary of the conclusions arrived at and presented in previous departmental publications will prove of interest.

The first published account of the Mt. Bischoff area was from the pen of G. Thureau,(2) and appeared in the Secretary of Mines' Report, 1884.

Thureau considered that the Brown Face deposit consisted of the fillings of a large vent by precipitation from silica-bearing solutions. He states, *inter alia*: " The workings disclose a siliceous deposit, stained brownish-red by decomposing pyrite, which occurs in its original

(1) Weston-Dunn, J. G.: Economic Geology of Mt. Bischoff Tin Deposits, Economic Geology, vol. xvii., May, 1922.

(2) Thureau, G: Report on the Waratah Mining District.

condition below the present working level. When the brown matrix is carefully examined it will be seen that the whole of it consists of small crystals of quartz closely impacted together. This mass eventually closed the vent through which by means of hydrothermal action the tin ores ascended and caused the impregnation of the material with cassiterite."

Writing in 1894, Montgomery(3) remarks: "The celebrated Mt. Bischoff deposit, though often spoken of as a lode, is of a somewhat mixed character, combining features of alluvial deposits, impregnations, and veins and lodes. It is probable that the great surface deposit that has been worked so successfully by the Mt. Bischoff Company is the result of the wearing down and concentration by atmospheric agencies of a large mass of rock which was at one time penetrated in every direction by large numbers of tin-bearing lodes, veins, and porphyry dykes. The tin ore, from its great weight and resistance to the chemical action of the atmosphere, has remained unchanged almost *in situ*, while much of the lighter and more decomposable rock in which it was enclosed has been disintegrated and washed away. There is thus a deposit of alluvial tin ore resting immediately upon the parent lodes. It is possible that the upper parts of these lodes were larger and richer than any yet found underground. The Brown Face workings are in the top portion of what is probably a bulge in one of the lodes. The ore is here found in a matrix of brown oxide of iron, which is most likely the result of oxidation of a large mass of pyrite. The cause of the formation of deposits of tin ore at Mt. Bischoff appears to have been an intrusion of eurite porphyry and topaz rock through the ancient sandstones and slates of which the main mass of the mountain is composed."

Twelvetrees regarded the greater part of the tin-bearing deposits at Mt. Bischoff as detrital. In a report to the Secretary for Mines in 1900, he states: (4) "The aforesaid dykes bound the Brown Face deposit, near the top of the mountain, on three sides, and dip toward the enclosed central area. This underlay suggests that they will form junctions in depth. The central area is fissured slate, and has been worn down into the form of a basin, which has

(3) Montgomery, A.: Mineral Resources of Tasmania. Dept. of Mines, Tas., 1894.

(4) Twelvetrees, W. H.: Report on the Mineral Fields between Waratah and Corinna, 1900.

collected the gossanous and stanniferous waste of the dykes and their contained veins for countless ages . . . It is impossible to predict exactly what will occur at the intersection, but the normal stanniferous contents of the dykes are likely to improve at that point. We must bear in mind, however, that the detrital deposits worked at the three faces average between two and three per cent. of cassiterite. The stanniferous dykes themselves are very much poorer, and a good deal of enrichment would be required for the solid dykes to yield a payable return. The detritus and gossan forming the ore-body of the Brown Face may be described as an immense body of natural concentrates.

In a later report Twelvetrees([5]) referred briefly to the discovery of tin-bearing ore at Pryde and Walsh's prospect, south of the Badger Plain.

In the year 1897 Harcourt Smith([6]) paid a hurried visit to the Mt. Bischoff area. A short description of the prospects and some of the geological features which he observed is contained in a publication of that year.

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III.—HISTORY.

The mountain received its name in honour of James Bischoff who in 1828 occupied the position of chairman of the Van Dieman's Land Company. But for a fortuitous circumstance the Mt. Bischoff Tin Mine would have been included in the Surrey Hills estate of the company, the western boundary of this selection being only 1½ mile distant.

In 1843 a party of surveyors under the leadership of James Sprent visited the area, and placed a trig. station on the summit of the mountain. At the time of their visit the surveyors had no suspicion of the wonderful store of wealth that lay hidden beneath their feet, and so the secret of Bischoff was kept for another generation. Few explorers visited the district, and not one of the early explorers attempted to break through the barrier of horizontal and bauera scrub, which like a high wall surrounded the base of the mountain. The area possessed no visible prospect to encourage the explorer, and for long it was neglected.

James Smith, the discoverer of tin ore at Mt. Bischoff, was born at George Town, Tasmania, in 1827. He was educated in Launceston. At an early age he lost his parents, and was placed under the guardianship of John Guillan, a merchant and miller of that town. In 1851 he participated in the gold-rush to Victoria, and was stationed for two years at Mt. Alexander. Returning to Tasmania in 1853, he settled at Hamilton-on-Forth, and this town subsequently became the base of operations for his many expeditions into the hinterland. Many years were spent in prospecting the mountainous country traversed by the Leven and Forth Rivers, and fair success attended his efforts. He later concentrated attention on the Mt. Bischoff area, at that time very difficult of access. The region he selected for exploration is extremely rugged, and is dissected by numerous fast-flowing streams. The mountains are heavily clothed with forest, and progress over them is impeded by a thick undergrowth of bauera and horizontal scrub. Into this dismal region Smith forced his way, and carried on his self-appointed task with extraordinary fortitude, returning to his base only when exhausted by fatigue and hunger.

The history of Mt. Bischoff as a tin-producing district dates from 4th December, 1871, when, after many fruitless journeys, Smith discovered tin ore on the south-west slope of the mountain in the bed of Tinstone Creek. A sample of the resinous-looking substance was obtained, and conveyed by the discoverer to W. Moore and J. Quiggan, of Table Cape, who handed it to E. B. E. Walker, a local mineralogist, for identification. Disappointment was expressed when it was learnt that the mineral was an ore of tin, and not of silver, as was at first supposed.

In August, 1872, accompanied by W. M. Crosby and a small party of workmen, Smith returned to Mt. Bischoff, in order to institute the search for the source of the loose blocks of ore found in the creek bed. After cutting a track from Knole Plain to the southern portion of the leased ground the work of exploration was resumed. The prospectors were unable to locate the lodes that shed the ore because of the thick vegetable cover and the large amount of detrital material that was strewn over the surface. However, by the end of June, 1873, several tons of tin ore had been recovered in the process of development. A 7-ton parcel shipped to Melbourne created much interest in mining circles, and negotiations were entered into with a syndicate for the sale of the leasehold. An engineer, named W. Dick, was detailed to inspect and report upon the ore-deposits. Although this engineer was greatly impressed by the magnitude and evident richness of the deposit, its situation, remote from lines of transport, detracted so much from its value that it was reluctantly decided not to continue negotiations with the vendor. Subsequently, William Ritchie, of Launceston, after visiting the mine, expressed his willingness to undertake the flotation of a company to exploit the deposits. Thus, in 1873, the present company was formed in 12,000 shares of £5 each, £1500 and 4400 paid-up shares going to the discoverer for his two 80-acre sections. It may be said, in passing, that those two sections included the richest deposits. Owing to the depressed state of the money market at the time, it was decided to make only one call of 20 shillings per contributing share, and arrange with the bank to advance the remainder of the money required to develop the mine. It was considered that a working capital of £15,000 would prove sufficient for this purpose, and that the first dividend would be available within twelve months of the commencement of operations

Unfortunately these hopes were not realised. Over £100,000 was expended in developing the mine and equipping it with machinery before the first dividend was paid in February, 1878. At the time the hopeful shareholders forgot about the isolation of the mine, the lack of transport facilities, the inhospitable nature of the country, and the everlasting rains, and had no idea of the difficulties confronting them. W. M. Crosby was appointed mine superintendent in 1873, and during his tenure of office a great deal of preparatory work was accomplished. Owing to failing health Crosby resigned in 1875, and was succeeded by H. W. F. Kayser, under whose control the rate of production was greatly increased. By the end of 1877 over 1585 tons of clean tin oxide had been accumulated at the mine, and the output had reached 250 tons per month. This was due to the increase in the number of sluices, and to the erection of a five-head battery of stampers to crush the tin-bearing stone discarded in the first sluicing operation. As the reserve of detrital material became depleted it was found necessary to add to the crushing power in order to retain the rate of production at 200 tons per month. In 1879 the milling plant was increased to 15 head of stampers, to 40 in 1880, 60 in 1882, 75 in 1885, and ultimately 115 heads were in operation.

Shortly after the Bischoff Company started work, the Stanhope (Walker and Beecroft's lease) and Don Companies were formed. As all the operating companies had certain common interests, it was decided to share expenditure on works that would prove mutually beneficial. Under this agreement tramways were constructed, dams were built, and over £10,000 was spent in the formation of a road between Burnie and Waratah. In consequence of the heavy traffic the road became almost impassable during winter. However, the difficulties which had attended the carriage of ore to the seaport were overcome by the construction of a tramway by the Van Diemen's Land Company without any concessions from the Government. This work was completed early in 1878, and the problem of transport was thenceforth a matter of small moment.

The Mt. Bischoff Company, seeing the steady and large output of ore from its mine, soon resolved to erect smelting furnaces. Four of these were built in 1874 under the supervision of W. L. Jenkin, on a site in Launceston close to the wharf. The establishment of these smelting works proved of great benefit also to other tin-producers in Tasmania, and, in addition, a considerable proportion of the tin ore mined in New South Wales and other States is smelted at the Mt. Bischoff Company's works.

The company, having overcome the difficulties of transport and treatment of the ore, continued the works of development and exploitation without serious interruption until the outbreak of the Great War.

In 1907 H. W. F. Kayser was succeeded by J. D. Millen as superintendent of the mining operations at Waratah. Mr. Millen resigned in 1919, and C. W. Gudgeon was appointed in his stead.

IV.—GEOGRAPHY.

(1)—Location.

Waratah district is in the County of Russell, near the north-western corner of Tasmania. The township, from which the district receives its name, lies at the foot of Mt. Bischoff on a basalt-covered plateau, over 2000 feet above sea-level. It is the only organised settlement in a region the greater part of which is still unexplored. The 1200 inhabitants are now dependent upon silver-lead and osmiridium mining for their maintenance, but it is expected that tin-mining will again become the chief industry of the people. All the products of the Corinna, Savage River, and Mt. Jasper fields pass through Waratah in transit to the markets, and the business in connection with the exploitation of these fields is transacted there.

A branch line of the Burnie to Zeehan railway unites Waratah by way of Guildford Junction to the seaport (Burnie), which lies 46 miles distant to the north-east. These towns are connected also by a road of moderate grades passing through Yolla, and by an old mountain road through the Van Diemen's Land Company's properties. The latter road is now impassable for vehicles, and is seldom used.

(2)—Topography.

(a) *General Description.*

Waratah is a district of youthful topography, but of high relief. Its physiographic development is due both to tectonic and erosional agencies, the latter being the more important. At the beginning of the Tertiary period the greater part of the surface had been reduced to base level, and only a few residual mountains, such as Bischoff, Magnet, Pearse, Wombat, Cleveland, and Ramsay, remained above the general level as survivals of a very long cycle of erosion. Upon this peneplanated surface of Palæozoic rocks lacustrine sediments of Tertiary age were laid down to a depth of 150 to 200 feet. Toward the close of this period, accompanying the eruption of basaltic lava, the land was uplifted to its present position, 2000 feet above sea-level, and thus the present cycle of erosion was introduced. The high elevation and the very heavy rainfall are directly responsible for the minute dissection of the land surface as it appears to-day.

Although the sheets of basaltic lava formed a highly-resistant cover to the soft sediments on the peneplain, the very heavy rainfall, aided by Tertiary and Post-Tertiary faulting, soon exposed the weak rocks to attack, and the present drainage system gradually came into being. Even now the plateau plains over a wide area are covered with basalt, but to the north and west only remnants of this once extensive formation remain. The Tertiary sediments, likewise, are found in small areas only outside the Waratah district. The rivers and their tributaries have cut deeply into the Palæozoic rocks below the level of the peneplain, and the rate of corrosion is still very rapid. There is no evidence of Pleistocene glaciation in this district. Periodic changes have brought about alternate stages of alluviation and degradation as exhibited by the terraces of alluvial material in the broader valleys of Whyte and Arthur Rivers. These streams are now entrenched in the bedrock below their flood-plains, and the rate of corrosion continues undiminished.

(*b*) *The Peneplain.*

From the summit of Mt. Bischoff as a vantage point a remarkably even horizon is presented in all directions. It will be observed, however, that the general evenness of the horizon is broken here and there by mountain remnants, which, occupied by the more resistant rocks, stand out as residual peaks of erosion. The plateau, nevertheless, is the outstanding feature of the landscape, and manifestly represents a mature erosion plain. The attainment of its present position, 1800 feet above sea-level, is regarded as having taken place in late Tertiary time, and its preservation as a striking topographic feature is attributed largely to the protection afforded by the covering of Tertiary sediments and basaltic lava. Outside the Waratah area remnants only of these formations remain, and the elevated surface of the peneplain minutely dissected by numerous fast-flowing streams presents a very irregular topography. These youthful streams have carved sharp V-shaped valleys 800 feet below the peneplain, and are still far above the base level of erosion.

This peneplain extends for many miles in all directions far beyond the confines of this district, and has been observed by earlier investigators in other parts of the island.

(c) *The Mountains.*

The mountains of this district consist of the highest erosion residuals of the peneplain. They are neither very extensive nor of any considerable altitude, being merely remnants of the older Palæozoic land surface. From the level of the peneplain they appear as isolated peaks and low ridges. Few of them attain 3000 feet above sea-level or 1000 feet above the peneplain. The more prominent are Bischoff (2596 feet), Ramsay (3200 feet), Cleveland (3100 feet), and the Magnet Range. Invariably they are capped with hard erosion-resisting rocks, such as quartz-conglomerate, chert, or quartz-porphyry, and the summits are generally very narrow. The shape of Mt. Bischoff is conditioned by the outline of the porphyry dykes. Mt. Cleveland has a backbone of very hard chert, which on the south side has been denuded of the much softer tuff, and is exposed in precipitous walls 400 to 800 feet high. Mt. Ramsay is capped with 600 feet of West Coast Range conglomerate, and in consequence has survived the effects of erosion to a far greater extent. Magnet Range and Wombat Hill owe their existence to igneous intrusives and beds of chert and quartzite. From these formations the soft tuffs and slates have been removed to a depth of 800 feet, thereby accentuating the mountainous effects of the landscape.

(d) *Drainage.*

Two main drainage systems have been developed since the uplift of the land surface toward the close of the Tertiary period. These are represented by important tributaries of the Pieman and Arthur Rivers. The main channel of the Pieman, 30 miles to the south, follows a due westerly course to the sea; the Arthur rises in this district, and flows northerly for 35 miles, thence turns abruptly to the west, emptying into the sea 50 miles north of the Pieman. Magnet Range forms the watershed between the chief tributary streams of these rivers, and also between two prominent tributaries of the Pieman. Ramsay River and its affluents rise on the east side of

Magnet Range, and empty their waters into the Huskisson before reaching the main channel. Whyte River rises on the other side of the range, and, after receiving the waters of the Heazlewood and other important streams, flows direct to the Pieman, discharging its waters at a point 20 miles from the mouth of that river. Prominent tributaries of the Arthur and Pieman have cut back into Magnet Range and the plateau until their waters pass each other, flowing in opposite directions. On the plateau along the road to Corinna the earlier mature topography is still preserved, but to the north and south the numerous streams have cut deep V-shaped gullies into the rapidly disappearing flat country. The streams meander slowly to the edge of the plateau, thence they fall in cataracts to the bottoms of the main valleys 800 feet below.

(3)—Climate.

(a) *General Description.*

Situated on an elevated plateau 2000 feet above sea-level, and unprotected by mountain ranges, the township of Waratah is exposed to winds from every direction. As a rule winds from the east indicate fine weather, while winds that blow from the west are almost invariably accompanied by boisterous conditions. North-west winds bring heavy rains of medium temperature, easterly are sometimes accompanied by misty rains, and the southerly and south-westerly are ice-cold blasts that bring hail and snow in their wake. The climate is remarkably healthy and bracing, the result of cool, rain-cleansed air and a high altitude. A short summer, extending from December to March, is followed by a cool autumn of average duration, a long, rigorous winter, distinguished by occasional snowfalls and heavy rainfalls, and a cool spring marked by unsettled weather.

The meteorological record shows an average annual precipitation exceeding 85 inches, as shown in the subjoined table. There are no periods of drought, but January and February are dry in comparison to June, July, and August. Rain falls during 250 days of the year, the average of summer and winter being equal in volume to that of autumn and spring. It will be observed on reference to the accompanying table that the lowest annual rainfall during the past 37 years was 67·17 inches in the year 1914, and the highest was 117·24 inches in 1906.

Information relating to extremes of heat and cold is not available, but it may be stated that a shade temperature of 90 degrees Fahr. is exceptional, and in the coldest period the thermometer shows a register of only a few degrees of frost.

Details of the rainfall during the period 1883 to 1922 are given in the subjoined table:—

(*b*) *Rainfall.*

Year.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1883	160	401	587	302	405	1278	988	1151	396	673	415	753	7509
1884	642	222	119	620	836	772	910	1016	1514	767	625	1011	9054
1885	324	786	955	413	929	1152	548	1308	962	423	508	373	8681
1886	270	537	444	549	1126	354	647	1066	1054	922	523	320	7812
1887	454	170	959	841	604	624	1425	541	1082	504	346	271	7821
1888	600	291	715	475	594	1501	1044	1016	428	687	809	158	8318
1889	604	408	501	541	833	1202	523	846	668	809	522	730	8187
1890	220	400	316	391	148	692	603	990	1334	1379	576	596	7645
1891	601	325	369	296	500	100	539	631	534	928	302	872	5997
1892	292	175	353	649	824	1528	722	810	349	316	580	783	7381
1893	492	173	17	502	857	565	993	987	658	888	455	307	6894
1894	279	238	334	665	876	838	1636	725	861	816	782	335	8385
1895	—	—	—	—	—	—	—	—	—	—	—	—	—
1896	—	—	—	—	—	—	—	—	—	—	—	—	—
1897	538	300	811	584	682	697	1069	645	438	1387	1016	64	8231
1898	409	65	322	1040	263	847	1228	602	1386	482	1503	211	8358
1899	914	483	434	404	648	778	462	279	728	787	912	754	7583
1900	478	361	575	663	491	1213	981	1230	358	1189	255	797	8591
1901	695	205	619	838	863	1053	580	495	1444	1153	425	393	8763
1902	841	618	270	281	518	715	716	557	852	409	545	497	6819
1903	560	558	894	1023	836	1048	1059	1205	814	601	487	717	9802
1904	645	520	400	409	1047	1289	900	1113	934	721	1149	652	9779
1905	594	758	583	736	703	1377	1217	1025	1180	680	845	318	10,016
1906	277	313	198	1497	1147	1722	2075	839	918	1450	770	518	11,724
1907	333	302	544	1184	770	754	1416	1460	1539	1228	337	998	10,865
1908	187	364	1181	532	1406	708	791	882	859	559	549	634	8652

(*b*) *Rainfall*—continued.

Year.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1909	336	110	937	1329	797	880	769	1227	371	1060	663	983	9462
1910	201	270	157	711	1442	1225	540	1508	1146	851	632	1034	9717
1911	267	600	629	979	530	1092	665	614	504	952	602	1409	8843
1912	520	57	427	536	726	843	613	1125	1358	918	836	759	8718
1913	493	278	637	216	541	560	1136	1263	1209	576	1340	600	8849
1914	489	162	313	1481	762	632	843	656	478	144	312	445	6717
1915	352	172	838	815	841	1090	759	1126	1394	1333	1613	206	10,539
1916	631	166	327	1287	907	587	532	1207	632	940	696	1115	9027
1917	411	604	533	540	1245	1152	2007	741	1198	977	838	192	10,438
1918	350	366	372	353	1131	1132	1020	487	385	969	299	799	7663
1919	426	272	610	409	682	1593	957	739	977	813	315	408	8201
1920	77	285	635	563	822	1044	1458	845	777	671	725	444	8346
1921	334	283	435	764	360	870	1332	1266	1137	466	793	322	8362
1922	316	337	661	947	795	618	—	—	—	—	—	—	—
Avge. 37 yrs. to end '21	440	340	523	687	777	960	965	925	888	822	673	589	8589

V.—GEOLOGY.

(1)—Geological Map.

The geological map accompanying this bulletin includes the Mt. Jasper, Mt. Stewart, Godkin, Magnet, and Persic silver-lead producing areas examined by P. B. Nye. This arrangement of plotting the surveys in one map was considered advisable in order to show the distribution of the various deposits in relation to one another, and to the igneous and sedimentary formations associated with them. A considerable part of the remaining area was mapped by H. G. W. Keid, who was engaged as assistant to the writer in this investigation.

The map, although based on the mineral charts of Waratah and Heazlewood districts, was drawn largely from notes of extensive surveys performed in connection with the field work. The location of the more prominent features beyond the charted area was determined by prismatic compass and chain, and may be taken as substantially correct. Heights above sea-level were calculated from aneroid readings based on rail-level at Waratah station. The mileage pegs along the Waratah-Corinna-road, which formerly were marked from Corinna, have been adjusted to commence from Waratah; accordingly, these alterations have been recorded on the geological map. In uncharted areas a few streams of considerable size have been named, for convenience of reference, after early explorers of these districts.

In addition to the general geological map of the district another is presented dealing with the Mt. Bischoff area only. This map is drawn to a larger scale, in order to more clearly illustrate the particularly intricate structure of that area. Cross-sections through Mt. Bischoff and Mt. Cleveland and a longitudinal section complete the list of illustrations of this kind.

It is hoped that these maps will not only serve as a guide to prospectors and others directly engaged in the mining industry, but will prove of assistance also to the general reader in following the interpretation of the geologic and physiographic development of the region.

(2)—Geological Summary.

The geological column attains a great thickness in this district, but sedimentation has not been continuous. During certain periods in its history this section of Tasmania formed part of the very extensive land surface. In fact, from the close of the Silurian to the Tertiary the degradation of the land has been going on without serious interruption.

In the neighbouring districts to the west Proterozoic formations of great extent occur. They consist of mica and quartz-schists, and hard, black slates. Intruding them are altered igneous rocks of basic character likewise rendered schistose by the effects of regional metamorphism. These formations are succeeded in the Waratah district by early Palæozoic rocks many thousand feet in vertical measurement. The Lower Palæozoic consist of two quite distinct formations represented by the Magnet Range red and purple slates, cherts, and tuffs, and by the Mt. Bischoff bluish-grey slates, quartzites, and sandstones. In addition to these, Silurian limestone, shales, and sandstones occur. The Upper Palæozoic and Mesozoic are not represented, but Cenozoic formations extend over a fairly large area.

Massive plutonic and hypabyssal rocks of Devonian age (granites, peridotites, pyroxenites, syenites, and gabbros) cut and intrude the older sedimentary formations in every quarter of the district. In addition to these, dykes of diabase of Upper Mesozoic age protrude here and there, and volcanics belonging to the Upper Tertiary extend over a wide area. These basaltic sheets constitute the resistent cover of the earlier Tertiary sediments.

(3)—Sequence of the Sedimentary Rocks.

System.	Series.	Group or Formation.	Lithological Character.
Cambrian	Dundas	Magnet Range	Red and purple slates, tuffs, breccias, &c.
to	Unconformity		
Ordovician	Balfour	Bischoff	Blue, black, and grey slates, quartzites, pebbly conglomerates, grits, and sandstones
	Unconformity		
Silurian	Lower to Middle	Heazlewood and Godkin	Tubicolor sandstones, clayey sandstones, shales, and bluish-grey limestones
	Unconformity		
Tertiary	Deep Lead	Waratah	Sub-basaltic gravels, sands, conglomerates, muds, lignites, and clays
	Unconformity		
Quaternary	Recent	Arthur and Waratah Rivers	Alluvium and recent gravels

(4)—Sedimentary Rocks.

(a) *Dundas Series.*

The oldest rock-formation in the district is a complex of Cambrian (?) tuffs, breccias, basaltic lavas, cherts, slates, and basic intrusives of indeterminate constitution, resting unconformably on the schistose sandstones and slates of Pre-Cambrian (?) age exposed in the adjoining Long Plain area. This formation belongs to the Dundas series of rocks so prominent in the district of that name.

They occupy a considerable part of the Renison Bell district, extending three miles toward Rosebery, and occur also in the Leven district, and at Mt. Claude. The whole series, with the exception of the cherts, which are altered slates, consists of igneous material, but doubt exists as to the origin of some members. The tuffs or breccias are fine, even-grained rocks of two quite distinct types—one mica-bearing, the other not. They weather in rounded outlines like igneous rocks, but they appear to be imbedded with the associated slates and cherts in massive, compact bodies of great extent. Inclusions of slaty material are common near the line of junction, but in the body of the rock the absence of such inclusions is conspicuous. The micaceous type consists of equi-dimensional angular fragments of mica, quartz, and plagioclase set in a groundmass of the same minerals. In addition, chlorite, calcite, and limonite are present. The non-mica variety consists largely of plagioclase, with calcite, chlorite, and an altered pyroxene. These rocks have been variously called felspathic sandstones, greywache, tuffs, breccias, and pyroclastic sediments. Their correct interpretation has not been proved, but a clue to their identification may be found in (1) the homogeneity of their fragments, (2) the evenness of grain of the materials composing the rock, (3) the nature of the cementing material, consisting as it does of fine particles of the same constituent minerals, (4) the absence of definite bedding-planes, (5) the association of basalt and other contemporary igneous rocks, (6) the interbedding of these rocks with cherts and slates, (7) the weathering in spheriod forms, and the irregularity of their thickness from point to point. Considering the evidence adduced, the writer is inclined to believe that these rocks are tuffs that were deposited under sub-aqueous conditions.

The slate members of the formation are purple to brick-red coloured rocks of extremely fine grain size. The only determinate minerals are secondary calcite and oxide of iron. Narrow bands of grey to black slates also occur.

The chert member is prominent at the Cleveland Mine, and forms the backbone of Mt. Cleveland standing up in escarpments 400 to 600 feet above the softer tuffs. These latter are well exposed in the Whyte River area, on Magnet Range, and again at Waratah, and in places are 2000 feet thick. The thickness of the series as a whole could not be determined with any degree to exactitude, but they are not less than 10,000 feet, and are probably much thicker.

In some places the bedding-planes can be seen, and appear fairly uniform, in others the direction of strike shows such variation that a general course cannot be assigned to them. The strike in some places is a little east of north, in others it is east.

The igneous members are of basic character, but the constituent minerals are decomposed, and they cannot be recognised now. Some have been altered to a brownish-clay, others show traces of pyroxene minerals, and although the effusive are the more prominent, intrusive members occur in fairly large bodies.

(*b*) *Mt. Bischoff Series.*

Unconformably overlying the Dundas formation is a series of conglomerates, grits, sandsones, quartzites, and slates of quite different character. Whereas the sedimentary rocks of the older formations are largely of pyroclastic origin, these are typically clastic deposits. The Pre-Silurian igneous rocks intrusive into the former have not been observed in the latter, thus indicating a time interval between the two formations. The Bischoff series on lithologic and stratigraphic grounds have been correlated with the Mt. Balfour group. In the absence of palæontologic evidence these rocks have been tentatively assigned to the Upper Cambrian or the Ordovician.

The conglomerates and grits are composed largely of small, well-rounded pebbles of quartz cemented by silica. They occur in their beds intercalated with the sandstone and slate. The sandstones are grey to yellow in colour, fine in grain, and range in hardness from loosely coherent sands to dense quartzites. One variety contains a considerable proportion of sericite, the others are siliceous. Only the quartzite is thickly bedded.

The other important members of this formation consist of bluish-black and light-grey fissile slates separated by relatively thin beds of quartzite.

These strata occupy the greater part of Mt. Bischoff, and extend westward to Magnet. They lie to the north of Waratah, and strike in a general north-easterly direction. No attempt has been made to determine the aggregate thickness, as the outer limit of the formation is beyond the surveyed area. At Mt. Bischoff they have been dislocated by faulting, crumpled and folded into sharp, broken anticlines and synclines, and have been affected by the intrusions of basic and acidic rocks of Devonian age. The irregularity of the line of junction between this and the Dundas formation is indicative of great earth movement and faulting.

(c) *Silurian.*

Silurian sediments are poorly developed. Siliceous sandstones, clayey sandstones, grits, conglomerates, shales, and bluish-grey limestones outcrop in remnants of no great extent in the Godkin and Heazlewood areas. That deposition during the period was extensive is quite manifest, but it is also evident that during the Devonian period especially, the deposits were greatly reduced by erosion. Other remnants of this formation occur at Wilson River, Huskisson River, Zeehan, Moina, Macquarie Harbour, and Queenstown. The latter have been described in early, official publications, and the former in greater detail by the(7) writer and(8) P. B. Nye.

(d) *Permo-Carboniferous.*

No distinct beds of this age have been recognised in this district, but boulders containing fossils typical of this period are abundant in the lower members of the Tertiary formation.(9) Moreover, enormous blocks of granite, unlike that occurring in the neighbourhood, have been found resting on the Palæozoic slates of Magnet Range. Similar blocks of granite are of common occurrence in the lower members of the Permo-Carboniferous in other parts of the island. Again, at Waratah, Long Plain, and Brown Plain, the basal member of the Tertiary is made up of boulders of hard conglomerate resembling rocks of much greater geological age. It is significant that the conglomerate consists of boulders only, and by reference to the bore records it will be found that the occurrence is not general.

(e) *Tertiary.*

The best sections of Tertiary strata seen by the writer lie on the north side of Arthur River valley between Corinna-road and Magnet tramway. Another good sec-

(7) Reid, A. McIntosh : Tas. Geo. Surv. Bull. No. 32, p. 47.
(8) Nye, P. B. : Tas. Geo. Surv. Bull. No. 33.
(9) Nye, P. B. : Tas. Geo. Surv. Bull. No. 33.

tion is exposed to view at the Bischoff-Taylor Mine on the east side of Waratah River, and complete sections of the strata have been obtained at many points by boring. In some places the basal member is a coarse conglomerate overlain by loosely compacted gravels containing cassiterite; in others, clay or mudstone rests directly on the slate bottom. Owing to the tendency of the mud matrix of the cemented gravels to rapid weathering this material soon disintegrates into its constituent particles, and the cassiterite component is easily separated by sluicing. This bed is succeeded by alternate bands of sandy clay and mudstone containing decomposed vegetation, and the latter by 50 feet of mudstone with seams of lignite. The mudstone beds only appear to be persistent over the whole area. Beds that are of considerable thickness in one part peter out in a short distance indicating an uneven floor. Near Arthur River a bed of calcareous clay 10 to 15 feet thick is exposed. This consists of grey, egg-shaped shells, set in a dense brown matrix of clay. Probably these peculiar pisolitic forms were built by accretion of calcium carbonate around organic nuclei, or perhaps round grains of sediment. The shells are partly filled with brownish clay. It is evident that the inorganic material of the mudstone and clay beds was derived largely from the Cambro-Ordovician rocks, but the lower members of the Tertiary contain also pebbles and boulders from all succeeding formations. The maximum thickness of this formation is nearly 200 feet, and the base is 1700 to 1750 feet above sea-level. These strata have survived in the Waratah area because of the protective covering of basalt.

Although there is direct evidence of stream deposition, the nature of the materials composing the strata and their extent indicate that lacustrine conditions prevailed.

(*f*) *Recent*.

The recent unconsolidated deposits consist of deep beds of detrital materials on the mountain slopes, terrace gravels of fairly large extent on the sides and bottoms of the valleys, and present stream-beds and flood-plains. The more extensive terraces of alluvial ground are on the bottoms of the broad valleys not far above the level of the streams. Alluvial deposits are still being formed by streams.

On the slopes of Mt. Bischoff the deep beds of detrital material contain cassiterite in appreciable amount, and the sorting action of streams in other parts has resulted in the concentration of rich deposits of this tin ore in gravels consisting largely of granite.

(5)—Sequence of the Igneous Rocks.

Cambrian	Basaltic lavas and tuffs; basic intrusives now completely decomposed
Ordovician	—
Devonian	Peridotite, pyroxenite, gabbro, syenite, granite granite porphyry, and diorite porphyrite
Upper Mesozoic	Diabase
Lower Tertiary	Basaltic lavas and tuffs

(6)—Igneous Rocks—Acidic Division.

(a) *Granites.*

Granites are the most widespread igneous rocks in the district. A large body extends from the southern part of the district in a north-easterly direction to a point within 4 miles of Mt. Bischoff. It forms part of the great batholith represented in neighbouring districts by the masses at Meredith Range and Mt. Ramsay, and probably it extends unbroken at surface to Parson's Hood. To the north-east of Mt. Bischoff the batholith outcrops again at Mt. Housetop, and several smaller projections are known in that district.

The width of the outcrop at the southern boundary is 3 miles. Going north it tapers gradually to a point 25 chains north of Corinna-road. From the northern end a dyke of quartz felspar porphyry extends toward Magnet Silver-lead Mine, and another dyke of similar character outcrops in the valley of Arthur River a little to the eastward. The Mt. Bischoff quartz porphyries lie 4 miles to the north-east on the main trend line of the granite body.

This intrusive body is composed of several distinct varieties of granite. The general stock type is a medium-grained biotite granite consisting essentially of quartz, orthoclase, biotite, and oligoclase. Orthoclase is the most prominent felspar and constitutes a large proportion of the rock. Oligoclase is the most common variety of plagioclase felspar, and is present in varying amounts. It is always subordinate to orthoclase, and in some specimens it is not present. Biotite is a universal component, except where alteration has taken place by pneumatolytic action. The muscovite variety of mica, on the contrary, is rare as a primary mineral, but abundant as a secondary product. Of the accessory minerals hornblende is more common than titanite or zircon, though none of these is anywhere prominent. Tourmaline and topaz are sporadically distributed, and apatite is a fairly constant accessory component.

The normal rock is a dark-grey biotite granite composed of felspars, mica, and quartz. In places the rock has a decided pink tone due to the predominance of orthoclase over plagioclase, but in the grey rock the felspars occur in almost equal proportions. Oligoclase, the acid variety of plagioclase, is the usual associate. The orthoclase is devoid of the idiomorphism which characterises the plagioclase and sometimes shows perthitic intergrowths of albite. The common type is a medium to coarse-grained rock with a varying proportion of biotite.

At Wombat Hill the biotite granite, of coarse medium-grain size, consists of orthoclase, plagioclase, quartz, biotite, and a little green hornblende, the dark minerals giving the rock that colour. Many small prisms of apatite are scattered through the rock and small grains of titanite occur sporadically distributed.

On the Mt. Ramsay track, 8 miles from Corinna-road, a coarse-grained pinkish yellow granite was found to consist principally of quartz and orthoclase with carlsbad twinning. In addition a little oligoclase is present, biotite is fairly abundant, and a few flakes of muscovite are scattered through the rock. A specimen from Bett's track revealed a similar composition and character.

On Bett's track, near the dam, a small area of hard, dark-grey granite of medium grain size is exposed. In this rock albite-oligoclase predominates over orthoclase and quartz, and the dark silicates, hornblende and biotite, are abundant. This tendency to a dioritic phase is unusual in the body of the great granite mass.

The acid dykes which accompany, and in some cases intrude, the granite, may be divided into six groups, namely:—

Topaz quartz porphyry.
Quartz felspar porphyry.
Granite porphyry.
Quartz felspar (eurite).
Aplite.
Pegmatite.

The first and second groups are not found intruding the granite at surface. They represent off-shoots or apophyses of the parent rock, and occur as dykes in the surrounding strata. On the contrary, the third, fourth, fifth, and sixth groups nearly always accompany the granite. The line of demarcation between one type and another is sharp and distinct, and the evidence provided clearly indicates the order of intrusion. As a rule the acid dykes course to the north-west, whereas the main granite body has a north-easterly trend. The chemical composition is slightly more acid than the granite, and except for the presence of secondary minerals the components are not greatly different.

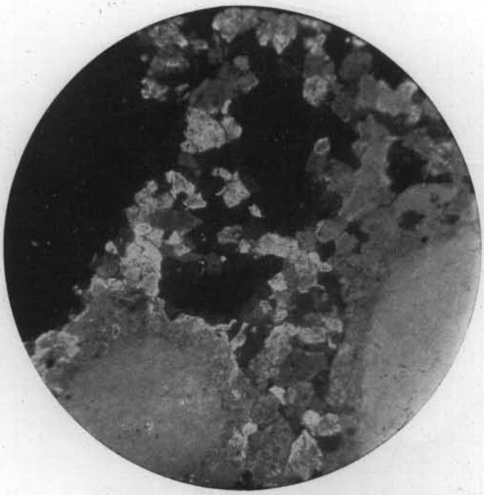
In addition to the acid dykes the granite is accompanied by diorite porphyrite. This rock is a basic differentiate, and occurs as a fringe round the granite outcrop, and occasionally as dyke-like projections in the surrounding slates. Such basic derivatives of the magma are of no direct importance in connection with tin deposits, but they indicate the outline of the granite body at surface. In this case the presence of diorite suggests a heavy cover of sediments between the north end of the granite and the Mt. Bischoff porphyries.

(b) *Topaz Quartz-Porphyry.*

The topazisation of the original quartz felspar porphyry rock is most prominently developed within the range of mineralisation at Mt. Bischoff.

([10])The following account of the topazised quartz-felspar porphyries of Mt. Bischoff is taken from the transla-

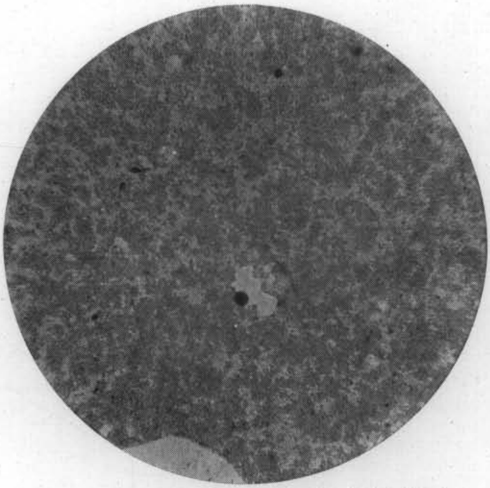
([10]) **Von Groddeck: Remarks on Tin Ore Deposits at Mt. Bischoff, Tasmania, Proceedings of the Royal Society of Tasmania, p. 388.**



[*A. M. Reid, Photo.*

Photomicrograph No. 1.—Quartz Porphyry, showing Topaz Corrosion of Quartz Phenocrysts, Stanhope Face.

To face page 31.



[*A. M. Reid, Photo.*

Photomicrograph No. 2.—Topazised Porphyry, Brown Face, Mt. Bischoff.

See page 33.

tion by G. Thureau of a paper communicated to the Journal of the German Geological Society in 1884:—

This rock resembles to a considerable degree the quartz-porphyries, whether such is examined by naked eye or by means of powerful lenses. It consists of a light, grey-coloured, dense, hornstone-like base, in which numerous transparent quartz crystals can be observed up to 3 mm. in size. One imagines, likewise, of being able to distinguish in the white-coloured cross-fractures of this rock, crystals of felspar. It carries also pyrite in both large and small crystals or in crystalline aggregations . . . . The special chemical analysis of this sample of rock, freed from pyrite through nitric acid, as carried out by Dr. Sommerlad in the Royal Academy's Laboratories, give the following results:—

	Per cent.
Silica (SiO_2)...	76·68
Lime (CaO)	1·19
Fluorine (F)	6·48
Alumina (Al_2O_3)	19·99
Magnesia (MgO)...	trace
Phosphoric acid (P_2O_5)	trace
Specific gravity	3·014

The high percentage of fluorine and the total absence of alkalis are regarded as convincing proofs of this rock not belonging to the quartz-porphyries, and it can now be stated that the rock consists of 35 per cent. of topaz, and 65 per cent. of quartz. To what form the lime content can be assigned is not quite clear; but it is quite possible that some very minute crystals of titanite contain this lime. In the same manner, it is doubtful how the phosphoric acid occurs, except with apatite. The solution which was obtained by treating the ores with nitric acid in order to secure their extraction was found to contain a considerable proportion of lime, owing to some calcite which the microscope had previously discovered.

On placing the pulverised rock in a "Thoulet's" solution of 3·202 sp. gr., the ore was gradually precipitated, and on analysis of that precipitate, the presence of pyrite was detected with slight traces of antimony, copper, and zinc. The chemical and microscopical examinations which followed established the composition of the rock as follows:—Quartz, topaz, pyrite, calcite, titanite, and apatite, of which the first two form the leading, and the remainder the less important constituents. The base of the topaz appears as an aggregation of colourless and irregularly-formed crystalline grains not above 0·02 mm. measurement. Every now and then—especially in the vicinity of the crystals of pyrite, the basic topaz partakes of a more fibrous texture, gaining thereby an appearance which very closely assimilates with the denser whitish topaz referred to below. The very small crystals already alluded to as having been observed in the fractures of the rock itself sometimes enclose such fibrous topaz, 'and they are frequently coated by a white mineral which on account of its granular composition renders the inner or enclosed crystals necessarily less clear, but opaque. . . . They may be accepted as imperfectly formed minimised crystals of topaz (microscopic pycnite(?).) It remains now only to be observed that within those minute crystals grains or specks occur which exhibit vivid polarising colours (also of topaz) as well as irregularly formed particles of pyrite.

The quartz occurs in the basic mass of the rock in the form of crystalline grains or aggregations from 0·06 to several mms. in length. . . . On magnifying these transparent and polarising crysalline aggregations 400 times their original size, they exhibit frequently vesicular openings filled with fluids. . . . Very fine, needle-like crystals occasionally occur, and they may be hereafter recognised as apatite which would explain the presence of phosphoric acid as shown in the analysis. The aggregations of pyrite exhibit very interesting features as cubes can be recognised from 0·05 to 0·15 mm. in length, edgewise. These crystals are sometimes enclosed for half their length in quartz crystals, the remaining half being embedded in the basic topaz. Other very peculiar features are also observable with some very long fibrous forms, measuring from 0·1 mm. in width by 0·3 to 0·7 mm. in length. These, partly encrusted with a thin coating of calcite, are very probably lengthened cubes which have developed in one direction more than another. Besides these there also occur rectangular, nearly cubical, but otherwise irregular crystals of pyrite measuring from 0·35 to 2 mm. in size, impregnated as they are sometimes by crystals of quartz and calcite. These latter predominate sometimes to such a degree over the pyrite, which however retains its crystalline form, as to make it quite subordinate so far as proportions are concerned. The calcite occupies various forms and positions within the pyrite, and it is confined sometimes by peculiar minute botryoidal and oblong crystals, brownish red in colour, which from their general appearance, their distinct pleochroism, and the absence of the former fibrous forms, and being accompanied by a vivid, rainbow-like polarism, cannot be mistaken for any but titanite.

The calcite is easily distinguished by its iridescent properties, and occurs most frequently in the form of impregnations of the pyrite, also in distinct but smaller particles.

A sample of the pyrites—free porphyry, showed the following composition:—

	Per cent.
SiO_2	79·69
Al_2O_3	13·49
Fe_2O_3	0·14
FeO	2·08
MgO	0·60
CaO	0·46
Na_2O	0·08
K_2O	2·71

Further reference will be made to this rock in the discussion on the ore-deposits of the Mt. Bischoff Mine.

(c) *Quartz-Felspar Porphyry.*

Within a few yards of a completely topazised rock a body of quartz-felspar porphyry occurs at the western end of Brown Face. It is remarkable for its comparative freshness and the absence of extraneous minerals. It consists of large phenocrysts of orthoclase and quartz with idiomorphic outlines, set in a ground-mass of these minerals. Flow structure is perfectly developed. The only noticeable alteration is an incipient kaolinisation of the felspar.

In the valley of Falls Creek, an affluent of Waratah River, two dykes of quartz-felspar porphyry are exposed. This rock is distinguished by the presence of large perfectly-formed crystals of muscovite of undoubted primary origin. The muscovite is sparsely but evenly distributed through the rock, and the parallel arrangement of the crystals suggests a tendency toward the development of flow structure. The quartz and felspar crystals are inconspicuous, and do not possess the same degree of idiomorphism, but they are more abundant.

(d) *Granite Porphyry.*

On the road to Corinna, 4 miles from Waratah, a porphyritic variety of biotite granite is exposed in an open-cut. Its phenocrysts are orthoclase, oligoclase, quartz, and biotite, and the ground-mass consists of a later generation of quartz, biotite and orthoclase.

Porphyritic granite of similar character and composition occurs near the point of turn-off to South Bischoff. This rock contains the accessories zircon, titanite, and apatite.

A similar rock occurs at the South Bischoff. It consists of equal amounts of quartz and orthoclase in porphyritic crystals set in a later generation of quartz, orthoclase, oligoclase, and biotite, and a small amount of muscovite.

On the track to Mt. Ramsay beyond the South Bischoff junction the rocks show great diversity in both texture and composition, but they are true granites. In places the texture is decidedly porphyritic, some of the orthoclase phenocrysts measuring 6 centimetres in length. Biotite is the only ferro-magnesian component, and muscovite is unusually prominent. A small part of the quartz and orthoclase occur in micrographic intergrowth. Plagioclase is present, but other accessories are unimportant.

On the track to Ramsay, near the Wombat Mine, a coarse-grained porphyritic granite is well-exposed in a cutting. In general appearance it is a light-grey rock consisting of large crystals of orthoclase set in a medium-grained base of quartz, orthoclase, and biotite. The phenocrysts are exceptionally large, many being 5 centimetres across. These large orthoclase crystals are evenly distributed, and are spaced 1 to 2 inches apart. There is often a suggestion of flow structure in the parallel arrangement of the large phenocrysts, but in general there is no apparent tendency to assume any particular axial direction. The base consists of equal amounts of orthoclase and quartz, flakes of biotite, a little oligoclase, and a few stout prisms and rods of apatite. Joints in the rock are filled with molybdenite. This rock-mass is at least 450 feet wide, and extends north-east and south-west to the edges of the granite outcrop.

(e) *Eurite.*

Narrow dykes of quartz and orthoclase in very large partly-formed crystals have been observed in the South Bischoff area. Interstitial minerals are almost entirely absent, and there is little evidence of pneumatolytic action in the specimens examined.

(*f*) *Aplite.*

A rock consisting essentially of quartz, orthoclase, and muscovite in the isometric forms, characteristic of aplite, occurs in dykes, 40 to 120 feet wide, intruding the main body of the granite. Fresh specimens of this rock are difficult to procure owing to the rapid kaolinisation of the orthoclase component. It appears as a soft semi-decomposed body enclosed between walls of hard biotite granite. Three parallel dykes coursing in a north-westward direction have been traced, and in places mine openings have been cut into them. All contain short lenses of tin ore associated with lepidolite.

(*g*) *Pegmatite.*

Small bodies of pegmatite are commonly found in the granite, but none of them has proved of commercial importance. These rocks are particularly rich in tourmaline, muscovite, and topaz, and they contain in addition varying amounts of cassiterite, sphalerite, and chalcopyrite.

(*h*) *Syenite.*

A large body of syenite extends from the Godkin area in a northerly direction for 6 miles. It crosses Corinna-road between the 11- and 12-mile pegs, and forms the south-western flank of Mt. Cleveland. Its extension beyond Mt. Cleveland has not been determined. In the Godkin area, and again in the Heazlewood River valley, the syenite intrudes ultra-basic rocks of Upper Silurian or Lower Devonian age, and is therefore contemporaneous with the granites occurring in the neighbourhood. So far as examination has been carried no ore-bodies of economic importance have been found directly connected with the intrusion of this rock.

[11]P. B. Nye, who examined this rock, makes the following observations: "It has a holocrystalline, allotrio-

[11] Nye, P. B.: Tas. Geo. Surv. Bull. No. 33.

morphic, even-grained texture and granitic structure. The section consists of felspar, quartz, and an altered ferro-magnesian mineral, with felspar forming about 60 per cent., and the quartz slightly in excess of the ferro-magnesian mineral. The felspar shows much lamellar twinning, and is mainly plagioclase. The analysis shows that potash is absent, and that the ratio of soda to lime is nearly four to one, so that the plagioclase must closely approach albite in composition. Quartz occurs in the usual clear, glassy variety, with numerous small inclusions. Chlorite is present as an alteration product of a ferro-magnesian mineral, which occurs as irregular flakes with one prominent set of cleavage planes. This is suggestive of biotite, but in hand-specimens the general appearance is rather that of an altered amphibole or even pyroxene. Furthermore, the appearance of the altered mineral is very similar to the hornblende in the syenite porphyry described hereunder, the hornblende appearing as irregular flake-like fragments with only one prominent set of cleavage planes. The chlorite would, therefore, appear to have resulted from the alteration of hornblende, and this is in accordance with the determination of Twelvetrees.

(7)—Basic Division.

Rocks of basic character ranging from gabbros to peridotites are particularly abundant in the western part of this district, and are found also in association with the metalliferous deposits of Magnet Range and Mt. Bischoff. In this connection they have lately come into greater prominence, the full significance of which will be disclosed in another chapter. Recent investigations show that these rocks have never received the attention they really merit, but the variety is so diverse that their description in detail cannot be attempted in a work of this kind. A more thorough account is given in Geological Survey Bulletins, 32 and 33, to which the reader is referred for further information.

The many varieties of basic and acidic intrusive rocks occurring here represent the several phases of differentiation of a more or less homogeneous magma. Besides the acidic rocks already described the peridotite, pyroxenite, and gabbro groups are fully represented.

(a) *Peridotites.*

The rocks of the peridotite group show varying degrees of alteration to serpentine according to the proportion of the original olivine component. In colour, the various shades of green predominate, from a light greenish-yellow to deep greenish-black. The development of chrysotile indicates a further stage in the metamorphosis of this rock. Small intrusions of peridotite occur near Luina, and a large body bounds the granite westward of South Bischoff area.

(b) *Pyroxenites.*

The peridotites passes by almost imperceptible gradations into pyroxenite, many varieties of which occur here. Bronzitite, in the Bald Hill area, is found in large irregular bodies in association with other rocks of basic character. Smaller bodies showing alteration to bastite outcrop on the road near Luina. It is prominent also in the southern part of this district. Websterite, consisting of enstatite and diallage, outcrop in the eastern part of the Bald Hill area, and again as a narrow dyke near the Cleveland Mine. Websterite-porphyrite in the form of a dyke extends from the headwaters of Arthur River through the Magnet property to the confluence of Arthur and Waratah Rivers. Another dyke of similar mineral composition and character is exposed on the western fall of Magnet Range. Pyroxenites, now completely altered to chlorite or to dolomite, occur at Mt. Bischoff in association with the deposits of tin ore.

(c) *Grabbros.*

This group consists of gabbro, norite, and diabase. In the Whyte River Valley, near the foot of the Magnet Range, large bodies of gabbro of coarse granular texture are found. A rock of similar character occurs on both sides of Mt. Cleveland, and another of finer grain size flanks Crescent Hill. At Bald Hill, and again at the southern end of Wombat Hill, large masses occur in association with other basic rocks.

Norite is prominent at Bald Hill, and diabase porphyrite occurs with websterite at the Magnet Mine.

(*d*) *Diabase.*

Dykes of diabase of the kind so extensively developed in the Eastern and Midland districts outcrop on Magnet Range. These intrusions are believed to be contemporary, and are assigned to the Upper Mesozoic. The diabase is a greenish-grey, medium-grained rock, composed essentially of augite and plagioclase. It is fresh and very hard, and is exposed in small bodies only. The intrusion of this rock had no important effect on the ore-bodies.

(*e*) *Basalt.*

Extensive flows of basaltic rocks occupy the surface of the plateau to depths varying from 70 to 170 feet according to the nature of the surface upon which they were laid down, and to the later effects of erosion. No intrusive bodies have been reported, but they have never been carefully sought for, and may be present. Considerable variation in character has been noted in this rock from point to point. Tachylyte occurs near the 4-mile peg along Corinna-road, and scoriaceous varieties are widely distributed. The massive rock is frequently porphyritic, the phenocrysts in some cases being olivine, in others bleached augite and plagioclase. These flow-rocks rest upon Upper Tertiary sediments.

(8)—Structural Geology.

The necessity for a clear interpretation of the geologic structure of this region will be conceded when it is realised how closely associated therewith is the distribution of the various kinds of ore-deposits. It may be mentioned at the outset that the structural features are rather difficult to decipher and that, on the evidence available, a thorough interpretation is not possible. However, the information set forth here will serve as an expression of our present knowledge, and will prove of some assistance in arriving at an understanding of the effective forces that were in operation prior to, and contemporaneous with, the formation of the mineral deposits.

Reference to the geological map shows that the trend of the main lines of structure of all Palæozoic formations is to the north-east. This concordance in strike applies to igneous as well as sedimentary rocks, and also to the Proterozoic formation in the neighbouring Savage River district. The dip, however, of the sedimentaries varies in direction and degree from point to point in conformity with the folding to which the formations have been subjected. Faulting on a large scale has contributed to the complexity of the structure.

The oldest rocks here belong to the Magnet Range series which overlie Pre-Cambrian quartz and mica schists of the Savage River formation. They have not suffered the effects of the forces producing the extreme deformation of their older neighbours, but they have been crumpled into irregular folds, and have been dislocated by intrusions, and affected further by the resultant thrust faulting. The Mt. Bischoff formation succeeding them exhibits in greater detail the effects of tension and compression. These formations lie in faulted junction with one another, the line of contact being very irregular. Apparently the Magnet formed the pivot around which the thrust forces took effect, for one line of faulting leads a little east of north from that point past the Persic area, and another passes south of Mt. Bischoff in an eastward direction. The Mt. Bischoff series of rocks presents an intensely crumpled appearance, having no apparent continuity in any particular direction. A close examination outside the intruded area, however, reveals a north-north-easterly direction of the axes, the movement of thrust being toward the east. Subsequent faulting was due directly to the intrusion of igneous rocks. The intrusion of the granite batholith, producing tension in the overlying rocks, caused fractures to develop in planes normal to the maximum stress. As a consequence intersecting sets of fractures have been simultaneously formed at angles of 45 degrees to the axis of tension. Thus the fractures filled by porphyry at Mt. Bischoff show a main set parallel to the structural plane, and another set normal thereto. Again the aplite dykes in the body of the granite fill fractures trending in a north-westerly direction, whereas the strike of the main body is to the east of north. Furthermore, the lode-fissures in the Mt. Bischoff area are north-westerly in direction, but these were formed subsequent to the intrusion and solidification of the porphyry dykes, and later even than the main ore-deposits. Normal faulting on a comparatively small scale followed the formation of all the ore-deposits. Mineralisation, accompanied only the granite invasion, and the ore-bodies have not been greatly affected by the later intrusion of diabase nor the uplift that accompanied the extension of basaltic lava at the end of the Tertiary.

The effects of faulting on ore-deposition will be fully discussed in the part dealing with the description of the mines.

(9)—Geologic History.

The history of the geologic and physiographic development of this region may be summarised as follows:—

(1) Extrusion of Cambrian (?) tuffs and basaltic lavas, the former probably of submarine formation; deposition of sediments, consisting of the waste of similar materials—Dundas slates.

(2) Intrusion of basic igneous rocks in the form of dykes; uplift.

(3) Probable erosion interval.

(4) Deposition of Ordovician (?) conglomerates, grits, sandstones, and slates following subsidence of the land surface.

(5) Uplift and erosion.

(6) Submergence and deposition of Silurian sandstones, grits, shales, and limestones.

(7) Uplift at the close of the Silurian accompanying the intrusion of gabbro, pyroxenite, and peridotite, followed almost immediately by granite, syenite, and quartz-porphyry.

(8) Metamorphism of the intruded sedimentaries and earlier igneous rocks near the contact; fissuring and faulting caused by the intrusion of the granite batholith; advent of the ore-depositing solutions through fissures in the sedimentaries and igneous rocks.

(9) Long-continued erosion through the Devonian period exposing the dykes and batholiths, and the ore-deposits contained in the intruded sediments; reduction of the land surface to base level.

(10) Probable subsidence of the Devonian peneplain and deposition of Permo-Carboniferous strata; doubtful Trias-Jura sedimentation.

(11) Uplift accompanying the intrusion of diabase in Cretaceous time; further faulting.

(12) Removal of Upper Palæozoic strata by erosion; the re-exhuming of the ore-bodies, Devonian the Cretaceous intrusive rocks and earlier sediments; reduction of the surface to base level.

(13) Gradual subsidence of the land, and the deposition of gravels, and sands, and clays, lignites, and mudstones under lacustrine conditions.

(14) Uplift accompanying the Upper Tertiary extrusion of basaltic lava over the area, except those parts occupied by the higher peaks that stood above the level of the Tertiary basin; faulting.

(15) Further faulting.

(16) Rigorous erosion again exposing the older rocks in the valleys; development of the present drainage system, and the formation of alluvial deposits.

Subsequent to the intrusion of the granite and other igneous rocks that were derived from the same stock magma there were four principal periods in the development of the topography. The long cycle of erosion that followed this event, resulting in the removal of a portion of the overlying sediments, and the exposure in places of ore-bodies and granitic rocks, probably came to an end at the close of the Devonian. The history of events during the succeeding period is rather obscure, but there is some evidence of sedimentation during the Permo-Carboniferous period.([12]) Fossiliferous boulders of this age occur in the lower members of the Tertiary formation on the Magnet Range, and it is probable that the conglomerate boulders found at the base of the Tertiary in the Waratah and Long Plain areas represent the waste of the basal member of the Permo-Carboniferous. If not, transportation of these boulders must have been affected during the Trias-Jura or the Cretaceous. Diabase belonging to the Cretaceous intrusion so prominent in the eastern half of the island occurs here in the form of dykes. The intrusion of this rock had no direct effect on the ore-bodies, but it was accompanied by an uplift of the land surface, and another cycle of erosion was introduced. Before the close of this period the diabase had been exposed in small detached masses; and the land had been reduced almost to base level, forming a plain many thousand square miles in

([12]) Nye, P. B.: Tas. Geo. Surv. Bull. No. 33.

extent, broken here and there by residual mountains, such as Mts. Bischoff and Cleveland, Wombat Hill, and Mts. Ramsay and Pearce. The Tertiary was ushered in by the deposition of gravels and sands on the gradually subsiding floor of the old Palæozoic rocks. Probably deltaic conditions prevailed at the beginning, as tin-bearing, quartz-porphyry pebbles, evidently derived from the Mt. Bischoff formation, occur far removed from their source; but as subsidence continued, clays, lignites, and mudstones were laid down under lacustrine conditions on the basal member. The eruption of basalt in the late Tertiary was preceded by a great uplift of the surface. That eruption was intermittent is evinced by the presence of gravels and sands between beds of lava, and by the variation in the nature of the rock exhibited in the several flows. There is evidence also that faulting on a considerable scale followed each extrusion as the several kinds of basalt occurring between Waratah and the North Coast are found at different altitudes. The interpretation of the whole effect of the basalt extrusion is complicated by Post-Tertiary faulting. Vigorous erosion has continued since the eruption, and over a very great extent of country to the westward the basalt has been almost entirely removed. At that time the present drainage system came into being, and the numerous fast-flowing streams then formed are still actively engaged in carving their channels to base level.

VI.—ECONOMIC GEOLOGY.

(A)—General Character of the Ore-deposits.

There are many quite distinct kinds of ore-deposits in this district. Nearly all are represented in the Mt. Bischoff area, and all are genetically related to intrusions of granite or its apophyses. As this report deals specifically with deposits of tin ore, casual reference only will be made to the others.

The tin ore-deposits have been divided into groups according to their nature, and subdivided according to the form of their occurrence. Thus the following classification has been adopted:—

(1) Primary Deposits:

- (a) Veins or Fissure-fillings.
- (b) Replacement—Fissure Deposits.
- (c) Impregnations.
- (d) Porphyry Dykes.
- (e) Aplite Dykes.
- (f) Pegmatites.
- (g) Greisen.

(2) Secondary Deposits:

- (a) Detrital Deposits.
- (b) Placer or Alluvial Deposits.
- (c) Chemical Concentration.

The information contained under this heading is amplified by the more detailed remarks given under the descriptions of the mines.

(1)—Primary Deposits.

(a) *Veins or Fissure-fillings.*

An ore-bearing vein has been defined as a single body of metalliferous minerals occupying or following a fissure, both walls of which are generally well-marked. In the Mt. Bischoff area some veins, from 1 to 10 feet wide, extend at surface 2000 feet and more, and over 1000 feet on the dip. They may either cut across the enclosing strata, or as at the Cleveland Mine conform with them.

These veins, formed shortly after the consolidation of the porphyry, cut sedimentary and igneous rocks alike without being deflected in the slightest degree, though some of them in passing through rocks of dissimilar character show considerable variation in width. Sandstones and slates, being incompetent rocks, do not show the full effect of the fissuring, They tend to come together and close the opening. Quartzites show evidence of shattering, but porphyries are clearly cut, as also are most other igneous rocks. Deposits in quartzite, owing to irregular fissuring, are often split into a hanging-wall, and a foot-wall "make" with a large "horse" of mullock between. These split-veins coalesce in passing from quartzite to slate. The alternate pinching and swelling of a vein is not an uncommon feature, indicating a differential slipping of one wall on another; and in places a later deposition of ore suggests the reopening of the fissure. The variation in the effect of fissuring is unimportant compared with the effect produced by the action of ore-bearing solutions on rocks of dissimilar composition. The chemical action of solutions on quartzite is hardly noticeable; slates and sandstones likewise show little evidence of attack, consequently the ore-deposits in these rocks are confined to the fissures. The silicification of the wall-rock a foot or two on both sides of the vein, and the deposition therein of metallic minerals is the only alteration produced on porphyry by these ore-bearing solutions.

(*b*) *Replacement—Fissure-deposits.*

The conditions of ore deposition are quite different in places where the fissures pass through rocks easily susceptible to attack by ore-bearing solutions. Replacement and impregnation along fissures are fairly uniform in some sedimentary rocks (sandstones, cherts, and slates), producing tabular deposits parallel to the fissure. Where, however, the rocks differ in physical character and chemical composition, ore deposition extends out from the fissure in particular rocks, such as tuff and dolomite, for considerable distances, but leaves adjacent sediments largely unaffected. This selective replacement is due in part to chemical, and in part to physical differences in the rocks. Where fault-fissures intersect vein-fissures access for solutions is far greater, and replacement conditions are in consequence more favourable, the resultant deposits forming boomerang-shaped "chimneys" that follow the intersection of fault and ore-fissures. Selective replacement in certain slates and other siliceous and argillaceous sediments appears to be due largely to physical conditions. In these rocks the fissures are narrow, in places closed up, and are relatively difficult of access to solutions, consequently it is natural to find that the ore-bearing solutions have not been so active, and have not extended so far into the wall-rock.

The replacement of dolomite at Mt. Bischoff, and of tuff at Cleveland are typical examples of large irregular deposits of this kind.

(c) *Impregnations.*

Deposits of this kind, formed by the introduction of minerals in a fine state of division into rocks, either as a filling of open spaces or as a replacement of certain constituents of the rock, are found at Mt. Bischoff. The ore occurs as disseminated particles, and as the fillings of joints and cracks in the sedimentary rocks adjacent to dykes of porphyry. The average tin content of the rock is not high, but the deposits are extensive, and the tin ore in them is easily concentrated.

(d) *Porphyry Dykes.*

In places the porphyry dykes of Mt. Bischoff contain tin ore in profitable amount, and large quantities of such ore have been removed from mines and quarries. The richest sections of the porphyry are confined within narrow limits near the summit of the mountain. As Twelvetrees and Weston-Dunn point out, the greater part of the tin ore so contained occurs near joints in the porphyry, the content decreasing toward the centre of the blocks formed by the jointing. In places the tin occurs as large pseudomorphs after felspar, but as a rule it is of fine grain size. It is a noteworthy fact that within the zone of mineralisation at Mt. Bischoff the porphyries invariably contain tin.

(e) *Aplite Dykes.*

When the granite cools, contraction fissures are formed which become filled with the acid differentiate of the magma, resulting in dykes of aplite, pegmatite, or quartz-porphyry. In some cases these acidic differentiates contain pneumatolytic minerals, and are often accompanied by cassiterite. Aplite deposits as a rule contain tin in comparatively small concentrations. In the South Bischoff area, and at Pryde's Prospect, the occurrence of short irregular lenses of tin-bearing material in an otherwise barren aplite suggests the reaction of tin-bearing vapours on an already solidified rock. Lithia—and fluorine—bearing micas are the invariable companions of cassiterite in these bodies.

(*f*) *Pegmatites.*

Small schlieren-like bodies of pegmatite are of fairly common occurrence toward the border of the granite. In this locality the pegmatites are no economic importance, and require no further description than is given in an earlier chapter.

(*g*) *Greisen.*

Greisen is the product of the action of mineralising solutions on granite, and may be regarded as the last phase of pneumatolytic activity. It consists essentially of quartz and mica, and is often accompanied by tourmaline, topaz, and cassiterite. Quartz is the substitute of felspar, and a white mica (lithia-bearing) is present in place of biotite. Greisenisation sometimes results in the complete silicification of the wall-rock of fissures in granite. As a rule the greisen itself is not particularly rich in tin, the greater part of which is usually found with quartz and tourmaline in the fissure through which the solutions ascended.

The topazisation and tourmalinisation of the quartz-felspar porphyries of Mt. Bischoff is a form of greisenisation.

Veins of this type occur generally toward the fringe of the granite, and have been explored by surface-workings at Badger Plain, Campbell's Prospect, King Billy Prospect, Wyatt's Prospect, Wombat Mine, and Palmer's Prospect. The primary mineral components of this ore are crystalline quartz, black columnar tourmaline, fine to coarsely crystalline cassiterite, orthoclase, a little apatite, and traces of pyrite. Quartz and tourmaline predominate over all other constituents, and in places compose the bulk of the ore. Cassiterite in variable quantity occurs in the forms of bunches and disseminations in the quartz, the tourmaline containing only traces of this mineral. It is noticeable that where these greisen veins occur in granite porphyry they are tin-bearing; in normal granite they are almost barren of this metal. The tin-bearing lenses are very short, and are erratic in their content, and in their distribution.

The alteration of the wall-rock varies slightly according to the original composition. In general the final product consists almost wholly of quartz and massive sericite. The presence of chlorite in the walls of some of these veins suggests a derivation from biotite.

Alteration has extended only a few feet from the veins, the intensity lessening with the distances therefrom.

(2)—Secondary Deposits.

(*a*) *Detrital Deposits.*

In Waratah, where rich tin-bearing rocks weather rapidly at surface under the action of heavy rains, the tin ore becomes concentrated in place by the removal of the disintegrated waste material. Such are called detrital deposits.

(*b*) *Placer or Alluvial Deposits.*

As erosion proceeds the detrital material is carried into depressions, and freshets result in its carriage to gullies and ultimately to permanent streams. The coarser particles of tin ore tend to remain near their source; the finer are carried more easily to creeks, from creeks to rivers, and even to the sea. In steeply inclined gullies very little alluvial collects, but as the streams approach grade lateral erosion increases the widths of the valleys, and gravels and sands then accumulate. The sorting action of the streams results in the concentration of the particles of tin ore by the removal of the lighter particles of gangue rock. In that way alluvial deposits are formed.

Placer deposits of two ages—Tertiary and Quaternary—occur at Mt. Bischoff. Tertiary are represented by sub-basaltic gravels, such as those of the Don workings and the Bischoff-Taylor deposit, and are very extensive. Quaternary gravels occupy the floors of Arthur and Waratah River valleys, and the beds of creeks flowing over tin-bearing granites in the South Bischoff area. Tertiary deposits have yielded very little tin ore; those of Quaternary age have been and are being worked with fair success.

(c) *Chemical Concentration.*

Under suitable conditions tin ore is concentrated in place by the solvent action of percolating waters on gangue rocks, and associated metallic minerals. The removal of some minerals in solution, and the decomposition and transformation of others not only changes the character of the ore materials but also affects the grade of the ore. Where the conditions have been specially favourable the natural concentration of tin ore by chemical agencies has been important.

(B)—Mineralogy of the Ore-Deposits.

(1)—Description of Minerals.

The commercially most important metal that occurs in this district is tin. In fact, the prosperity of the inhabitants is largely governed by the production of this metal. Closely associated with it are many other metals, such as lead, silver, zinc, copper, antimony, &c., but with the exception of silver and lead, no extensive deposits of these metals have been found. Within 3 miles of the Mt. Bischoff tin mine is the great Magnet silver-lead lode, and surrounding it are deposits of many kinds of minerals, some of which may prove of commercial value. The great variation in the character of these deposits and the number of kinds that occur here have resulted in the formation of many mineral species. Some are regarded as of primary origin; others are derived from these by secondary reactions. As a rule the secondary minerals are of little or no economic importance, but a description is given of them because of their association with, and derivation from, the valuable minerals.

For convenience of description the minerals are grouped according to their chemical occurrence, and in the order of their commercial importance.

A list of the most important occurring in the district follows:—

Lode-forming Minerals.

Oxides—
- Cassiterite
- Tungstite
- Limonite
- Hematite

Sulphides—
- Galena
- Sphalerite
- Pyrite
- Pyrrhotite
- Chalcopyrite
- Arsenopyrite
- Marcasite
- Bismuthinite
- Molybdenite
- Stibnite
- Berthierite

Sulphates—
- Copiapite
- Melanterite
- Halotrichite
- Goslarite

Tungstate—
- Wolfram

Phosphates and Arsenates—
- Monazite
- Scorodite

Silicates—
- Tourmaline
- Quartz
- Hisingerite

Carbonates—
- Azurite
- Malachite

Native Elements—
- Sulphur
- Bismuth
- Gold
- Copper
- Arsenic

Haloids—
- Fluorite
- Sellaite

Coal—
- Lignite
- Brown Coal

Rock-forming Minerals.

Silicates—
- Orthoclase
- Plagioclase
- Muscovite
- Pholerite
- Sericite
- Hornblende
- Actinolite
- Asbestos
- Enstatite
- Bronzite
- Diallage
- Augite
- Hypersthene
- Biotite
- Chrysotile

Silicates—*continued*.
- Pilotite
- Pycnite
- Prosopite
- Topaz
- Chlorite
- Talc
- Lepidolite
- Damourite

Phosphate—
- Apatite

Carbonates—
- Ankerite
- Dolomite
- Calcite
- Siderite

(*a*) *Oxides.*

Cassiterite (Tin-stone, Tin Ore).—Cassiterite, tin dioxide, $Sn\,O_2$ (oxygen, 21·4 per cent.; tin, 78·6 per cent.) with a little $Fe_2\,O_3$, is the most important ore of tin. It occurs, crystallised and massive, replacing porphyry and dolomite at the Bischoff Mine, as a vein filling with quartz and pyrite at the Bischoff, Bischoff Extended, and Cleveland Mines, and as a constituent of aplite and pegmatite dykes in the South Bischoff area.

Limonite.—Limonite, hydrated peroxide of iron, forms the capping of nearly all the lodes in the district. It is an oxidation product of pyrite, siderite, and other iron-bearing minerals. Pseudomorphoses of limonite after pyrite are common.

Hematite.—Hematite, peroxide of iron, is commonly associated with limonite, and occurs under similar conditions.

Tungstite.—Tungstite, tungsten trioxide, WO_3, occurs as a yellowish, earthy incrustation on quartz in the Bischoff Extended Mine.

Ilmenite.—Ilmenite, titanic iron, $Fe\,Ti\,O_3$, occurs at Mt. Bischoff, and in abundance in the alluvial gravels in the South Bischoff area.

(*b*) *Native Elements.*

Sulphur.—Sulphur has been found in the Slaughter-yard deposit. It occurs 24 feet below the surface in the form of small crystals in white cellular quartz, with tin ore above and below. Sulphur is formed in the first stage of the alteration of pyrite according to reaction: $Fe\,S_2 + Fe_2(SO_4)_3 = 3Fe\,SO_4 + 2S$.

Bismuth.—Bismuth has been reported in minute quantities only.

Gold.—Gold has been reported as occurring in the Slaughter-yard quartz vein. Tests of the vein material from a winze sunk below Main Tunnel level revealed traces only. The same remarks apply to its reported occurrence in lodes on the east side of Waratah River valley.

Copper.—Native copper occurs in thin veins intersected by the western crosscut, Bischoff Mine. It has been recognised also in the Bischoff Extended workings.

Arsenic.—Arsenic occurs in the lowest level, North Valley lode, Bischoff, in blades between laminæ of siderite with fluorspar, pyrite, and black sphalerite.

(*c*) *Sulphides.*

Galena.—Galena, lead sulphide, PbS (sulphur 13·4 per cent.; lead 86·6 per cent.) occurs associated with tin ore in the Bischoff and Bischoff Extended Mines. The silver content ranges from 25 to 100 oz. per ton of galena. Silver-bearing galena occurs also in great abundance in the Magnet Mine and associated with siderite in veins around the base of Mt. Bischoff.

Sphalerite (Zinc Blende).—Sphalerite, zinc sulphide, ZnS (sulphur, 33 per cent.; zinc, 67 per cent.), is a very common associate of galena in the veins and lodes of this district. The black variety, mariatite (sulphide of zinc and iron), is associated with tin ore in all the lodes and veins of Bischoff, Bischoff Extended, and Cleveland Mines. Mariatite is a comparatively high-temperature mineral.

Pyrite.—Pyrite, iron disulphide, FeS_2 (sulphur, 53·4 per cent.; iron, 46·6 per cent.), is an important primary component of the porphyry dyke-rock, and the tin-bearing lodes, and veins associated therewith. Pyrite appears to have been formed by precipitation from acid solutions, and pyrrhotite from alkaline solutions.

Pyrrhotite.—Magnetic iron pyrites, sulphide of iron, Fe_5S_6 to $Fe_{11}S_{12}$ (sulphur, about 40 per cent.; iron, about 60 per cent.), is particularly abundant in dolomitised pyroxenite, and may be largely of secondary origin. Possibly it is derived from the original iron of the pyroxenite by the action of solutions containing hydrogen sulphide. Its common association with this so-called dolomite at the Mt. Bischoff Mine is particularly striking; but it occurs as an ore-mineral in chert at the Cleveland Mine and there it is primary.

Chalcopyrite.—Copper pyrites, sulphide of copper and iron, $Cu\,Fe\,S_2$ (sulphur, 35 per cent.; copper, 34·5 per cent.; iron, 30·5 per cent.), occurs sparingly at Mt. Bischoff, but it is abundant in the Cleveland ore-deposits associated with pyrrhotite and cassiterite.

Marcasite.—Iron disulphide, FeS_2 (sulphur 53·4 per cent.; iron, 46·6 per cent.) with often a little arsenic, occurs as a secondary mineral resulting from the alteration of pyrrhotite out of contact with the air. A large proportion of the great sulphidic ore-bodies of Mt. Bischoff consists of marcasite. On exposure to the atmosphere oxidation of this mineral is so rapid that the heat generated is sufficient to cause spontaneous combustion.

Arsenopyrite.—Arsenical pyrites, sulpharsenide of iron, Fe As S (iron, 34·3 per cent.; arsenic, 46 per cent.; sulphur, 19·7 per cent.), though nowhere present in great abundance is nevertheless a very common associate of tin ore at the Mt. Bischoff, Mt. Bischoff Extended, and Cleveland Mines.

Molybdenite.—Molybdenite, disulphide of molybdenum $Mo S_2$, occurs in the ore-body at Cundy Mine, and in the joints of porphyritic granite on the track to Wombat Mine.

Bismuthinite.—Bismuthinite, bismuth trisulphide, $Bi_2 S_3$ (sulphur, 18·8 per cent.; bismuth, 81·2 per cent.), commonly affects a bladed habit, but is found in capillary and acicular forms in the Bischoff and Bischoff Extended Mines. It is not abundant.

Stibnite.—Unimportant deposits of stibnite, antimony trisulphide, $Sb_2 S_3$ (antimony, 71·4 per cent.; sulphur, 28·6 per cent.), have been developed in the Bischoff Extended Mine, and it has been noted also in the ores of the Bischoff deposits.

Berthierite.—Berthierite, sulphide of iron and antimony, $FeS\, Sb_2 S_3$, has been found in small quantity at Bischoff. The silver content is low.

Azurite.—Azurite, $2\,Cu\,CO_2\,Cu\,(OH)_2$ (copper 55 per cent.), is present in the oxidised portion of the Bischoff, Bischoff Extended, and Cleveland Tin Mines, and is associated with malachite.

Malachite.—Malachite, $Cu\,CO_2\,Cu(OH_2$ (copper 57·4 per cent.), is found as an alteration product of chalcopyrite in the oxidised portion of the ore-bodies, and as incrustations on the walls of drifts in the Bischoff, Bischoff Extended, and Cleveland Mines.

(*d*) *Sulphosalt.*

Jamesonite.—Jamesonite, $Pb_2 Sb_2 S_5$ (sulphur, 19·7 per cent.; lead, 50·8 per cent.; antimony 29·5 per cent.), has been recognised in the ores of the Bischoff Extended Mine.

At this locality its common mode of occurrence is filiform and amorphous, the entangled fibres often forming large masses of a dark, almost black colour.

(*e*) *Sulphates.*

Copiapite.—Copiapite, a basic ferric sulphate, $2\,Fe_2O_3$ $5\,SO_3$ $18\,H_2O$. This yellow sulphate of iron occurs in small quantity as a result of the alteration of melanterite in the old adits at the Bischoff Mine.

Melanterite.—Melanterite, hydrous ferrous sulphate, $Fe\,SO_4 + 7\,H_2O$. This green mineral occurs in great abundance at Bischoff, especially in the Brown Face workings, where it originates from the decomposition of marcasite.

Halotrichite (Iron Alum).—Halotrichite, $Fe\,SO_4\,Al_2(SO_4)_3 + 24\,H_2O$, is found on the walls of the old mine workings as an effloresence or as stalactitic growths.

Goslarite.—Goslarite, hydrous sulphate of zinc, $Zn,\,SO_4 + 7\,H_2O$, is formed by the decomposition of sphalerite, and is found in the passages of the Bischoff and Bischoff Extended Mines.

(*f*) *Tungstate.*

Wolframite (Wolfram).—Wolframite, tungstate of iron and manganese $(Fe\,Mn)\,WO_4$, occurs with quartz usually in embayments in the walls of tin-bearing veins at the Bischoff Extended Mine.

(*g*) *Phosphates and Arsenates.*

Monazite.—Monazite, phosphate of cerium lanthanum and didymium, essentially $(Ce\,La\,Di)\,PO_4$, with also thoria and silica. It is found widely distributed in the South Bischoff area, associated with cassiterite in gravels derived from granite. The proportion of thoria in this mineral is 2·5 to 3 per cent.

Apatite.—Ordinary apatite is fluor-apatite $(Ca\,F)\,Ca_4(PO_4)_3$. It occurs at Bischoff as small pale crystals in stanniferous topaz porphyry, and as crystalline particles in wolfram at the Bischoff Extended Mine.

Scorodite.—Scorodite, $Fe\,As\,O_4 + 2H_2O$, occurs as an oxidation product of arsenic minerals at Bischoff.

(h) *Haloids.*

Fluorite (Fluorspar).—Fluorite, CaF_2 (fluorine, 48·9 per cent.; calcium, 51·1 per cent.), occurs as a gangue mineral in the veins and lodes of Bischoff and Cleveland Mines. It is commonly found in association with siderite in the gossan trenches of the Bischoff Mine, but occurs also in company with cassiterite and pyrite in veins.

Sellaite.—A mineral corresponding to sellaite, MgF_2, occurs in the altered pyroxenite near Brown Face, Bischoff Mine.

(i) *Silicates.*

Orthoclase.—Orthoclase, $KAlSi_3O_8$, is an important constituent of the granite porphyries and granites. In pegmatites it is coarsely crystallised and abundant.

Plagioclase.—Although a variety of plagioclase occurs in the granites it is in other varieties a more important constituent of the basic rocks of the district.

Amphibole Group.—Members of the amphibole group are important constituents of syenites and basic igneous rocks in this district. Hornblende is prominent in syenite on Mt. Cleveland; actinolite occurs at Bischoff, near Whyte River settlement, and at the Cleveland Mine; amphibole asbestos has been recognised at Bischoff.

Pyroxene Group.—Enstatite and bronzite are important constituents of the ultra-basic rocks, as also are diallage, augite, and hypersthene.

Pycnite.—This mineral is distinguished from normal topaz by its columnar habit and compact structure. It occurs here in radiating groups with interstitial quartz, constituting the rock topaz quartz-porphyry.

The dense white crystalline topaz was analysed by Dr. Sommerlad, and found to contain silica, alumina and fluorine in the following proportions:—

	Per cent.
Silica (SiO_2)...	33·34
Alumina (Al_2O_3)...	37·02
Fluorine (F) ...	17·64
Lime (CaO) ...	0·83

This content, with the exception of the lime impurity, is typical of topaz.

Probably the Mt. Bischoff occurrence is the finest development of the pycnite variety of topaz that has hitherto been found. In the north open-cut it occurs in association with radiating acicular crystals of zeuxite, this structure indicating abnormal conditions of formation.

Prosopite.—Prosopite, hydrous aluminium and calcium fluoride, occurs as a granular powder, often kaolinised. It is commonly associated with green tourmaline, and pseudomorphoses after pycnite and crystalline topaz are reported. In its decomposed condition it is often mistaken for kaolinised orthoclase.

Topaz.—Topaz of the normal type occurs here in crystalline form in the porphyry dyke-rock of Mt. Bischoff.

Tourmaline.—Tourmaline, a complex silicate of boron and aluminium with magnesium, iron, or alkali metals is found in many forms widely distributed. The black variety is found associated with quartz in veins near the granite-slate contact, especially in the South Bischoff area. It occurs also as nodular masses in granite. Zeuxite, a green and blue variety, is extremely abundant at Bischoff, and practically constitutes a rock-mass in portion of the replacement lodes. Fine, tufted masses of radiating acicular crystals occur as complete replacements of quartz-felspar porphyry. The original quartz component of the porphyry is represented by nodules of tourmaline from which extremely fine acicular crystals project in all directions. Pycnite is commonly found associated with it in the form of radiating, acicular crystals.

Zeuxite was indentified at Mt. Bischoff by Dr. Sommerlad. An analysis of a specimen of this mineral showed the folowing constitution:—

	Per cent.
SiO_2	36·86
Al_2O_3	36·72
FeO	5·66
MgO	3·92
MnO	0·66
CaO	0·34
Na_2O	3·57
K_2O	1·11
B_2O_3	10·56
F	0·61

Chlorite.—Under this general name a number of minerals are embraced which are closely related to the micas. They are, however, more basic, hydrated, and free from alkalies. A variety corresponding to penninite occurs in masses of great extent at Mt. Bischoff. It is an alteration product of peridotite.

(*j*) *Carbonates.*

Calcite.—Calcite, calcium carbonate, $Ca\,CO_3$, occurs as a gangue mineral in the ore-deposits and abundantly in certain parts as a by-product of the alteration of pyroxenite.

Dolomite.—Dolomite, carbonate of calcium and magnesium ($Ca\,Mg\,CO_3$), like calcite, has been formed by the action of carbonate solutions on pyroxenite. The mineral that goes by this name is not a true dolomite. It consists largely of magnesium carbonate, and contains very little calcium carbonate, the variations in the proportions being in accordance with the amounts of the bases in the original pyroxenite. Dolomite of sedimentary origin is not known in Tasmania, but the crystalline form of this mineral is commonly found in lodes in association with lead and tin ores.

Ankerite.—Ankerite, carbonate of calcium, iron and magnesium, $Ca\,Mg\,Fe\,CO_3$, resembles dolomite in appearance and mode of occurrence. The iron and calcium content is small as a rule, but accessory iron in the form of pyrrhotite is abundant. This mineral in the process of oxidation gives ankerite a gossanous appearance, and as such it is termed at Bischoff. In places it is stained apple-green by chromic acid. It is derived from pyroxenite direct by the action of carbonate solutions, and not through the intermediate development of serpentine.

Siderite.—Siderite, $Fe\,CO_3$, an impure carbonate of iron, is especially abundant at Bischoff. The variety manganosiderite is common, and in some specimens the proportion of manganese is high.

Gilbertite.—Gilbertite, a variety of muscovite mica, is a common constituent of the ore-bodies at Mt. Bischoff. It has usually a golden yellow to greenish colour, but it is sometimes found silver-white and pink, with a glimmering lustre. Samples of similar mica were obtained from the North Valley lode, and from the No. 2 level, Brown Face workings, and showed the following constitution:—

	Sample No. 1.	Sample No. 2.
SiO_2	49·47	51·16
Al_2O_3	33·48	30·80
Fe_2O_3	1·55	4·00
FeO	0·83	—
MgO	0·47	2·10
CaO	0·16	Nil
Na_2O	1·47	0·60
K_2O	8·86	5·75
H_2O + ...	2·86	—
H_2O −	0·34	—
F	1·21	—
SO_3	—	0·17
Loss on ignition ...	—	6·26

Analyst—A. D. Mackay.

W. D. Reid.

No. 1 sample was cleansed from impurities by puddling in water and decanting before analysis. The material collected yielded 42·9 per cent. of water when dried at 100° C., setting like cement.

No. 2 sample was obtained from a flat, tin-bearing vein below Brown Face workings. It occurs there in golden yellow scales, soft and unctuous, and contains in its mass a large amount of coarsely-crystallised cassiterite.

Hisingerite.—Hisingerite, a hydrated ferric silicate of uncertain composition. It occurs in amorphous masses of an intensely black colour, with a conchoidal fracture, in the pyritic ore-bodies of the Mt. Bischoff Mine. An analysis of this mineral by W. D. Reid showed the following composition:—

	Per cent.
Silica (SiO_2)	8·80
Pyrite (FeS_2)	2·21
Ferrous oxide (FeO)	5·55
Ferric oxide (Fe_2O_3)	4·67
Alumina (Al_2O_3)	9·39
Lime (CaO)...	0·58
Magnesia (MgO)	0·43
Potassa (K_2O)	Nil
Soda (Na_2O)	0·50
Sulphurous oxide (SO_3)	19·35
Combined water	36·30
Titania (TiO_2)	trace
Organic matter and loss on ignition	12·22

Its common mode of occurrence is in the form of stalactites suspended from sulphidic lode matter in the drifts hundreds of feet below the surface. It is found also in the form of veins, and resembles lignite in appearance and occurrence. In the analysis given the high proportion of sulphurous oxide is due to the oxidation of pyrite with which it is associated.

Pilotite.—Pilotite, hydrated silicate of aluminium and manganese. This is an altered variety of actinolite which has been termed "rock cork." It occurs in felted fibrous masses, of a pale grey to almost white colour, in considerable quantity on the east side of the Brown Face deposit at Mt. Bischoff.

Pholerite.—Pholerite, hydrated silicate of aluminium. This is a soft friable substance with a sub-metallic, almost pearly lustre, and large scaly structure. It occurs at Mt. Bischoff.

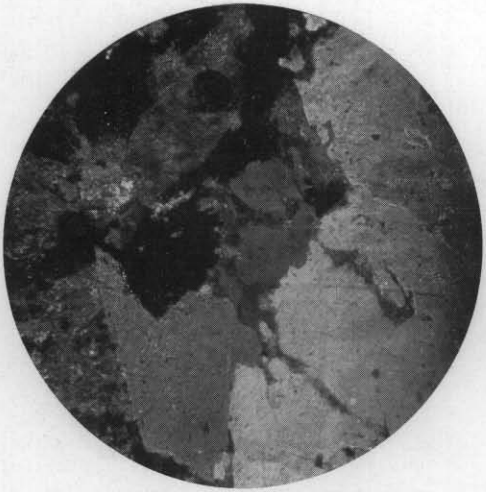
Lepidolite.—Lepidolite, lithia mica. It forms granular masses in aplite in the South Bischoff area, and is associated with cassiterite there. It is abundant also in a similar association at Cundy's, Moore's, and Pryde's prospects.

(*k*) *Organic Matter.*

Lignite.—A semi-formed coal sometimes retaining the texture of the wood from which it was formed. It occurs in rather extensive seams two to three feet thick in a Tertiary formation in the Waratah and Magnet areas.

(2)—PNEUMATOLYSIS.

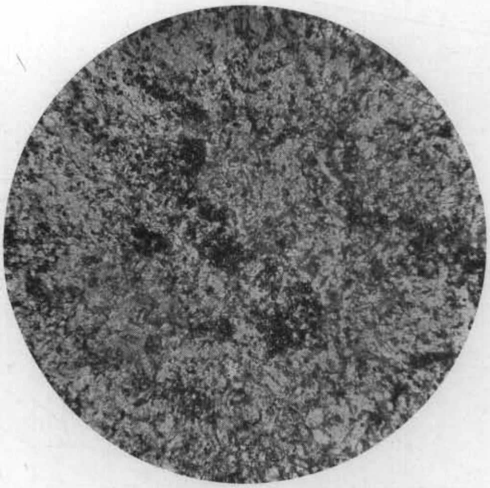
Pneumatolysis has been defined as the process of formation of minerals by the reaction of highly heated gases and vapours upon one another. This condition of chemical activity is indicated here by the development of topaz, tourmaline, and cassiterite. Topaz was formed by the action of fluorine on felspar in porphyry; tourmaline was produced by the action of boron either on already existing brown mica on the intruded slates, or on felspar; cassiterite was deposited in porphyry from fluorine solutions commonly as pseudomorphs after felspar, but in some cases



[A. M. Reid, Photo.

Photomicrograph No. 3.—Cassiterite in Quartz Porphyry, Western Dyke (Crossed Nicols).

To face page 58.



[A. M. Reid, Photo.

Photomicrograph No. 4.—Cassiterite-Quartz Replacement of Dolomite (Ord. Light).

See page 96.

5 cm

it was an original component of the granite or the porphyry.

(*a*) *Topazisation.*—Topazisation of the felspar component of the quartz-felspar porphyries is confined to the small area enclosing the replacement tin deposits. Outside this area comparatively fresh phenocrysts are found, and even in the ground-mass of the rock felspar can easily be detected. In the west end of Brown Face within a few yards of completely altered porphyry incipient kaolinisation is the only alteration noticeable. The development of topaz by the action of fluorine on felspar directly followed the intrusion of the porphyry, and while the rock was still in a molten condition. Quartz likewise, but to a less extent, has suffered the effects of this action. Phenocrysts showing corroded borders are frequently observed in the porphyry near the ore-bodies.

(*b*) *Tourmalinisation.*—Tourmaline of the variety zeuxite, commonly found at Mt. Bischoff, is generally believed to have been formed by the action of boron and fluorine vapours acting on the felspar and mica components of the porphyries. Tourmalinisation directly succeeded the initial stage of topazisation, for the two minerals pycnite and zeuxite occur in intimate association. This association is particularly noticeable in the North Face ore-body, where all stages of pneumatolytic metasomatism of porphyry is illustrated. In some parts the felspar only is replaced by zeuxite and radial pycnite, in others the outline of the original quartz-phenocryst of the porphyry is indicated by sperulitic aggregates of tourmaline needles, and the whole body of the porphyry is replaced. The brown magnesium-bearing tourmaline is commonly found associated with dolomite, from which it evidently has been derived.

(*c*) *Cassiteritisation.*—Cassiterite is found as an original constituent in the porphyry, but the great bulk of it occurs in this connection as a pneumatolytic replacement of felspar. Perfect pseudomorphs of cassiterite after felspar are very common. The formation of cassiterite commenced with the development of topaz and tourmaline, and continued to the hydrothermal stage. Under pneumatolytic conditions cassiterite replaces felspar in porphyry; under hydrothermal conditions cassiterite replaces dolomite. Sections of cassiteritised porphyry show idiomorphic outlines of cassiterite with geniculate twinning and zonal structure.

(3)—HYDROTHERMAL REPLACEMENT

Sericitization.—Sericite, so abundantly developed in all the large ore-bodies, has been derived from topaz by hydration or by the action of alkaline solutions, or directly from orthoclase by the chemical activity of carbonated water under high temperature conditions. Sericite may easily be confused with talc, which is also very abundant, and is sometimes closely associated therewith. The development of sericite commenced during the early and continued to the waning stage of pneumatolytic activity, but has had little or no direct effect on the deposition of the ores. Gilbertite was formed under pneumatolytic conditions; damourite under hydrothermal.

(*a*) *Silicification.*—The alteration of the wall-rocks of veins by silica-bearing solutions is not so pronounced as might be expected. Silicification of slates is common, and sandstones have been converted into quartzites, but the greatest effect is noticeable in the replacement of dolomite. Where this rock has been completely replaced layers of fine quartz crystals, no larger than the head of a pin, and each perfectly crystallised, may be seen intercalated with layers of tourmaline and cassiterite.

(*b*) *Kaolinisation.*—The formation of kaolin is generally attributed to felspathic decay, but probably thermal waters are necessary to bring about the transformation. Kaolin is common only outside the immediate range of intense mineralisation, and is often found in association with pyrophyllite. It seems likely, however, that portion of the pyrophyllite was formed with dolomite prior to the injection of the porphyry.

(*c*) *Dolomitisation.*—The large bodies of dolomite, chlorite, and serpentine, frequently referred to in the foregoing pages in connection with the replacement ore-deposits, represent different stages in the carbonation of an intrusive rock of basic character. It is considered that the original rock consisted largely of peridotite, but the presence of much lime in some of the dolomitised materials suggests a variation of pyroxenites. The general association of dolomite with ultra-basic rocks rich in magnesia and lime has been recorded by the writer in ([13])Mineral Resources, No. 6. The heated carbonated solutions responsible for the conversion of the olivine and pyroxene

([13]) Reid, A. McIntosh: The Iron Ore Deposits of Tasmania, pp. 84 and 85.

contents of the rock into serpentines and dolomites accompanied the early intrusion of the granite prior to the injection of the porphyries. It is generally recognised that the early emanations of the granite magma consist largely of carbonic acid solutions. The formation of talc, commonly found in all the large ore-bodies associated with dolomite, may have originated from peridotite in a similar way; but its commonest derivation seems to have been by the alteration of pyroxenes or even amphiboles. Siderite and manganosiderite occur also in abundance, and were formed in part contemporaneously with the dolomite and the so-called ankerite.

In pursuing these invesigations the writer was impressed by the fact that all the known important tin lodes of Tasmania—as distinct from vein-fillings—are associated with large bodies of dolomite. In all cases observed the greater part of the dolomite so found occurs as an alteration product in place of original basic rocks of the gabbro, pyroxenite, and peridotite types, especially of the last two. It should be noted, however, that bodies of crystalline dolomite are found in the nature of fissure-fillings also in the same localities, having been deposited with siderite from solutions that came into contact with the basic rocks. These deposits are comparatively barren of tin, and are not likely to be confused with the more important replacement bodies to which these remarks have particular reference.

In this district, besides those of Mt. Bischoff. tin deposits in dolomitised pyroxenites occur at Cleveland and at Whyte River. At Renison Bell, not only are all the important ore-bodies found as replacements of dolomite, but the geologic structure is remarkably similar to that of Mt. Bischoff. A similar association has been noted at the Peace Mine, Dundas. Here the tin ore-deposits occur in silicified and dolomitised serpentines near their contact with slate. A quartz-porphyry dyke outcrops nearby, and courses parallel to the line of contact. At X River all the important lodes occur at the margin of the basic rocks, and the gangue materials are dolomite and steatite. Again, in the Stanley River district tin ore occurs with pyrrhotite in dolomite in the Mt. Lindsay lodes; and large bodies of dolomite, much of it the white crystalline variety and of secondary origin, are found in the Stanley Reward property. These constitute all the important tin-bearing lodes in the western district thus far discovered.

The constant association of tin deposits and dolomite is so striking that a casual connection is looked for between them. The explanation is not as difficult as it appears. On page 66 reference is made to the fact that the basic portion of the original stock magma was injected into the overlying strata prior to the intrusion of the acidic or granitic portion. The course of this intrusion conforms to the direction of the general structural planes of the district. The subjacent granite mass, from which the porphyry dykes were derived, like its predecessor, followed the main trend lines. From this granite magma enormous quantities of carbonic acid and sulphuretted hydrogen gases were emitted, and found their way through the overlying fractured rocks completely transforming those more readily susceptible to attack. In this way the dykes of pyroxenite were converted into dykes of dolomite, and a considerable amount of the original iron was converted into pyrrhotite. It is evident, that, though the porphyries have a granite source, they represent the fillings of fissures traversing alike the slates and the granite which immediately underlie them. The porphyries, of course, were the conductors of the mineral-bearing solutions from their reservoir in the granite to the fissured slates and the dolomite.

(4)—PARAGENESIS.

(*a*) *Pyrite.*—Pyrite occurs in great abundance in the porphyries of Mt. Bischoff. Within the zone of intense mineralisation it is usually pseudomorphous after felspar, whereas outside that zone, as exhibited in the Northern and Ringtail dykes, it occurs in large, perfectly formed, cubic crystals. The sharp edges of the cubes, which are set in a white felsitic groundmass of quartz and felspar, show little evidence of corrosion. Occasionally similar cubic pyrite is found in the less altered porphyries of Brown and White Faces, sometimes in elongated forms; but as a rule the pyrite blebs, simulating the outline of the felspar are made up of minute crystal aggregates more or less affected by mineralisers. It is noteworthy that where pyrite pseudomorphs are abundant cassiterite is not prominent, and *vice versa.* A more complete pyritisation of porphyry is exhibited by specimens obtained from the western side of Brown Face. These reveal the replacement of a large portion of the porphyry, and in their minute crystal form assume the habit of the original minerals composing the rock. As the porphyry recedes from the centre of mineral activity the pyrite accessory becomes less and less until it entirely gives out. The presence of pyrite in this association clearly indicates its contemporaneous formation with that of the later cassiterite when the porphyry was still in a fluid condition.

An analagous case to this is the occurrence of pseudomorphous chalcopyrite after felspar in the ore-bodies contained in granite porphyry at the Mammoth Mine, Weldborough, Tasmania.

(*b*) *Pyrrhotite*.—Pyrrhotite is distinctly a high temperature mineral, and, in this area, is usually found as a replacement of dolomite. Some of the pyrrhotite orebodies contain a high proportion of tin, both in the form of cassiterite and stannite. Tin-rich pyrrhotite is common to all the large lodes of this type in Tasmania. At the Cleveland Mine the intercrystallisation of pyrrhotite and chalcopyrite clearly proves their contemporary formation under similar conditions. Much of the pyrrhotite at Mt. Bischoff is older than chalcopyrite, but it is in part contemporaneous, and with the mariatite variety of sphalerite also. Apparently pyrite and pyrrhotite were formed at the same time, under like conditions of temperature, but under different conditions of replacement. Pyrite, likewise, is an important carrier of cassiterite and stannite, which when set free are found to be in an extremely fine state of division. It is noteworthy that below the zone of oxidation the sulphidic ore in every lode of this type in Tasmania consists of pyrrhotite with its occluded tin in the forms of cassiterite and stannite. The variation in the tin content of pyrrhotite ore is extraordinary and very difficult of explanation.

(*c*) *Marcasite*.—The large bodies of marcasite that occur at the point of intersection of fault and lode fissures almost certainly represent the first alteration product of pyrrhotite. Specimens showing secondary marcasite attached to pyrrhotite and evidently derived therefrom are fairly common. Marcasite is found usually at the margin of pyrrhotite bodies but are covered by a few feet of soil and rock debris. When exposed to the action of the atmosphere it rapidly oxidises to sulphate of iron, and under favourable conditions, ultimately to limonite, leaving behind a soft friable mass locally termed "ashes." This residue is the remains of the skeleton of quartz always found in the pyrrhotite of such bodies.[14] A similar occurrence is reported by Hartwell Conder at Renison Bell. In some cases the quartz occurs as a network of small, perfectly-formed acicular crystals; in other cases it is not well crystallised, but is likewise of contemporary origin with the associated pyrrhotite. The oxidation and removal of the pyrrhotite leaves a lattice-work of quartz crystals. Under pressure of the fingers the cementing silica breaks, and the crystals becoming detached are found to be almost perfect in form. The quartz-pyrrhotite ore of this kind is obviously a replacement product—in this case of dolomite. One decomposition product of pyrrhotised dolomite, brought about by the action of meteoric waters, is a gossanous steatite, which is very often regarded as a decomposed ore of tin. As a rule this material is not tin-bearing, and is quite unlike the "ashes" product of ore decomposition referred to.

(*d*) *Arsenopyrite.*—Arsenopyrite is a contemporary of pyrrhotite, and probably arrived a little earlier than pyrite. It is most commonly found on or near the slate and sandstone walls of ore-bodies out of association with pyrrhotite, and the relations to these minerals, in consequence, cannot be determined.

Galena, Sphalerite, Siderite.—These minerals are typical of the hydrothermal phase of ore-deposition. They occur in intimate association, the siderite apparently being a little later in some cases and earlier in others.

Manganese-iron Oxide.—Bodies of manganese-iron oxide occur in the Gossan Face ore-body. These are secondary bodies derived from mangano-siderite deposits similar to those occurring in association with pyrrhotite and dolomite. According to Emmons, the process of the alteration is as follows:—Meteoric waters attack the upper portion of the original carbonate of iron and manganese, and convert it into iron-manganese oxide setting free any contained silica. In so doing the waters lose their dissolved oxygen and become carbonated, in which condition they readily dissolve ferrous-carbonate and some of the contained silica, and transfer it to lower levels. Surface oxidation being complete, waters charged with atmospheric oxygen percolate downward, mingle with the iron solutions previously formed, and precipitate limonite. It has been estimated that the alteration of siderite to

[14] Conder, Hartwell: The Tin Field of North Dundas, Bull. 26.

limonite is attended by a contraction of 27·5 per cent., whence limonite ore-bodies are often porous and spongy. The mangano-limonite deposits are very porous, and contain incrustations of silica. Crystals of quartz deposited from these infiltrating solutions in cavities are common. The tin content of these so-called black gossans is very small. This is due to the fact that they were derived from siderite which was deposited from aqueous solutions during the waning period of mineralisation long after the deposition of the bulk of the tin ore. The presence of the tin-rich brown gossan in association with the black gossan ore-bodies is easily explained. Pyrrhotite and pyrite, associated with the siderite, were the tin carriers. They were readily attacked by meteoric waters, and were thereby converted into limonite, setting free the contained cassiterite.

(C)—Period of Mineralisation.

The ores of this district, although showing a wide variation in the conditions of their formation were deposited during one general period of mineralisation. This period began and ended in Devonian time with the intrusion of granite and its associated porphyries. The intimate association of the ore-deposits with the porphyries leaves no doubt of their close genetic relations. That ore-deposition continued after the consolidation of the porphyry is evinced by the fact that deposits occur in the intrusive rocks as well as in the intruded sediments and basic igneous rocks. Ores, characteristic of both pneumatolytic and hydatogenetic conditions are found in juxtaposition, and so intimately associated that there can be no doubt as to their common origin. For instance, ores of copper, lead, zinc, and antimony are found in the one channel closely associated with ores of tin and tungsten. These minerals were deposited in a certain definite order, but there was a transitional period between successive groups during which some minerals transcended others. The occurrence of definite hydrothermal minerals with those typical of pneumatolytic conditions is due to a reopening of the fissures or channels of circulation. Highly heated solutions deposited tin and tungsten ores, less highly heated ones bismuth, iron, arsenic, copper, zinc, antimony, and lead sulphides.

In the consideration of the formation of these ore-deposits it must be kept in mind that the dykes of porphyry did not intersect the thick beds of quartz-conglomerate which at one time capped the mountain. This massive, impenetrable cover of West Coast Range conglomerate confined the action of the mineralising solutions to a small area, and aided in keeping the porphyry magma in a viscous condition, thereby permitting the accompanying solutions full play in a restricted field of action. The result of this is shown by the great development of pneumatolytic minerals in the ore-bodies.

(D)—Genesis of the Ore-deposits.

It may be affirmed that the original source of all metals is in igneous magmas, and that igneous rocks of all kinds far removed from metalliferous channels contain them. Again, different types of igneous rocks contain different types of metals. Tin and its congeners, for instance, are invariably associated with acid intrusives, such as granite or its differentiation products—quartz-porphyry, aplite, pegmatite, &c. On the contrary, nickel, platinum, osmium, iridium, and some other metals accompany rocks of decidedly basic character. Both basic and acidic plutonic rocks, the differentiation products of one stock magma, occur in the district, and both types of the metals mentioned accompany them.

In order to convey an idea of the principles involved in the formation of the tin deposits a brief outline will be given of the several stages of differentiation through which the stock magma passed in the process of its ultimate separation into rocks of such diverse character and composition. We are not concerned here as to the nature of this process, but as to the results that have been brought about. Accepting Bowen's theory that the original stock magma had the constituency of normal basalt the first stage in rock formation was the differentiation in place of the stock magma into a basic and an acidic portion. After intrusion these derivatives by further differentiation were separated into their respective groups of rocks. The basic portion injected first into the overlying sediments, separated into peridotites, pyroxenites, gabbros, &c. After a short interval this intrusion was followed by the relatively large acidic portion of the magma. In some cases the basic rocks are surrounded by those of acidic character; in others apophyses of the acidic magma are found intruding the basic rocks. Large bodies of syenite and granite represent the acidic rocks—the latter fringed with diorite porphyrite, a border differentiate. Granite occurs in a huge batholitic body of indeterminate extent under cover of Cambro-Ordovician formations, the partial removal of which by erosion exposed the rock at surface. Owing to the irregularity of its upper outline the batholith is represented by disconnected areas of granite which convey only a vague idea of its actual extent. Apophyses of the granite (quartz-porphyry, quartz-felspar porphyry, aplite, and pegmatite), occur in the form of dykes, the first and second named extending beyond the parent granite into the overlying sediments.

The undifferentiated granite magma contained a large amount of water vapour, and the chemically active elements, fluorine, boron, and chlorine. As the magma cooled the relative solubility of the different portions decreased, and it separated into two parts, one of which had the composition of the final crystallised granite, whereas the other contained the excess of silica, a portion of the alkalies, and nearly all of the water vapour and the "mineralisers." As the granite contracted on cooling, fissures were formed in it and the overlying sediments providing a way of escape for the imprisoned gases and vapours that formed the "acid extract" of the magma. The fillings of these fissures resulted in the dykes of quartz-felspar porphyry, aplite, pegmatite, and quartz veins, the last however of later formation. The development of quartz and felspar phenocrysts in the porphyries implies a partial crystallisation of the component minerals prior to injection. Accompanying the intrusion of rock magma were the vapours and the chemically active elements fluorine, boron, and chlorine, probably in combination as tin fluoride, boron fluoride, and hydrochloric acid. The gaseous products reacted on the porphyry and the various intruded rocks, giving topaz, tourmaline, cassiterite, &c. Before the consolidation of the porphyry magma, the fusibility of which had been increased by the action of the "mineralisers," an enormous amount of metallic sulphides found access by these channels as shown by the abundance of perfectly crystallised pyrite in the porphyry, and the presence also of much pyrrhotite and arsenopyrite. The foremost agent in the dissolution of tin and tungsten is fluorine, which directly combines with these elements forming fluorides. Chlorine in the form of hydrochloric acid also plays an important part in the extraction of metallic elements from the magma, and their concentration in veins. Many of these mineralisers act as catalysers, that is, they promote combination, but do not necessarily enter into the composition of the resulting mineral. Catalytic action was largely responsible for the influence of such mineralisers as fluorides, chlorides, tungstates, borates, manganates, &c., in the formation of the deposits. In addition to the mineralisers already mentioned it is probable that sulphides played a most important part as carriers of tin oxide and other metallic compounds.

To face page 69. Photo. No. 1.—WHITE FACE, LOOKING NORTH. [J. *Robinson*, *Photo*.

VII.—THE MINING PROPERTIES.

(A)—The Mt. Bischoff Tin Mining Company Registered.

(1) *Area, Situation, &c.*

Many of the mines which were worked in the early days as individual properties such as the Don, Stanhope, Waratah, and North Valley, now form part of the consolidated areas leased by the parent company. These consist of consolidated leases 4187-M, of 871 acres, and 5579-M, of 205 acres, lease 6988-M, of 21 acres, and dam sites 1129-W, of 250 acres, and 131-W, of 189 acres. The largest section is bounded on the west by the Mt. Bischoff Extended property, and on the north by the Weir's Surprise. It encloses the greater part of Mt. Bischoff, and nearly all the tin-bearing lodes. It is interesting to note that the original sections pegged by the discoverer, James Smith, enclose the most important tin ore deposits in the area.

The workings at Mt. Bischoff are on the eastern and south-eastern slopes, from one to three hundred feet below the summit. They consist of a series of open-cuts, quarries, tunnels, and adits extending over 2600 feet in length, and 1000 feet in width. Including the North Valley veins and talus deposits, and the Don alluvial deposits at the south end, the workings extend over one mile in length, but the great ore-bodies from which the bulk of the ore has been obtained are confined to a small area. Some of the ore-bodies are separated from one another by dykes of porphyry, and apparently have no direct connection. From the south the Happy Valley and Gossan ore-bodies, separated by a dyke of porphyry, are succeeded by White and Slaughter-yard Faces, which in turn are separated from Stanhope and Brown Face workings by other dykes. North Face lies directly beyond Brown Face, and Summit workings are situated at the north end of the peak.

(2) *Mining Methods.*

The rich detrital material on the summit and slopes of the mountain was removed originally by sluicing. This method was gradually superseded by open-cutting and mining, as the ore material became harder, and, in some cases, quarrying was resorted to. The method of excavation varied according to the requirements of the particular case in hand. Thus, the ore-fillings of narrow, continuous veins were removed by mining, whereas the lode material of the large, irregularly-shaped ore-bodies occurring at the intersection of fault and lode fissures were more economically excavated by quarrying and open-cutting.

Since the inception of operations a progressive change has taken place in the methods employed. An idea of the effect of this change may be gained by reference to the cost-sheets issued by the company which, over a very long period, show a remarkable uniformity in the cost of production, but a wide disparity in the value of the crude ore. The decrease in the value of the ore has been counterbalanced by the decrease in cost of production resulting largely from the use of modern machinery, and a consequent greater output of crude ore. Improvements were made in the processes from time to time, but the general principles remain the same to-day, although, in the case of the large ore-bodies, the two systems are employed in conjunction. Nearly all the work of excavation has been performed through adits and tunnels, some of which connect with open-cuts and quarries.

There are no unusual features to record in the method of ore excavation. The ore is broken by hand, loaded into half-ton trucks, and conveyed to bins or to ore-passes centrally situated, the transport system being arranged to converge on the trunk line leading to the milling-plant. In the open-cuts and quarries the benches are from 10 to 40 feet in height, the degree of slope being determined by the nature of the material. Tramways of 20-inch gauge lead from the various faces of each bench to a main travelling way connecting with storage bins. On the resumption of operations at the Brown Face in 1920, crosscuts were driven underneath the deposits, and a "milling" system of mining was instituted. This system of ore excavation has proved economical and expeditious, and will be applied to other deposits. In the underground workings of the Brown Face deposit considerable difficulty is experienced in the operations of developing and stoping owing to the rapid oxidation of the marcasite component of the ore. In order to retard this action, and prevent open firing the stopes are filled with low-grade gossan, and carefully packed, but despite these precautions fires break out frequently necessitating the sealing-up of sections of these workings, and thereby making operations very costly and extraction slow.

A different system is employed in working the comparatively narrow veins. Either a stull and headboard, or a modified three-piece splayed set is used for stopes, and the usual three-piece splayed level set is employed for drifts. In cases where the vein dips at a low angle, such as in the Wheal and Queen bodies, drifts are cut 60 to 80 feet apart on the slope. The ore is broken by overhead stoping and rilled to the chutes.

Square-set timbering is used in stoping the Queen porphyry dyke in the underground workings.

An 80-horsepower electric locomotive running on a 3-feet gauge line draws a train of 20 two-ton trucks from the mine to the milling-plant at Waratah. Detrital material from the North Valley side of the mounain is transported to storage bins on the south side by means of an endless-rope haulage line, whence it is conveyed to the mill along another aerial ropeway.

(3) *Power Supply.*

Dams containing 500,000,000 gallons of water supply power for the generation of electric energy. The power-station equipment consists of two T.G. sets of 375 K.V.A., and two T.G. sets of 140 K.V.A. operating under a head of 600 feet. The electric current is transmitted at 2200 volts to the various substations. One motor generator set of 100 kilowatts transforms the power for the electric locomotive from 2200 volts alternating current to 600 volts direct current, and another generator set transforms the power for the smaller electric locomotives (2) from 550 volts alternating current to 110 volts direct current. Motors are used of 2200 and 550 volts a.c., the latter being the standard pressure on the mine. Including spare motors held in reserve, 49, of a total capacity of 821 horsepower, are available for use. Power for lighting is supplied at 110 volts, alternating current.

(4) *Equipment.*

In addition to the plants already mentioned the mine is equipped with machine, moulding, and carpenter shops, fitted with modern appliances. In these workshops mining and milling machinery are repaired, and additions to the plant are manufactured. The work performed includes castings in bronze, steel, and iron, replacements of worn-out parts of plant, construction of building parts, and general repair and smithy work. The advantage in having such extensive workshops in Waratah are quite obvious.

(5) *Metallurgy.*

(a) Milling and Concentrating.

Lode material as it is broken in the mine contains only a small proportion of tin. Of this amount the greater part occurs in combination with oxygen as the mineral cassiterite, but some of the tin encased in pyrite and pyrrhotite is considered to occur in combination with sulphur. Free cassiterite is distributed through the gangue in particles of various grain size, in bunches and masses, and in veinlets and joint fillings. That contained in sulphidic minerals occurs in a very fine state of division.

Tin ore should be free from other compounds before it is introduced into the smelting furnace. To effect this dissociation several processes are employed depending upon the differences between the physical and chemical properties of cassiterite and its accompanying minerals. The separation of tin ore from the gangue and other associated minerals and its concentration to smelting grade is performed in five operations:—

(1) Selection of pay-dirt for treatment.
(2) Milling of the selected material.
(3) Concentration of the tin oxide (cassiterite component of the crushed dirt), and the separation of the tin-bearing pyrite therefrom.
(4) Calcination of the pyrite concentrate in order to liberate the contained tin oxide.
(5) Concentration of the tin oxide component of the calcined pyrite.

The separation of tin oxide (cassiterite) and other metallic minerals from gangue materials, such as quartz and dolomite, is easily accomplished because of the great disparity between their specific gravities. It is, however, a more difficult matter to effect the complete separation of cassiterite from its metallic associates. In order of quantitative importance these minerals are:—Pyrite (sp. gr. 5·0), marcasite (4·85), pyrrhotite (4·6), sphalerite (3·9 to 4·1), galena (7·5), arsenopyrite (5·9 to 6·2), and chalcopyrite (4·2). Of these, arsenopyrite and chalcopyrite are present in negligible quantities; galena is prominent in parts, but can be separated by hand-sorting in the mine; pyrrhotite is abundant, but pyrite and marcasite constitute the bulk of the ore-bodies. With the exception of galena no serious difficulty is presented in the separation of these minerals.

The specific gravity of cassiterite, 6·8 to 7·1, is not very high, compared with that of pyrite, 5·0, marcasite, 4·85, and pyrrhotite, 4·6, but the difference is sufficient under normal conditions to bring about a complete separation by means of water-concentrating appliances. Close classification is necessary in order to obtain the bests results, as the relative quantities of these minerals are disproportionate. The great preponderance of the sulphidic minerals causes an appreciable loss of cassiterite by entanglement of particles if the tables are fully loaded. However, any free cassiterite lost in this way is collected with the tin-bearing pyrite and pyrrhotite on another section of the concentrator, and is recovered in the subsequent treatment after their calcination.

Cassiterite is as hard as quartz, and much more brittle, so that in pulverising a considerable proportion is reduced to an impalpable powder. In this condition it is difficult to save, therefore it is desirable to separate as much as possible in the coarse state. The plant was designed with this object in view. In the old mill the relative yields were:—

Jigs, 60 to 75 per cent.
Tables, 5 per cent.
Slime tables, 15 to 20 per cent.

One of the greatest difficulties to contend with in the concentration of this ore is the separation of fine tin oxide from the comparatively large proportion of clayey material in which it is contained. The tin ore in this material can be released only after comminution and puddling in the stamper batteries. It will be perceived, then, that the occurrence of free "slime" cassiterite with that of much coarser grain increases the difficulty of the separation.

At first the object to be attained is the production of a concentrate as high in tin content and as free from other minerals as possible. In order to bring about this desideratum at a minimum loss of tin, the ore is subjected to processes of milling, concentrating, and calcining. These operations are performed at the mine, and two grades of concentrate are produced; a high-grade containing 60 to 67 per cent. tin, and a low-grade containing over 40 per cent. tin. The second objective is the reduction of the tin oxide to the metallic state. This is accomplished at the company's works in Launceston.

As already mentioned the tin ore-deposits were originally regarded as alluvial. That being the considered opinion it naturally followed that in the early operations a sluicing system of ore recovery was recommended. But other considerations influenced the company's advisers in arriving at that decision. At the time the only line of communication with the nearest organised settlement (Burnie), was an ill-formed track, and the cost of transport was excessively high. Consequently, the introduction of milling and concentrating machinery was out of the question.

As development progressed the necessity for a milling-plant to crush the tin-bearing rock discarded in sluicing became apparent, but the transition from sluicing to crushing and machine concentration was gradual, and the two processes were employed in conjunction for many years. After the completion of the road between Burnie and Waratah a battery of five light stampers was transported to the mine and erected. The number of batteries was added to from time to time until there were 115 stampers in operation, and the crushing capacity had reached 200,000 tons per year. The depletion of the rich White Face deposit, the reduction in quality of the ore, the greater hardness of the material, and the change in nature from a clean to a sulphide ore led to the scrapping of the obsolete plant, and the erection in 1914 of the new mill, consisting of forty 1000-pound stampers. The capacity of this plant is 100,000 tons per year.

The treatment of the crude ore, after being crushed at the mine, is now confined to the new milling and concentrating plant. The flow-sheet (Plate IX.) illustrates the various operations of this plant, and also the follow-on processes in the sliming and calcining departments. Although there are no unusual features requiring special mention, a brief description of the processes involved in this system of treatment will prove of interest.

Milling Plant.—In consequence of the sticky nature of a large part of the ore the material is hand-fed to the mortar-boxes. It is here crushed to pass through a 12-mesh screen, and carried in launders to classifiers, the coarse product going to jigs, and the fine to 3-compartment classifiers. The overflow from the jigs, after its reduction to powder in a grinding-mill, is also sent to the 3-compartment classifiers, from which it flows to the card tables. The head concentrate from the tables is of smelting grade; the middle is re-treated; the low-grade concentrate is sent to the roasting furnace; and the tailing goes to the slime-plant.

Slime Plant.—The tailing from the milling-plant is received in settlers (75 small and 2 large), from which it flows to the concentrating tables. The head concentrate is of smelting grade; the middle product and tailing are re-treated for a pyritic concentrate, which is sent to the roasting furnace.

Calcining or Roasting Plant.—The roasted material is delivered to a classifier from which the coarse product is passed to jigs, and the fine to No. 2 classifier. The medium product goes to No. 1 Wilfley table, and the fine to No. 2 Wilfley table. The overflow from the jigs, and the tailing from No. 1 table are conveyed to a grinder, thence to a series of 30 settlers and to tables.

The second-grade concentrate is re-treated.

The proportionate amounts of tin saved in the three concentrating plants are as follows:—

	Per cent.
Forty-head milling and concentrating plant	52
Sliming plant...	6
Calcining and concentrating plant	42

The milling and concentrating cost per ton of crude ore, based on 1921 figures, is as follows:—

	s.	d.
Supervision	0	1·13
Milling department...	1	8·75
Sliming department	0	2·95
Roasting department	0	6·34
Repairs and maintenance	0	1·68
	2	8·85

(b) Calcination.

Prior to 1920 no serious attempt had been made to treat the pyritic ore. The aim of the operators was the production of two grades of concentrate only; a high-grade containing about 62 per cent. tin and 7 per cent. pyrite, and a low-grade concentrate containing 27 to 30 per cent. tin. The high-grade concentrate was sent direct to the company's smelters, and the low-grade to a small roasting furnace to be prepared for further treatment on the concentrating tables.

The pyrite tailing from the first operation, after having been subjected to further comminution and classification, was carried to the slime plant and the process of treatment repeated there. In this operation two grades of concenrate were obtained; a high-grade containing 52 per cent., and a low-grade containing 25 per cent. tin.

The average content of tin in the tailing amounted to 0·18 per cent. (0·25 by chemical assay). This loss, taking into consideration the low-grade of the crude ore, was rather high. A considerable reduction was effected by altering the point of cut-off on the tables. The separation of the first and second-grade concentrates was effected in the ordinary way, and a third product was obtained by the inclusion of the heavy pyrite component of the tailing. The operators were thus enabled to save the greater part of the free cassiterite that became entangled with the pyrite, and also that contained in the pyrite. The saving of the third product reduced the tailing loss to 0·103 per cent., and obtained another grade with 1·5 to 4·5 per cent. tin. Ten to 13 tons of this material was obtained daily, and stored for future treatment. As this third-grade concentrate contained only about 2 per cent. tin, a cheap method of treatment was essential. In order to obtain the requisite information upon which to base estimates of cost of recovery, a 50-ton sample of the heap was treated in a small calcining plant, and subsequently concentrated to smelting grade. The result of this test showed that a recovery of 2 per cent. tin could be obtained, and, with a large and efficient furnace, it was considered possible to effect this at cost of 12 shillings per ton.

By the time the large furnace was ready for operation over 3000 tons of pyritic concentrate had been accumulated, the composition of which was:—

	Per cent.
Tin (Sn)	2·59
Iron (Fe)	41·80
Sulphur (S)	48·45
Lead (Pb)	0·11
Arsenic (As)	0·15
Zinc (Zn)	0·40
Copper (Cu)	0·55
Antimony (Sb)	trace
Insoluble	5·04
Loss	0·91
	100·00

A large Edwards furnace was erected close to the slime plant, and so placed that the main tramway would serve as the line of transport from the slime plant, and also from the stack of pyrite concentrate to the hopper of the furnace. This furnace consists of two 60-foot roasting plants set end to end on a uniform grade of 2 per cent. The rabbles, 27 in all, are arranged in series, and are driven from one line of shafting. The furnace is encased in ordinary red brick, and the archway and fire-boxes are constructed of fire-brick. Broken rubble, capped with 2 inches of lime mortar, forms the base upon which a 12-inch layer of low-grade concentrate rests. Over this the rabbles move and form their own bed. Water-jacket rabbles of the plough type are in general use here.

A furnace of this length is required in order to allow the ore to remain in contact with the hot gases until it is thoroughly dry before passing it to the calcining section. The wet concentrate may, in consequence, be introduced in that condition without in any way affecting the efficiency of the furnace. Owing largely to the length and depth of the bed sufficient heat is generated in the combustion of the sulphur component of the pyrite to render the process of roasting complete without the aid of external fires.

A chamber 12 ft. × 12 ft. × 12 ft. is provided at the end of the furnace to arrest flue dust before it can reach the smoke-stack. The stack, 36 inches in diameter, is laid on the hillside, and has a vertical draught of 85 feet.

In consequence of the inconvenience to the townsfolk caused by the fumes from the furnace, a water-blast fume eliminator was designed and built into the plant. This water-blast has not only eliminated the sulphurous acid fumes from the furnace buildings and the township, but has brought about an appreciable reduction in the quantity of fuel required in the operation of roasting.

The fumes discharge into an enclosed concrete chamber, and are met and propelled forward by a series of water-jet sprays into a covered flume. Another series of water-sprays operates in the flume maintaining a regular flow of vapour, and an even furnace draught. The now thoroughly saturated vapour is discharged into Waratah River and carried away.

In the operation of roasting the pyrite concentrate is delivered to an adjustable automatic feeder from which it falls through the arched feed-hole to No. 1 rabble. It is then carried forward and downward from one rabble to another over the three fire-boxes to the discharge orifice. The fire-boxes are so adjusted that the heat applied to the pyrite is increased as the material approaches the end of the furnace. The last rabble discharges the roasted material into an inclined trough along which it is borne to an enclosed chamber. It is now dampened to pulp, then passed through screens to a water-jet elevator, and, by that agent, returned to the concentrating plant.

The discharge pit in which the elevator operates is constructed of concrete, and has a storage capacity of 40 tons. The capacity of this elevator is 15 tons per day, operating under a static head of 40 lbs. per sq. inch.

The flue dust is found to be sufficiently roasted, and is sent direct to the concentrator.

Pulp removal in all parts of the plant is performed by water-jet elevators, which have proved effective and economical instruments in this operation.

Electricity, at a pressure of 550 volts, provides the motive power for the plant.

The rabbles are driven at the rate of one and a half revolutions per minute by a geared 15-horsepower motor. This motor is housed in a small dust-proof room in the main building.

The working cost for the year 1921 is as follows:—

Item.	Cost per ton roasted. s.	d.	
Wages	6	11·73	
Materials	0	5·97	
*Firewood	1	7·63	(probable reduction by 75 per cent.)
Power	1	0·23	
Maintenance	0	8·45	
Total	10	10·01	

From the day operations commenced to the 31st December 1921, nearly 2500 tons of low-grade pyrite concentrate were treated in this plant.

* Since the writer's visit it has been found that the calcination of the pyrite ore can be effected without the use of firewood or any other fuel. There is sufficient sulphur in the ore to make it self-burning.

In these operations 82·9 tons (dry weight) of cassiterite containing 64·98 per cent. tin was obtained. This represents a recovery of 2·18 per cent. tin from the concentrate. The efficiency of the plant is estimated at 84 per cent. Flue dust represents 10 per cent. of the loss, and tailing 6 per cent.

The total cost of plant, including equipment, excavation and erection, buildings, &c., was £4022.

(c) Smelting.

The following account of the processes employed in the smelting of tin ore at the Mt. Bischoff works was furnished by G. J. Latta, late manager, and appeared in the annual report of the Secretary for Mines, 1900. Since then there has been very little alteration in the methods employed by the company, consequently that description is applicable to present-day operations.

Particulars of the ores received at the Mt. Bischoff works for the half-year are given hereunder. These ores represent the average grade of material received and smelted:—

820 tons from Mt. Bischoff, first-grade, contained 72·1 per cent. tin.
69 tons from Mt. Bischoff, second-grade, contained 67·5 per cent. tin.
541 tons of ores (chiefly alluvial) received from other producers contained 71·7 per cent. tin.

1430 tons of ore smelted.

From a smelter's point of view these ores are, as a rule, remarkably pure, there being no impurities in them to prevent the metal being refined up to market quality. The impurity in the Mt. Bischoff ores is principally iron, and that in the alluvial ores is silica. It is a mutual advantage to smelt both together, the iron in the former and the silica in the latter combining to form slag. When the alluvial ores are smelted by themselves it is often necessary to add iron in some form.

The furnaces used are of the reverberatory type, the draught being supplied by a chimney. A charge is made by mixing 50 cwt. of the various ores with about 10 cwt. of small coal. This is thrown into a hot furnace, and the doors are carefully closed to exclude air. The time taken to completely reduce the charge is 8 hours, during which time it is subjected to several rabblings or mixings. When properly smelted the metal sinks to the bottom of the furnace, and the slags or impurities float on the top. The metal is then tipped into a float or brick-lined vessel, allowed to cool a little, and the slag is skimmed off and reserved for future treatment. Another charge is then thrown in and the operation is repeated. The metal in the float is ladled into a large kettle, in which it is refined by sinking billets of green wood under the surface, the heat of the metal converting the moisture of the wood into steam, thereby causing the contents of the kettle to be violently agitated. This has the effect of releasing any entangled portions of oxide or dross, which rise to the surface and are skimmed off. Samples are taken at various times, and when the metal is sufficiently refined it is ladled into moulds. This metal is of 99·8 per cent. grade.

The slags from the ores vary in richness according to the quality of the ore smelted and the working of the furnace. These slags are broken up and mixed with small coal and lime and again smelted, the metal produced from them being very impure, because of the large amount of iron present. The iron is got rid of by smelting it with the next charge of ore.

A few small parcels of ore contain traces of arsenic and copper, and sometimes lead, zinc, and antimony. These have to be treated separately. When arsenic is present every trace must be got rid of by roasting before the ore is smelted, otherwise it causes the metal to be hard, and there are no means of eliminating it once it is alloyed with the tin.

Metal is sent from the works in the form of ingots, weighing 75 lbs.; this is for shipment to England. Smaller ingots are made for the Australian market.

A deduction of 2 per cent. is made on ore sent by other companies to cover loss in smelting; that is, for 20 cwt. of ore at 72 per cent. grade, 14 cwt. of metal or 70 per cent. would be returned to them. This allowance is for ore of 70 per cent. grade or over. When the quality falls below that a larger deduction is made, as the loss in smelting increases in proportion to the decrease in the grade of the ore.

(6) *Statistics.*

Period 1873 to 1921.

	£
Authorised capital of the company—12,000 shares at £5	60,000
Uncalled capital—7600 shares at £4	30,400
Subscribed capital	29,600
Crude ore treated (tons)	4,524,689
Tin oxide obtained (tons)	75,979

	£	s.	d.
Total value of product	5,284,667	0	0
Total amount of profit distributed... ...	2,539,500	0	0
Total cost of operations...	2,745,167	0	0
Dividends paid per authorised share ...	211	12	6

Average recovery of tin per ton of crude ore (per cent.) ... ... 1·17

	£	s.	d.
Average value per ton of crude ore treated...	1	3	4·3
Average profit per ton of crude ore treated ...	0	11	2·7
Average cost per ton of crude ore treated ...	0	12	1·6

(*a*) *Analysis of Ore-production.*

Period Ending.	Crude Ore Treated.	Tin Oxide Recovered.	Proportion of Tin in the Crude Ore.
	Tons.	Tons.	Per cent.
1891.........	867,000	37,088	2·99
1901...........	955,000	22,022	1·61
1911...........	1,342,318	10,803	0·56
1921...........	1,360,371	7066	0·31
Total	4,524,689	76,979	1·17

(b) Analysis of Distributed Profit.

Period Ending.	Crude Ore Treated.	Distributed Profit in Pounds Sterling.	Distributed Profit.		
			Per Ton Treated.	Per Share.	Per Share per Year.
	Tons.	£	Shillings.	£	£
1891......	867,000	1,138,500	26·26	94·875	5·58
1901......	955,000	681,000	14·26	56·75	5·675
1911......	1,342,318	474,000	7·06	39·5	3·95
1921......	1,360,371	246,000	3·61	20·5	2·05
	4,524,689	2,539,500	11·22	211·625	4·5

(7) *Production.*

Commencing with an output of 324 tons of concentrated tin ore in 1874 the rate of production increased rapidly year by year until in 1878 it reached 2283 tons, and in 1885 the record of 2746 tons was produced. An output of over 2000 tons per year was maintained for 21 years. Since 1900 there has been a gradual decline in the output, the fluctuating market value of tin affecting the rate considerably. During the period of operation by this company the market value of tin has been as low as £52½ in 1878, and as high as £419½ in 1920.

In the subjoined table all the information available relating to the production of tin ore is given.

Production of Tin Ore.

Year.	Quantity Crude Material Treated.	Content of Metallic Tin per ton of Crude Ore Treated.	Tin Oxide Produced.		Content of Metallic Tin in Concentrate.	Cost of Production per ton of Crude Ore.		Total Quantity of Tin Oxide Produced to Date.	
	Tons	Per cent.	Tons	Cwt.	Per cent.	s.	d.	Tons	Cwt.
1874........	...	...	324	3	67·3		...	324	3
1875..	...	...	415	6	70·5		...	739	9
1876	...	...	877	12	70·5		...	1617	1
1877..	...	...	1816	16	70·3		...	3433	17
1878......	...	...	2283	14	70·1		...	5717	11
1879...... ..	...	...	2586	7	69·8		...	8303	18
1880	...	...	2465	14	70·4		...	10,769	12
1881.........	...	...	2408	2	...		...	13,177	14
1882... ...	...	...	2526	17	...		...	15,704	11
1883.........	...	...	2511	15	...		...	18,216	6
1884.....	...	...	2606	14	...		...	20,823	0
1885.........	...	...	2746	2	...		...	23,569	2
1886..	...	...	2589	12	...		...	26,158	14
1887...	...	...	2555	14	...		...	28,714	8
1888..	...	...	2574	19	...		...	31,289	7
1889........	...	...	2423	11	...		...	33,712	18
1890.........	...	...	2291	8	...		...	36,004	6
1891...... ..	...	...	2384	8	...		...	38,388	14
1892...... ..	...	...	2235	14	...		...	40,624	8
1893...... ...	...	...	2274	10	64·67		...	42,898	18
1894......	82,998	...	2183	10	65·03		...	45,082	8
1895.........	92,896	...	2281	5	66·74		...	47,363	13
1896...	92,769	...	2477	0	...	6	1·1	49,840	13
1897......	85,653	..	2466	0	...	6	1·37	52,306	13

Production of Tin Ore—**continued.**

Year.	Quantity Crude Material Treated.	Content of Metallic Tin per ton of Crude Ore Treated.	Tin Oxide Produced.		Content of Metallic Tin in Concentrate.	Cost of Production per ton of Crude Ore.		Total Quantity of Tin Oxide Produced to Date.	
	Tons	Per cent.	Tons	Cwt.	Per cent.	s.	d.	Tons	Cwt.
1898.........	85,515	...	2256	0	...	5	10·9	54,562	13
1899.........	111,745	...	1933	2	...	5	4·22	56,495	15
1900.........	99,084	...	1911	5	...	6	0·81	58,407	0
1901.........	102,204	...	1349	0	...	5	9·39	59,756	0
1902.........	100,954	1·325	1291	0	...	5	8·40	61,047	0
1903	94,219	1·35	1284	4	...	6	0·77	62,331	4
1904.........	104,529	1·217	1272	0	69·77	6	5·4	63,603	4
1905.........	100,609	1·321	1272	0	68·06	6	7·18	64,875	4
1906.........	83,573	1·49	1058	0	...	7	3·33	65,933	4
1907.........	122,527	...	730	0	67·21	5	2·70	66,663	4
1908.........	157,577	...	930	0	67·26	5	0·47	67,593	4
1909.........	198,771	...	1025	0	67·64	4	1·44	68,618	4
1910	204,502	...	1080	0	67·00	4	0·48	69,698	4
1911.........	204,772	...	1100	0	66·00	4	2·87	70,798	4
1912.........	244,206	...	1202	1	63·30	4	7·94	72,000	5
1913	228,664	...	1206	13	...	4	10·72	73,206	18
1914.........	160,583	...	716	10	...	5	4·24	73,923	8
1915.........	110,522	...	454	15	...	5	10·93	74,378	3
1916.........	99,060	...	479	16	...	7	5·67	74,857	19
1917.........	103,925	0·304	443	10	...	7	6·74	75,301	9
1918	92,771	0·291	466	15	...	7	8·34	75,768	4
1919.........	102,187	0·257	426	14	63·74	7	9·14	76,194	18
1920	103,297	0·353	454	9	64·47	9	2·88	76,649	7

(8) *Ore-reserve.*

No close estimate of the reserves of ore can be made as insufficient data are available for this purpose. There are certainly very large reserves of low-grade sulphidic materials containing occasional bonanzas, but the average tin content cannot be accurately gauged. In addition to sulphidic ore a large quantity of tin-impregnated slate is available for extraction in the Summit Face, and small supplies of comparatively rich ore are being drawn from vein fillings.

A rough estimate of the ore-reserve is given in the following table:—

Ore-body.	Ore in Sight.	Probable Ore.	Total Quantity.
	Long tons.	Long tons.	Long tons.
Gossan Face	103,000	85,000	188,000
White Face	17,300	17,000	34,300
Slaughter-yard Face	2,900	4,300	7,200
Brown Face	118,000	131,000	249,000
North Face	680	1,800	2,480
Summit Face	1,000	4,000	5,000
Queen Dyke	2,100	4,800	6,900
Stanhope Dyke	3,000	7,000	10,000
Queen Vein	920	1,500	2,420
North Valley Vein	3,000	4,900	7,900
Slaughter Vein	1,100	1,000	2,100
Thompson Vein	1,080	1,100	2,180
Giblin Vein	650	1,000	1,650
Happy Valley Vein	150	700	850
South-west Vein	1,380	1,300	2,680
No. 1 North-east Vein ...	1,590	4,500	6,090
	257,850	270,900	528,750

These figures, furnished by the company, may be taken as an indication of the quantity of ore available in the several deposits. On the basis of hundreds of samples taken from all the ore-bodies it has been estimated that the proportion of tin in the ore in sight is 0·353 per cent.

It is considered that large bodies of richer ore will be revealed when the development work in progress has been completed.

(9) *Geology of Mt. Bischoff.*

With the exception of unconsolidated Tertiary gravels, clays, and muds at the southern base of the mountain, the sedimentary rocks of this area consist of contorted slates, sandstones, quartzites, grits, and breccias with intercalated beds of volcanic ash, the whole belonging to the Mt. Bischoff series of the Cambro-Ordovician. Intrusive into these sedimentaries are igneous rocks of two kinds and ages. First, there are representatives here of basic dyke rocks now hardly recognisable as such owing to complete alteration. In places these rocks have been converted into dolomite and chlorite, as witness the occurrences in Happy Valley, Gossan, White, Brown and Slaughter-yard faces. Fairly fresh serpentine remnants, amphibole asbestos, talc, and tremolite are found in association with the dolomite and chlorite. A small specimen obtained from Gossan Face has the mineral components of a typical peridotite. In this section it is found to consist of serpentinised olivine veined with magnetite and the bastite alteration product of bronzite or enstatite. The dolomite preserves the outlines of the original minerals which were in some cases the components of pyroxenites. The southern continuation of this dyke into the Magnet Range series, which junctions with the Bischoff series between the township of Waratah and the mountain, has not been traced. This is due to the fact that the old peneplanated surface in that direction is covered with Tertiary sediments and basalt lava sheets. In a northerly direction the basic rock does not extend beyond the north open-cut.

The following analyses convey an idea of the variation in the composition of the dolomitised and chloritised rock:—

Radicle.	No. 20.	No. 21.	No. 22.	No. 23.	No. 24.	No. 25.
SiO_2	53·60	24·16	6·24	6·00	1·00	34·88
Fe_2O_3 ...	10·86	14·59	11·06	...	...	2·86
Al_2O_3 ...	2·34	2·40	4·50	0·95	1·56	12·05
CaO	1·58	0·50	0·10	21·08	3·20	Nil
MgO	25·42	29·64	32·95	11·75	14·46	20·28
Na_2O	0·85	0·69	0·49	...	...	1·22
K_2O	Nil	Nil	Nil	...	...	5·91
SO_3	0·34	1·03	0·41	...	...	...
$H_2O\pm$ ...	4·90	4·52	12·10	7·00	6·40	0·32
FeS_2	...	...	2·39	...	...	...
MnO ..	...	0·78	2·23	0·92	13·26	...
CO_2	...	13·08	28·55	49·64	47·40	...
F	0·31	1·50	...	...	...	3·06
FeS........	...	10·01	...	...	...	19·85
FeO........	...	...	...	2·56	12·72	...

Sample 20 represents an altered pyroxenite found near the old entrance to main tunnel. The rock appears to be composed largely of hypersthene. A little purple fluorspar occurs as an incrustation and as a filling of joints in the rock. Sample 21 from Brown Face is a chloritised pyroxenite or perhaps peridotite containing a large amount of pyrrhotite and some fluorspar. The composition conforms to that of penninite. Sample 22 is a dolomitised product of the pyroxenite occurring within a few feet of the chloritised rock.

Sample 23 from Happy Valley Face represents a different type of dolomitised rock, approximating more to the amphiboles in composition than to the pyroxenes. Sample 24 conforms to carbonated schefferite, but in occurrence and character it seems more likely a rock deposited from mineralising solutions. Sample 25 is a pyrrhotised chlorite.

The next are rocks of acidic character represented by numerous connected dykes of topaz quartz-porphyry, quartz-porphyry, and quartz-felspar porphyry. Interest is directed particularly to these rocks in so far as this investigation is concerned, because they are responsible for the cassiterite and other ores found in the area. These dykes intrude both the sedimentary rocks and the altered peridotite and pyroxenite, and extend in a north-easterly direction far beyond the limit of the ore-bodies. The tin-bearing topazised porphyry is confined within the small area occupied by the mountain peak, beyond which it gives place to a hard, sterile, felsitic rock containing occasional phenocrysts of quartz. The main dykes in roughly parallel lines trend in a north-easterly direction, and are connected by subsidiary transverse dykes so as to form one connected mass with protruding sills thrust into the surrounding strata. Fluoric and boric vapours accompanied the intrusion, and replaced the felspar of the porphyry by topaz and tourmaline, the former conversion being the more common. The resultant rock, topaz quartz-porphyry, is the normal type found in association with the ore-deposits.

A complete description of this rock is given in a paper communicated to the Royal Society of Tasmania by F. W.

Petterd and W. H. Twelvetrees in 1897, from which the following is taken:—

"That dykes of an acidic porphyritic rock traverse the Palæozoic slates and sandstones at Mt. Bischoff is well known. This rock carries topaz, both crystalline and amorphous, and that mineral at Mt. Bischoff appears always to be associated with cassiterite. Professor Krause, alluding to these dykes, says: 'The white porphyry composing the summit of Mt. Bischoff contains in a felsitic base crystals of quartz and abundance of fine-grained amorphous topaz, with here and there a cavity lined with groups of radiating acicular crystals of topaz. Pseudomorphs of topaz after quartz are also not uncommon.' This, perhaps, is the latest description of the rock in question, but it applies to only one variety of a very variable rock. We have succeeded in finding specimens showing constituents which have not succumbed to the obliterating process of topazisation. When sliced they reveal quartz-felspar and mica as porphyritic constituents. The felspar outlines are mostly filled in with talc and radiating crystals of topaz (pycnite). This explains the rarity of felspar in the altered rocks. Topaz crystals settle in the interior of a crystal of felspar, replace its substance, and finally its outline is lost in the ground-mass of the rock. In this way many phenocrysts are now indeterminable. This topazisation is what Rosenbusch calls a pneumatolytic phenomenon, viz., the development of topaz and tourmaline in rocks proceeding from granite. Fluoric and boracic vapours, given off at the time of intrusion and consolidation of the vein-matter, are recognised as agents competent to effect the observed results. These solfataric vapours under hydroplutonic conditions act upon a magma protruded from a deep-seated rock-mass containing the elements of a granite. The protruded rock-vein thus becomes topazised and tourmalinised. It is hardly possible to separate physically the moments of topazisation and final consolidation for we must conceive of this process being at work while the vein-mass was, as a whole, still viscous. The phenocrysts of felspar were probably attacked and digested during their passage from below. The Mt. Bischoff rock is essentially a vein-rock, and we are disposed to refer it to the elvan group as a topazised elvan-rock (now topazised quartz-porphyry). . . . . In the Mt. Bischoff rock the felspar of the ground-mass has been replaced by topaz. The analysis recorded by Von Groddeck showed no alkali, and the rock consisted practically of quartz and topaz; but this would naturally be the case in parts of the rock when the topazisation process had proceeded to its ultimate stage. In certain of our slides the substance as well as the form of the felspar has survived, and we are thus able to diagnose the original rock as containing porphyritic crystals of quartz, felspar, and mica floating in a ground-mass which is sometimes composed of granular allotriomorphic quartz, sometimes of crypto-crystalline or felsitic matter, but usually besprinkled with scales of aluminous talc, derived from felspar and mica. When the dykes contain less topaz, as on the North Valley side, we have detected a felsitic ground-mass. We may here mention that the survival of felspar is a rare occurrence. What petrological observers have seen hitherto have been crystal forms only; and what is pointed out to the visitors at the mount as kaolin is really a white decomposed product of pseudomorphous topaz and tourmaline. The quartz-phenocrysts are idiomorphic, sometimes with perfect outlines, or with rounded corners and indentations. Fluid inclusions are present with fixed and moving bubbles . . . A very interesting feature is the conversion of quartz to topaz, which is visible in hand-specimens. A quartz-sinterylooking rock, composed of quartz in hexagonal prisms, shows its individual crystals bordered with a white, cloudy, marginal zone of pseudomorphous topaz. This topaz effervesces slightly when treated with hydrochloric acid owing to the unexpected presence of lime, derived possibly from the alteration of sphene and apatite. We witness here a second conversion—that of topaz into prosopite, a double fluorite of calcium and aluminium. When this change is effected topaz loses its transparency, becomes cloudy and opaque, its hardness diminishes, and its specific gravity becomes less.''

The following tables show the chemical composition of the altered porphyries, and indicate the change that has taken place from their original mineralogic constitution:—

Radicle.	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
$Si\ O_2$	63·58	67·79	76·56	63·16	66·30	79·69
$Al_2\ O_3$ ...	19·34	16·88	16·99	16·46	17·78	13·49
$Fe\ O_3$ ...	0·96	9·04	1·10	3·02	1·26	0 14
$Fe\ O$	1·40	0·19	0·15	0·58	0·33	2·08
$Mg\ O$	0·87	0·83	0·46	0·84	0·97	0·60
$Ca\ O$	0·38	0·24	0·26	0·27	0·21	0·46
$Na_2\ O$	2·27	1·53	1·55	2·30	0·50	0·08
$K_2\ O$	2·17	1·57	1·54	1·68	2·81	2·71
$H_2\ O\pm$ ...	0·20	1·54	0·31	0·10	0·20	...
	0·27	0·17	0·07	0 16	...	...
$Sn\ O_2$	0·09	0·11	0·44	0·10	0·40	...
F	0·08	0·39	0·55	0·12	0·23	...
$Fe\ S_2$	8·04	...	...	10·90	8·81	...
Cu	trace	...	...	0·21	trace	...
Co_2	0·29	0·10	0·37	0·08	0·04	...
Total ..	99·94	100·43	100·35	99·98	99·84	...

(Analyst, A. D. Mackay.)

Sample No. 1 represents the pyritic quartz porphyry from the Brown Face dyke. It consists of quartz phenocrysts and cubic crystals of pyrite set in a dense white ground-mass composed largely of silica or quartz.

Sample No. 2 represents the brown-coloured quartz porphyry from the same locality as No. 1. In many respects it is similar to that, the difference in colour being due to the oxidation of the pyrite to hematite and limonite which occur lining the walls of small vughs. The specific gravity of this rock is: powder, 2·956; lump, 2·809; voids, 5·0 per cent.

Sample No. 3 was obtained from the Brown Face deposit also, and consists of white, friable, quartz porphyry of similar appearance. The rock shows quartz phenocrysts in a white ground-mass composed largely of quartz with numerous small vughs lined with glassy needle-like crystals with or without cassiterite. The specific gravity of this specimen is: powder, 2·853; lump, 2·651; voids, 7·1 per cent.

Sample No. 4 represents the dark, pyritic, quartz porphyry occurring in the Stanhope dyke workings. Microscopically it appears to consist of quartz phenocrysts in a quartz-orthoclase ground-mass containing abundant pyrite. In places this rock contains also tin oxide in profitable proportions. The specific gravity in the powdered form is 3·119, and in lump 2·996. Voids represent 3·9 per cent.

Sample No. 5 represents the quartz porphyry of Queen dyke. The rock consists of clear quartz phenocrysts with pyrite aggregates set in a white base composed of quartz, orthoclase, and topaz. This rock in places contains cassiterite in appreciable amount.

Sample No. 6 represents the normal quartz porphyry outside the zone of topazisation. It is a hard glassy rock consisting of rounded phenocrysts of pellucid quartz set in a felsitic base consisting largely of quartz.

A further series of analyses was made of samples representative of the various kinds of porphyry occurring in association with the Mt. Bischoff ore-bodies:—

Radicle.	No. 7.	No. 8.	No. 9.	No. 10.	No. 11.	No. 12.	No. 13.
SiO_2	75·12	75·28	67·40	76·20	75·88	71·80	71·00
Al_2O_3 ...	20·18	13·22	21·08	8 63	16·56	14·45	14·51
Fe_2O_3 ...	1·50	1·50	4·15	0·47	3·43	4·15	2·13
FeO	...	...	...	...	...	...	...
MgO	0·58	0·22	0·14	0·43	0·30	2·17	0·65
CaO	Nil	...	...	...	0·90	0·43	...
Na_2O	0·50	...	0·67	...	...	1·69	0·89
K_2O	1·29	...	Nil	...	...	2·68	2·89
H_2O	0·24	...	...	...	...	...	...
SnO_2	0·23	0·71	0·41	...	...	...	...
F	...	...	3·65	...	...	...	...
FeS_2	...	7·63	2·36	13·36	...	...	6·25
MnO_2 ..	...	...	...	...	Nil	...	...
TiO_2	...	...	...	...	trace	...	...
Total ...	99·64	98·56	99·86	99·09	97·07	97·37	98·32

Sample No. 7 represents a typical variety of quartz-porphyry found in Brown Face workings. It consist of phenocrysts of pellucid quartz in a dense white-opaque base. Sample 8 was taken from Stanhope dyke, and Sample 9 from White Face dyke. Under the microscope the quartz phenocrysts show corrosion of the borders by topaz, which also occupies part of the ground-mass. The topaz is now a white- opaque mineral, it having undergone partial decomposition.

Radicle.	No. 14.	No. 15.	No. 16.	No. 17.	No. 18.	No. 19.
SiO_2	60·00	48·00	77·80	71·28	57·68	81·48
Al_2O_3	23·09	32·17	15·23	15·28	10·44	12·85
Fe_2O_3 ...	5·43	4·43	2·57	0·96	0·30	2·15
CaO	Nil	0·43	1·05	0·48	0·60	0·28
MgO ...	2·82	2·31	0·29	0·29	0·86	0·79
K_2O	3·48	3·98	1·75	1·76	2·19	...
Na_2O	1·52	3·61	0·09	1·65	0·37	...
SO_3	0·72	...	...	0·17	...	0·17
H_2O	3·70	4·30	1·80	0·40	1·55	2·30
SnO_2	...	0·95	...	0·29	...	...
FeS_2	...	...	...	7·59	26·73	...
TiO_2	...	...	...	...	trace	trace

Sample 14 represents an altered mineralised porphyry occurring in Gossan Face, Mt. Bischoff Mine. Sample 15 was taken from a body of quartz felspar porphyry at the western end of Brown Face. Samples 16, 17, 18, and 19 indicate the degree of alteration in the mineral composition of quartz porphyries exposed in the underground workings of the Mt. Bischoff Extended Mine.

(10) *Structural Geology in Relation to the Deposition of the Ores.*

The tin ore deposits occur in an area of intensely crushed and folded sandstones, slates, and quartzites. The axial direction of these folds is toward the east of north, and the thrust coming from the west has produced a general inclination from that direction. In addition to folding the strata were disrupted and laterally displaced. Following the intrusion of basic rocks, came the great invasion of granite, which, placing the superincumbent rocks under tension, produced two sets of fractures in the strata, one normal to the other. Into these fractures, the walls of which exhibit extreme brecciation, quartz porphyry was injected under very great pressure, extending even into the brecciated rock. Subsequently normal faulting resulted in further displacements. The amount of throw occasioned by this fault is shown at Tilley's Rise by the lateral displacement of a small dyke of porphyry. This movement produced further brecciation of the quartzite wall-rock, for disconnected pieces of porphyry are scattered through the fault breccia. The earlier tin ore-bodies suffered with the rock formations the dislocation caused by this movement. The next event was the fissuring of sediments and igneous rocks, unaccompanied by serious displacement, and the filling of these fissures by vein minerals. That the porphyry dykes were still the media through which ore-bearing solutions arrived is shown by the much higher content of quartz composing the vein material in their vicinity. Differential slipping of the vein walls further complicated the structure.

The porphyry occurs as a network of dykes and sills from 1 to 70 feet thick, protruding here and there all round the flanks of the mountain, and near the summit standing out boldly from the softer sediments. At first glance there appears to be no particular direction of strike, but closer observation reveals a conformity of the more important dykes with the trend of the granite outcropping to the south. The dykes as a rule dip at low angles to the westward, the variation in direction of dip being in accordance with the variation in strike; but the western dyke, which is the most persistent of the subsidiary ones, is almost vertical. All the ore veins likewise have a corresponding westerly (or south-westerly) dip, but these all course in a north-westerly direction. On reference to the plan it will be seen that the Southern, White Face, Stanhope, and North-Eastern dykes form one continuous body trending to the north-east, and that the Northern and Ringtail, the Queen and Eastern, and Western and Little Stanhope dykes branch from it on either side in three groups of two each. The subsidiary dykes in turn have others branching from them. It will be noted also that the subsidiary fissures occur at right angles to, and intersect, the main fissure, and that the ore veins split the angles formed by them.

The large ore-deposits were formed where the crush fault zones were crossed by the lode fissures, and the ore shoots so formed dip with the intersections of the fissures and the fault zones to the west of south. Where the angle of crossing or intersection is oblique the ore-bodies flatten, giving rise to the idea of their occurrence in the form of "floors." However, in some instances, these so-called "floors" have been caused in part by subsequent normal faulting, thereby adding to the complexity of the structure.

Some of the most important ore-bodies of this type are found in the Brown Face, Gossan Face, White Face, and Happy Valley Face workings; but their size is due in part to favourable conditions for replacement of the wall-rock.

The loose brecciated rock along these " crush " planes or " breaks " furnishes the easiest course for the passage of solutions, and as the brecciation occurred prior to ore-deposition, replacement of favourable rock and impregnation of metallic minerals in less favourable rock may be attributed to this cause. In this way the localisation of the great ore-deposits was brought about.

The degree of replacement varies with the distance from the main channels of circulation; that is, the points of junction between the lode and fault fissures. Such replacements are made by tin-bearing pyrrhotite, and to a lesser extent by tin-bearing pyrite; and where action by mineralising solutions has been greatest a complete quartz-cassiterite replacement of the dolomite occurs. The pyrite ore is abundant also at these points, but is, nevertheless, usually found as replacements of porphyry and as impregnations of slates. In contradistinction, pyrrhotite not only occurs as a replacement mineral of dolomite at such points, but is, as a rule, the only sulphidic mineral found in the dolomite away from the fault and lode intersections. It was thought that all the pyrrhotite occurring in dolomite was formed by the action of sulphuretted hydrogen on the residual iron of the original peridotite and pyroxenite in the process of dolomitisation, but this origin is now discredited because pyrrhotite occurs also in association with siderite, and again as a tin-carrier in porphyry and slate.

A noticeable feature is that when the brecciated rock is slate it is generally found that the interstices between the broken rock are filled with quartz, pyrite, and cassiterite, and not pyrrhotite. Where dolomite and slate form the walls of a vein consisting of pyrite and quartz another type of replacement is found. This a fine-grained cassiterite replacement of an original pyroxenite, recognisable as such only under the microscope. It appears at first glance a fine-grained felspathic sandstone, but the microscope reveals an abundance of monoclinic pyroxene in some specimens, with also some felspar and much secondary quartz in minute acicular crystals. It is the waste of this material and the pyrrhotised dolomite, with its accompanying quartz, which largely formed the beds of granular quartz in the decomposed ore-bodies, and not so much the disintegrated porphyries. The plane of attack in many places was along nearly horizontal sheared surfaces in the dolomite, the differential replacement resulting in beds consisting largely of cassiterite, quartz, or talcose clay. Herman([15]), in his discussion on the origin of the ore-bodies, reviews the works of earlier writers, and provides very useful information bearing on the point at issue. He notes that the ore occurred in horizontal layers, some of which were of exceptional richness. He makes the following remarks:—" Ulrick considered the ' surface drift ' to be the result of disintegration of the rocks in close proximity; it was mainly composed of angular coarse and fine quartz sand, intermixed with some ferruginous clay, and angular or but slightly water-worn particles and fragments of porphyry, slate, and sandstone. The tin-ore particles dispersed through it varied, for the greater part, from the size of a bean down to nearly impalpable powder; larger specimens up to many pounds weight were not uncommon; crystals of tin oxide were rare; both grains and larger fragments were angular or showed but slight abrasion; their general colour was black, but some were light-grey, closely resembling the sandstone of the locality.

" The fact that all the material was being sluiced at the time of the inspection by Ulrick completes an attractive chain of evidence for what the writer (Herman) considers to be the illusion that all the material described was alluvial, or at least detrital. That some of it was surface detritus and a little of it talus is beyond doubt; but the depth of any such detritus or talus was probably not more than a few feet and its proportion to the whole mass was comparatively insignificant. The gullies probably contained redistributed material; and even now there may be on the Stanhope section of the mine some untreated remnants of undoubted surface detritus that lay—sometimes several feet deep—on the slate and sandstone bedrock surface. But Ulrick's excellent description might faithfully be applied to faces worked of recent years, where the *in situ* character of the material exposed was, in the authors' mind, unquestionable. In 1907, on Nos. 1 and 2 benches of the White Face, an open-cut was in rounded and subangular boulders of porphyry in a matrix principally of sand. The whole presented a striking appearance of fluviatile origin; but at intervals, as the work

([15]) Herman, Hyman: On Australian Tin Lodes and Tin Mills, Proceed. Aus. Inst. Mg. Engrs., No. 14, p. 297.

progressed from week to week, this loose aggregation occasionally merged into and from undoubted more or less decomposed porphyry *in situ*. The steep dip of the slate and sandstone wall terminating the material was strong corroborative evidence that it was really a wall of a lode and not the bottom of an alluvial or a detrital deposit. The peculiar mixture of fine impalpable powder with coarser tin ore, seen by Ulrick in 1874, in the 'alluvial,' may have been seen in 1906 at Nos. 2 and 3 benches east of White Face; the light-grey tin ore was there so fine and so rich that oven one ton of it, worth 30 per cent. to 40 per cent. metallic tin, was bagged at the mine and specially cleaned at the mill on rotary tables with a very slow stream of dressing water. This tin ore was so fine that it is inconceivable that it was deposited from moving water and afterwards permitted to remain while coarse material was carried over and beyond it; apart from which an overburden of hard slate and sandstone had to be removed to enable the formation in which it occurred to be excavated. . . . . The author's view is that the detrital stanniferous material is now, and probably has been throughout its existence, of quite minor importance, and that the great bulk of what apparently is, and has been, held by the majority of observers, to have that character is truly lode material, of a peculiar character, *in situ*."

The information relating to the nature of the ore and its occurrence, quoted in the foregoing paragraph is of great value, and provides confirmatory evidence of the hypothesis already set forward. The extreme fineness of the tin ore, its association with almost equally fine sands, and its occurrence between a slate cover and an altered dolomite bottom are evidences of replacement of dolomite along a horizontal plane. Very large blocks of extremely dense cassiterite associated with silicified pyroxenite may be seen in the "acid chamber" below the 50-feet level near Brown Face. This ore is undoubtedly a replacement product, and all the large blocks found in the gossanous material (altered dolomite) in the quarry are of similar character and origin. Replacement by cassiterite is usually accompanied by intense silicification, in some cases completely masking the original character of the replaced rock. In many places the dolomite has been converted into a hard, dense, quartzite-looking rock, difficultly recognisable in its altered condition.

In refutation of the idea that the large bodies of tin ore represent replacements of topaz quartz-porphyry, the following evidence is submitted:—

(1) The porphyry associated with the large ore-bodies is remarkably fresh, and in the west end of Brown Face still retains its felspar component.

(2) Cassiterite pseudomorphs after felspar except near the walls of dykes are sporadic.

(3) Complete replacement of porphyry has not been observed.

(4) The cassiterite found in porphyry is, as a rule, of coarse grain size.

(5) Rich ore-bodies of any considerable extent are always associated with dolomite or serpentine or their derivatives.

(6) Cassiterite, exhibiting typical replacement phenomena, from extremely fine powder to dense, massive blocks of clean ore are found in silicified dolomite or serpentine.

(7) The decomposed ore is similar to that occurring in place in the dolomite.

(8) Replacement of dolomite by tin-bearing pyrrhotite is common to all the large ore-bodies.

(9) The sands associated with the rich decomposed ores do not contain quartz phenocrysts derived from porphyry, but are made up largely of extremely fine acicular crystals of quartz.

(10) Unaltered sulphides in dolomite consist largely of perfectly formed crystals of minute grain size.

(11) Talc in massive form showing the outlines of pyroxene minerals occurs in all large ore-bodies.

(12) The great bulk of the clayey material associated with the ores was not derived from prosopite, but steatite, an alteration product of the basic rock.

(13) The tin ore associated therewith simulates the character of dolomite.

(14) Sphalerite, galena, and chalcopyrite replacements of dolomite are common.

(11) *Breccia and Selvage.*

The formation of the dyke fissures is attended by extreme brecciation of the wall-rock, especially the hanging-wall side. This brecciation extends in places 40 to 50 feet from the dyke, the width of which is generally small in comparison. At the time of intrusion the fluidity of the porphyry had been increased by the action of mineralisers, and propelled upward under ernormous pressure against a resistant cover was forced into the brecciated rock, ramifying through it in all directions. The extreme fluidity of the porphyry is well illustrated in the breccia, where apparently isolated pieces on closer observation are found to be connected by thin threads. In some cases a later earth movement has broken the connection. The comparative paucity of the brecciated rock—other than dolomite—is rather striking as one would expect such to provide a suitable receptacle for ore. At the Summit Face the interstices of the breccia are filled with cassiterite, but this occurrence is exceptional. Probably the open spaces were completely filled at the moment of injection of the porphyry magma, as the pieces have not suffered the effects of mineralisers to the same extent as the body of the porphyry.

In nearly all the veins selvage is developed in the walls to a greater or less extent, and is indicative of relative movement along the fissure planes. It consists of finely-ground wall-rock, produced by differential movement of the walls on one another. The finely-ground material has suffered chemical change by the action of mineral-bearing waters circulating along the channels thus formed. Selvage materials should not be confused with the secondary micas so commonly found filling horizontal joint planes. As a rule selvage is not rich in tin ore, whereas the secondary micas are.

(12) *Secondary Enrichment.*

Cassiterite, which is the most important primary mineral in the ore-bodies, is relatively resistent to weathering agents. Tin is one of the more inert minerals, and the ore, cassiterite, being a stable compound tends to remain in the upper parts of its deposits, and to accumulate in alluvial gravels.

According to Emmons([16]) sulphuric acid dissolves cassiterite very readily if a little metallic zinc is present.

([16]) Emmons, W. H.: The Enrichment of Ore Deposits, U.S. Geo. Surv. Bull. 625, p. 399.

He states that the zinc or the hydrogen formed by zinc and acid permits the tin to remain as stannous salt, which is less hydrolysed than the stannic salt; but as an oxidising solution converts the stannous to the stannic condition, neither of these salts of tin is stable in oxygenated solutions like the mineral waters in the upper zones in sulphide ore-bodies.

No trace of corrosion on the crystal faces of cassiterite has been observed at Mt. Bischoff, nor is there any direct evidence of the action of acid waters on the fine particles of tin oxide originally contained in the pyrite and pyrrhotite components of the lode materials.

In these iron-tin lodes the iron sulphides are in part leached from the upper parts of the lodes, and tin remains showing that in sulphate solutions tin oxide is almost insoluble. In the process of oxidation by meteoric waters part of the the iron sulphide is converted into limonite and sulphuric acid, and the fine particles of tin oxide remain with the limonite or "gossan," as it is called. The tin oxide liberated from the sulphides of iron by oxidation agents is in such an extremely fine state of division that it becomes more easily susceptible to attack by sulphuric acid, and possibly some of the irregular bodies of tin ore below the zone of oxidation represent deposits of secondary origin. It is noteworthy, however, that a considerable portion of the tin oxide in the upper parts of the lodes is of fine grain size.

Although secondary enrichment of the ore-bodies by deposition from meteoric waters has been inappreciable, the action of these solutions has been an important factor in bringing about the present condition of the ores. Little change has been caused in the metal content of the deposit; but large bodies of sulphide ore near the surface have been rendered susceptible to direct treatment by water concentration appliances, and the ores have been concentrated in place by the removal of the soluble constituents of the gangue.

(13) *The Vertical Range of the Ore.*

It has not been demonstrated to what depth the profitable ore extends; but it has been shown in the only deep mine (Mt. Bischoff Extended), that the ore decreases in value with increase in depth, and at the lowest level

(No. 9), of this mine the ore is very erratic in distribution and poor in quality. A noteworthy feature of this deposit is that galena and sphalerite increase in correspondence with the decrease in the content of cassiterite. If the lateral extent of an ore-body be considered a measure of its continuance in depth the workings on the Wheal or Giblin vein and the North Valley vein have reached the depth of profitable mining. In these bodies it has been proved that the size of the ore-body as well as the quality of the ore decreases with depth, and there are safe grounds for the assumption that the occurrence of rich ore below the No. 9 level of the Mt. Bischoff Extended Mine is improbable. The foregoing remarks apply especially to vein-fillings which were formed later than the lodes of the replacement-fissure type.

In regard to the latter the evidence disclosed by mine openings is misleading. These bodies do not, as has been supposed, cut out at the level of Main Tunnel at the Mt. Bischoff Mine. They not only continue below that level, but contain rich shoots of ore which may be expected to continue at least 100 feet deeper. Their present position is due to displacement by faulting. The largest and richest ore-bodies of the replacement-fissure type have been discovered; but these deposits, although decreasing in size and quality with depth, will continue to furnish a large amount of ore for many years.

In confirmation of the conclusion arrived at concerning the downward limitation of tin ore in these fissures, attention is drawn to the increase in the content of lead-zinc ore from level to level. At the No. 9 level of the Mt. Bischoff Extended Mine the ore consists almost wholly of sphalerite (zinc blende), and in some of the upper levels galena is very abundant. These minerals, especially the galena, were deposited largely from hydrothermal solutions during the waning stages of mineralisation in re-opened fissures; but there is strong evidence to show that they, in small amount, were deposited also from high temperature solutions contemporaneously with cassiterite. The black mariatite variety of sphalerite, so abundant in certain parts of the ore-bodies, is a common companion of tin ore, and was deposited under high temperature conditions.

These minerals in short shoots, and also in bunches and veinlets, occur in the Mt. Bischoff ore-bodies sporadically distributed in the gossanous material, and occasionally in association with pyrite in slate.

(14) *The Lateral Range of the Ore.*

A circle of 2000 feet radius, with the summit of Mt. Bischoff as a centre, encloses all the important tin-bearing veins and lodes in the Waratah area. Outside this circle tin is a rarity, but deposits of lead, zinc, silver, copper, and antimony occur in relative abundance. The latter are distributed around the base of the mountain, and in some places are concentrated in large and extensive deposits. They occur also in comparatively small quantity in association with tin within the circle, but there they doubtless represent a later phase of mineralisation, Tin and tungsten were deposited from highly-heated solutions, while copper, lead, zinc, and antimony were deposited from solutions of lower temperatures. This is illustrated in the zonal distribution of the metals. A little tin oxide occurs in the zinc-lead ore, but whether it was deposited from aqueous solutions with that ore or whether the latter was deposited around it could not be determined. The presence of tin oxide in large bodies of siderite suggests that deposition continued under hydrothermal conditions. Of this there is much further evidence, which will be set forth in another part of this chapter.

By far the most extensive and richest deposits of tin ore occur in a small area near the summit of the mountain. At this spot mineralisation was more highly concentrated, and here also the forces contributing to this action of nature were exhausted.

(15) *Effects of Oxidation.*

The primary minerals composing the ore-bodies have been exposed to the action of the air by the erosion of the overlying rock, and meteoric waters have found access to the ore along channels of deposition. These primary minerals, formed under varying conditions of temperature and pressure, are as a rule unstable under surface conditions, and many, susceptible to the action of oxygen and carbonic acid, are readily changed into other compounds. Sulphide ores in particular are easily attacked by meteoric water carrying materials in solution, but carbonate and silicate rocks also readily undergo decomposition, and are changed into minerals stable under the existing conditions. Of the former the sulphides of iron are usually the first to suffer alteration. The phases through which they pass in the process of conversion to their ultimate oxidation product (oxide of iron) varies according to the condition under which the change takes place, and to the nature of the minerals. This change is always attended by the formation of iron sulphates, and the liberation of sulphuric acid, both of which under favourable conditions dissolve some minerals, and bring about a complete transformation in others. According to Stokes,[17] free sulphur is formed in the first stage of the oxidation of pyrite. He gives the reaction:—

$$FeS_2 + Fe_2(SO_4)_3 = 3FeSO_4 + 2S.$$

The sulphur readily reacts with ferric sulphate to give more ferrous sulphate and sulphuric acid:—

$$2S + 6Fe(SO_4)_3 + 8H_2O = 12FeSO_4 + 8H_2SO_4.$$

The pyrrhotite compound of iron and sulphur is more easily oxidised than the pyrite. Out of contact with air this mineral is transformed, by the action of percolating waters, into marcasite; and under the direct influence of the atmospheric agents of oxidation it readily undergoes alteration to limonite. When the marcasite of the Mt. Bischoff ore-bodies is exposed to the action of the air oxidation is so rapid that spontaneous combustion takes place. The raising of the temperature sufficiently high to effect this rapid chemical change is due to the generation of sulphuric acid. In some parts a few feet of soil-cover is sufficient to retard and even prevent the oxidation of the marcasite, in other parts where water can circulate freely this unstable mineral is converted into hydrous sulphates of iron and sulphuric acid. The sulphuric acid is a solvent competent to effect a complete change in the mineral content of the ore-bodies. Doubtless this agent has been largely instrumental in the removal of zinc, lead, antimony, bismuth, and copper sulphides, in addition to arsenopyrite and other minerals from the deposits. Secondary compounds of these elements are found on the walls and roofs of mine openings far below the large ore-bodies.

Ground water-level is perhaps the most important factor in defining the zone of oxidation. Solution and precipitation take place in this zone, especially the solution of sulphides and the precipitation of oxides. Solution generally exceeds precipitation, and by solution the bulk is reduced, and the open spaces thus formed render the

[17] Stokes, H. N.: On Pyrite and Marcasite, U.S. Geo. Surv. Bull. 186, p. 15, 1901.

downward circulation of meteoric waters to ground level comparatively free. However, oxidation does not necessarily extend down to any well-defined level far below the workings, but is effective only where the conditions are favourable. The depth and extent of the zone of oxidation depend upon the permeability of the ores and their character and composition. The conditions differ greatly in different districts, and even in different deposits in the same district. Thus fresh marcasite and pyrite are found near the summit of Mt. Bischoff in the Brown Face ore-body, while oxidation has extended far below this level in other deposits nearby. Many other illustrations could be given of this irregularity of the water-table. In general, however, the zone of oxidation is not deep, for unaltered sulphides are found in many places within a few feet of the surface. This is due in large measure to the rapid rate of erosion which has kept pace with oxidation.

Many of the deposits owe their commercial importance to the decomposing action of surface agents. The effects of oxidation on the ores from an economic point of view may be summarised as follows:—

(1) A mechanical effect in conducing to the complete disintegration of the deposits, and the decomposition of the minerals composing the wall-rocks.
(2) The liberation of cassiterite from encasing pyrite and pyrrhotite.
(3) The conversion of stannite to tin oxide.
(4) The removal of associated minerals that interfere in the metallurgical treatment of the ore.
(5) A concentration of the ore by the removal of associated minerals in solution.
(6) A simplification of the metallurgic treatment.

(16) *Erosion of the Ore-bodies.*

The higher mountain peaks of this region, Mts. Bischoff, Cleveland, Pearse, and others, are erosion residuals of a very old land-surface. All the evidence points to the fact that since the uplift that accompanied or immediately preceded the intrusion of the tin-bearing granites and porphyries at the close of the Silurian, the land represented by these mountain remnants has been subjected to continuous erosion. The reason why these peaks survived by withstanding the erosive effects of air and water through all the succeeding ages is not very difficult of explanation.

These mountains belong to the West Coast Range system, from which they have been disconnected by the removal of weaker sections. The prominent peaks of the West Coast Range are capped by a great thickness of silicified quartz-conglomerate, a rock strongly resistent to erosion. The protection thus afforded by these great beds of conglomerate accounts for the survival of the mountain remnants in this district. Mt. Pearse, 6 miles to the south-east of Mt. Bischoff, is formed to a depth of 600 feet of West Coast Range conglomerate. The base of this formation provides a datum from which measurements may be taken to determine the effects of erosion on the Mt. Bischoff ore-bodies. Although Mt. Bischoff has been denuded of conglomerates the dykes of relatively hard porphyry that ramify through the mountain have contributed to the preservation of the ore-bodies. It seems that the porphyries were arrested in their ascent by the conglomerate, and the ore-bodies were formed below that formation. A similar occurrence of tin ore deposits between the upper surface of granite porphyry and quartz-conglomerate has been observed by the writer at Moina.([18]) Assuming that the conglomerate formed the upper limit of ore deposition, and taking into account the relative altitudes of Mts. Pearse and Bischoff it is considered that not more than 300 feet of ore-bearing material has been removed by erosion from the summit of the mountain.

In regard to the erosion of the ore-bodies in other parts of the district quite different conditions prevailed. Pre-Tertiary erosion had reduced the greater part of the land surface to base-level, exposing the granite and removing the overlying ore-deposits. This erosion plain is 700 feet below the present summit of Mt. Bischoff, and is now covered by 200 feet of Tertiary sediments, and 50 to 80 feet of basaltic lava. If any tin ore deposits originally existed in the area now occupied by these sediments they would have been almost entirely removed. In the valleys that have been cut through, the Tertiary sediments deep into the underlying rock during the succeeding Quaternary period, only one ore-body (Magnet) of any considerable extent has been found. Many zinc-lead veins occur around Mt. Bischoff 1000 to 1200 feet below the summit, but not one of them has proved of commercial importance. Probably ores of these metals may be discovered in profitable quantities below the Tertiary sedi-

([18]) Reid, A. McIntosh: The Mining Fields of Moina, Mt. Claude, and Lorinna, Tas. Geo. Surv. Bull. No. 29.

ments, but at that level tin ore-deposits of commercial importance are not likely to be found.

Post-Tertiary erosion has been extremely rapid, as exemplified by the deep valleys of the streams that came into being at the close of that period. In these valleys the metallic ores, removed from the lodes by erosion, have been concentrated in small alluvial deposits. At present the rate of erosion is very great owing to the high elevation of the land surface and the heavy precipitation.

(17) *The Ore-bodies.*

Replacement-fissure deposits occurring at the intersection of fault and lode fissures:—

(*a*) Gossan Face.
(*b*) Happy Valley ore-body.
(*c*) White Face.
(*d*) Slaughter-yard Face.
(*e*) Brown Face deposit.

Fillings of joints in and impregnation of sedimentary rocks such as slates and quartzites:—

(*f*) North ore-body.
(*g*) Summit ore-body.

Dykes of tin-bearing porphyry:—

(*h*) Stanhope dyke.
(*i*) Queen dyke.
(*j*) Western dyke.

Fissure fillings traversing both sedimentary and igneous rocks:—

(*k*) Wheal or Giblin vein.
(*l*) North Valley vein.
(*m*) Queen vein.
(*n*) Eastern vein.
(*o*) South-west vein.
(*p*) Thompson vein.
(*q*) Slaughter-yard vein.
(*r*) Brown Face vein.
(*s*) Happy Valley vein.
(*t*) No. 1 North-east vein.
(*u*) No. 2 North-east vein.
(*v*) Princess vein.

Alluvial and detrital deposits:—

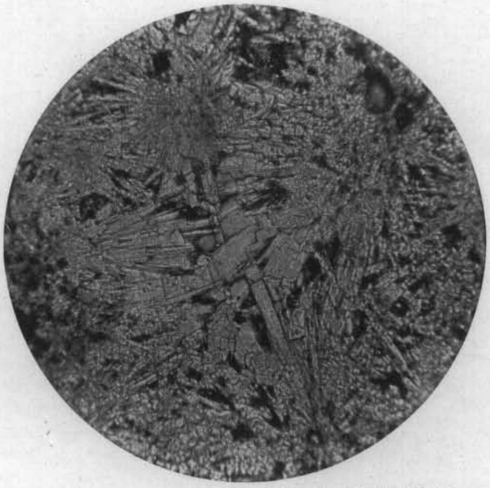
(*w*) Don alluvial.
(*x*) North Valley detrital.

(*a*) Gossan Face.

This deposit is situated at the southern end of the mountain, and is bounded on the north by Western dyke and on the east by White Face dyke. Fronting Western dyke is a fault wall extending right across the face through slates and dolomite. Like the others, this deposit was considered to be composed of alluvial materials, and the concentration of tin ore in it was thought to have been brought about by the agency of flowing water. A large proportion of the superficial material may be described as detrital, but the bulk of it represents the waste of replacement lode matter. This lode material consists largely of pyrite and pyrrhotite replacements of dolomite, which occupies the greater part of the floor of the deposit and is exposed for several hundred feet in main tunnel. The ore is confined largely to the wall of the fault, which dips at a fairly low angle to the south. Here talc, siderite, mangano-siderite, gossanous steatite form the bulk of the gangue, but the richest ore here, as elsewhere in this mine, is associated with quartz. Fluorspar is abundant, especially in association with siderite, and galena and sphalerite are sporadically distributed through the body of the altered dolomite is a large body of siderite and calcite seamed of marcasite with a cover of gossan is exposed. The material is valueless, but is interesting as indicating the plane of oxidation.

(*b*) Happy Valley Ore-body.

Situated east of Gossan Face and south of White Face, this ore-body is essentially similar to them, and was formed under like conditions. The special feature of the deposit, like the others, is the intrusion of dolomite by quartz porphyry, and its replacement by minerals carried in solutions along the channels thus formed. Replaced dolomite in the open-cut on this ore-body extends 40 feet below the lowest bench of White Face. The outlines of the component minerals of the original pyroxenite are preserved by thin threads of magnetite, giving the rock a brecciated appearance. The magnetite and the thin cells of quartz that ramify through the rock represent the residual products of dolomitisation. Unequal replacement of the rock has resulted in rounded irregular outlines similar to the surfaces formed by weathering in limestone. Large irregularly-shaped boulders of dolomite in the bottom of the



[*A. M. Reid. Photo.*

Photomicrograph No. 5.—Pycnite (Columnar Topaz).

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open-cut were once thought to be erratics because they rest on lignitic and other earthy materials which are actually the residual products of replacement. Associated with dolomite is a large body of siderite and calcite seamed with quartz. All the lode materials have now been removed, but several quartz-pyrite veins traverse the rock. Marcasite and sphalerite occur in massive dolomite as well as in the veins. An adit driven northward from the open-cut passes through 100 feet of gossanous material, then dolomite, which gives place to slightly dolomitised pyroxenite still preserving the original nature of the component minerals. At 170 feet from the entrance the adit caved on entering the pyritic ore-body exposed in White Face. No large replacement bodies are likely to occur below this level.

(c) White Face.

This face was so named because the upper layers of ore consisted largely of quartz sands. It lies to the east of Gossan Face, and is 900 feet long and 600 feet wide. For many years this ore-body constituted one of the main sources of supply of tin ore, and, with the exception of Brown Face deposit, has produced more tin than any other ore-body in the mine. After having been abandoned for many years rich ore was discovered by Mr. J. D. Millen, Mine Superintendent, who drew heavily upon these supplies as the rich ore was depleted. This ore-body is bounded on three sides by porphyry dykes and on the fourth by dolomite, which also, with a small body of porphyry, occupies the centre. In many respects this ore-body presents similar features to the Brown Face deposit. Like that, the minerals were for the most part loosely arranged, and could be dug out with a shovel; in fact, the whole appeared in section very much like a sandy drift arranged in layers. Layers of fine quartz crystals, then layers of green and brown tourmaline, succeeded by beds of talc, overlying layers of black crystallised cassiterite, in some places so clean that they could be shovelled direct into bags for shipment to the smelters. The tin crystals, as a rule, were very small and detached, but dense blocks of clean tin ore weighing several hundredweight were sometimes found. In places a fine powder mixed with fine grey tin ore occurred similar in character to the fine grey tin ore specimens found by the writer replacing partly silicified dolomite. The disintegration of this rock would produce powder of the kind.[19] Herman states that the friable sands and clays were often overlain by slates and sandstones, evidently the sedimentary cover of the basic intrusive from which the dolomite was derived. Near Brown Face deposit the chloritised dyke rock and dolomite also are overlain by slates. The steep fault wall of slate on the north side of this deposit bounds the dolomite in that direction, as it does in Gossan Face, and most likely represents the original wall of the basic dyke. The gradual transition of siliceous ore material to unaltered porphyry gave rise to the idea that the ore represents replaced porphyry. Naturally silicification of the dolomite would be more intense as the intrusive porphyry was approached. The occurrence of large bodies of marcasite below the layers of sands and clays is explained by the fact that replacement took place from the upper limit of the dolomite downward, the marcasite representing the alteration product of a tin-bearing pyrrhotised dolomite. On the east side of the deposit gossanous dolomite, intruded by small porphyry dykes, clearly illustrate the mode of formation. The porphyry there, as in the main body, is comparatively fresh. One of the striking features of the Mt. Bischoff deposits, especially those of the White and Brown Faces, is the enormous quantity of metallic sulphides accompanying the cassiterite. In this connection it is interesting to note that[20] Scrivenor refers to the plenitude of sulphidic minerals in tin ore replacements of limestone in some Malay States deposits. The replacement of dolomite by free cassiterite does not extend far from the channels of ingress, whereas tin-bearing pyrrhotite extends well into the surrounding rock. The layers of rich tin ore are not confined to the siliceous sections of the lode. This is evident from the results obtained in driving an adit into the sulphidic body from the level of the mine railway. Over the last section of 40 feet ore containing 0·75 per cent. tin occurs, and a layer 12 feet thick contains an equal proportion, whereas the sulphidic ore above and below is almost barren. At the north-east corner of this open-cut adits were driven to prospect for other "makes" of ore in that direction. The timber used in these openings proved too weak to support the weight of fractured wall-rock, and the workings caved. This fact should encourage further exploration in that direction, as

(19) Herman, *op. cit.*, p. 294.
(20) Scrivenor, J. B.: Origin of Tin Deposits.

it indicates the continuance of the loose lode material underneath the cover of slate and sandstone.. An interesting feature of the sulphidic ore is the occurrence of seams of lignitic material. How to account for its presence so far below the original surface under a heavy cover of ore and slate is a difficult problem to solve.

In the uppermost bench the porphyry dyke rock contains cassiterite pseudomorphs after felspar in sufficient numbers as to allow of it being worked at a profit. Cassiterite is more abundant in the pyrite-poor porphyry. In a branch dyke traversing this open-cut very rich gossanous material occurs on the footwall side. This is a replacement product of porphyry to which all gradations are represented. The richer portion of this material was separated from the poorer by spalling, and was sent to the milling plant for treatment.

(*d*) Slaughter-yard Face.

This deposit lies between Gossan and Brown Faces, and is similar in character to them, albeit more siliceous. It is 500 feet long, 220 feet wide, and 90 to 120 feet deep as exposed in the open-cut. From this open-cut enormous quantities of material have been taken, and for long this was one of the main sources of supply. Even now an appreciable amount of rich ore remains in the several bench faces. The occurrence of the ore here is essentially similar to that in other deposits. At the extreme south-west end a flat seam of clean cassiterite, 3 to 6 inches thick, was discovered by Mr. C. W. Gudgeon, Mine Superintendent, but it did not extend far into the silicified dolomite. Along Slaughter-yard dyke some very rich ore is exposed, but outside a short radius the material is poor. In this face the dolomite has been silicified, and much talc has been developed. At one spot large blocks of ore show pyrrhotite and quartz on one side and pyrite and quartz on the other. A small lode in altered pyroxenite—which here is only 40 feet wide—consists largely of quartz near the porphyry and gossan remote from it. The vein is fairly rich and is composed of crystallised quartz, cassiterite, and limonite.

Native sulphur was discovered in this ore-body, lying under a ferruginous crust. It occurred as small crystals in a bed of quartz grains, which was nearly 2 feet thick.

(*e*) Brown Face Deposit.

Apparently unconnected with any other important deposit, this enormous body of ore occupies the east-centre of Mt. Bischoff. It is a boat-shaped deposit with the prow—formed by the intersection of two fault walls—directed toward the summit of the mountain. These walls diverge going east until they are nearly 500 feet apart, continuing until they are intercepted by a lode fissure trending in a northerly direction.

From this deposit the greater part of the ore has been removed by quarrying. A little stoping has been performed, but the quantity of ore excavated by that means was comparatively insignificant. The quarry is 850 feet long at the top and 500 feet at the bottom. It is nearly 500 feet wide at the top, converging to 90 feet at a depth of 210 feet. The deposit has been proved to extend to a depth of 240 feet from the surface, but there is no evidence of its continuance below that point.

Tin ore to the value of £2,000,000 has been taken from this deposit. The average yield was a little more than 2 per cent.; but in places large bodies of almost pure cassiterite were found, one of which, 150 cubic yards in bulk, contained tin to the value of £60,000. Similar blocks, but of much smaller dimensions, have been found in the pyritic ore at the bottom of the quarry.

The upper portion of this deposit is repeatedly referred to in early reports as an alluvial one, probably because occasional water-worn pebbles of quartz were found in the disintegrated ore. The source of the pebbles was in the conglomerate that originally capped the mountain. Layers of extremely fine quartz sand intercalated with bands of tin ore were considered as providing further evidence of an alluvial origin, but these represent disintegrated replacement materials in dolomite which were deposited along horizontal joint planes. The term "detrital" is more applicable, as a considerable portion of the ore at surface was of this character, and on the slopes fairly large quantities of detrital and talus materials still remain.

Brown Face deposit consists of tin-bearing gossan to a depth of 200 feet in the centre, surrounded by pyritic ore, except on the north fault wall. All that remains of the ore-body, which rests on a floor of altered dolomite and slate horizontally bedded, consists largely of marcasite and the alteration products of dolomite and porphyry. Dolomite, exhibiting all stages of replacement by sulphides, may be seen on both sides of fresh porphyry. The sul-

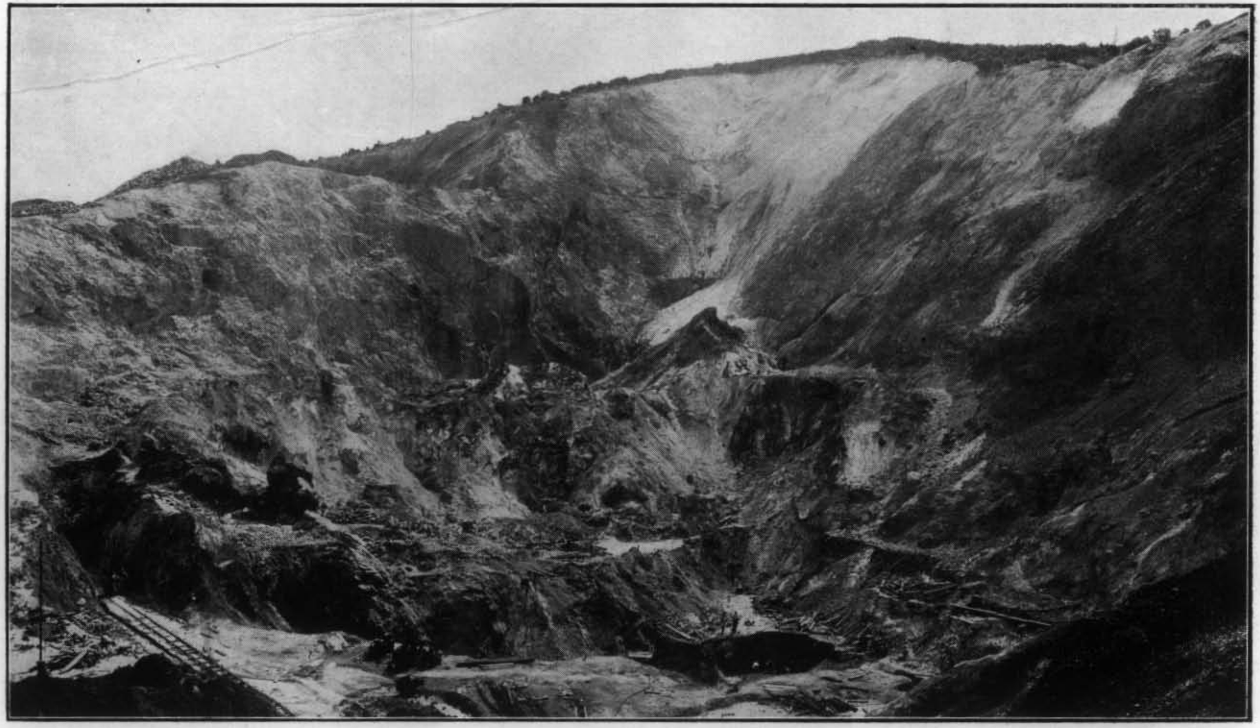

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Photo. No. 2.—BROWN FACE, LOOKING WEST.

[J. *Robinson, Photo.*

phides rapidly oxidise to sulphates, the chemical action of which aids in the complete decomposition of the materials composing the ore-body. Brown to black gossanous talc on the east side represent the waste of pyrrhotised dolomite, and farther eastward a large body of chloritised peridotite beyond the lode fissure shows only a minor alteration. Near the centre the original basic rock is represented by talc in which the outlines of original phenocrysts are easily discernible; on the west side unreplaced dolomite and quartz felspar porphyry occur. The localisation of ore-deposition is due to the more favourable channel of circulation provided at the intersection of fault and lode fissures. Near this point the replacement of porphyry by sericite, pyrophyllite, sulphides, quartz, and cassiterite is more intense; a little further removed very little alteration of the porphyry is noticeable. In places quartz and cassiterite bunches and pockets occur in the porphyry, some of which are of exceptional richness; but, as a rule, the replacement of felspar by cassiterite only is usual. Replacement of porphyry by cassiterite usually occurs in bands 18 to 20 inches thick, across the dyke. The tin-rich porphyry contains little pyrite, whereas the alternate bands contain a high proportion. Very rich ore was obtained on the south wall in the early days, and veinlets of clean cassiterite penetrate and extend at least 40 feet into the wall-rock. From the bench next to the lowest a rich seam of ore extended over the back of the 50-foot workings. It was only a little to the eastward of this that cassiterite in blocks of 5 to 70 hundredweight was found many years ago. This ore occurred in the gossanous dolomite near the porphyry intrusive. Nearby is the chloritised rock studded with pyrrhotite and seamed with fluorspar.

The wonderfully rich ore-body apparently peters out on a silicified dolomite floor (50 feet above the level of main tunnel). At No. 2 level, 31 feet above main tunnel, a flat seam of nearly clean cassiterite, 1 to 4 inches thick, has been mined. Ten feet overhead two bands of similar ore occur, and 5 feet above this the sulphidic ore is found. From the 50-feet level a drift extends in a southerly direction several hundred feet on a flat vein 2 to 3 feet wide. A few feet below 50-feet level a very rich body of ore is exposed in an opening in silicified dolomite. This ore, associated with marcasite, cannot be mined because the rapid oxidation of the marcasite causes ignition of the sulphur constituent.

In some of these very flat seams the materials consist wholly of golden scales of secondary mica and cassiterite.

(*f*) North Ore-body.

The open-cut on this ore-body is situated 500 feet northward from Brown Face. It was originally known as the "North Alluvial," having been regarded as an alluvial deposit. The ore-body consists largely of replaced porphyry and pyrite bands in slates and fine conglomerate. Dolomite cannot be traced in this body unless part of the clayey material on the south side represents the final product of decomposition. However, in this case the replacement is essentially of porphyry and slate. Pyrite assumes the laminated form of the slate, and on decomposition leaves a black pug from black slates, and a brown carbonaceous material from grey and bluish-grey slates. The pyrite is usually of fine grain size, but coarse material is not uncommon. Cellular quartz in association with pyrite is frequently accompanied by cassiterite. The most striking feature of this deposit is the progressive replacement of porphyry by zeuxite and pycnite. All gradations from replaced felspar to complete tourmalinisation of the whole rock are perfectly illustrated. Tourmalinisation and pyritisation were not associated processes, although most likely nearly contemporaneous. Where pyrite is prominent tourmaline is absent, and *vice versa*.

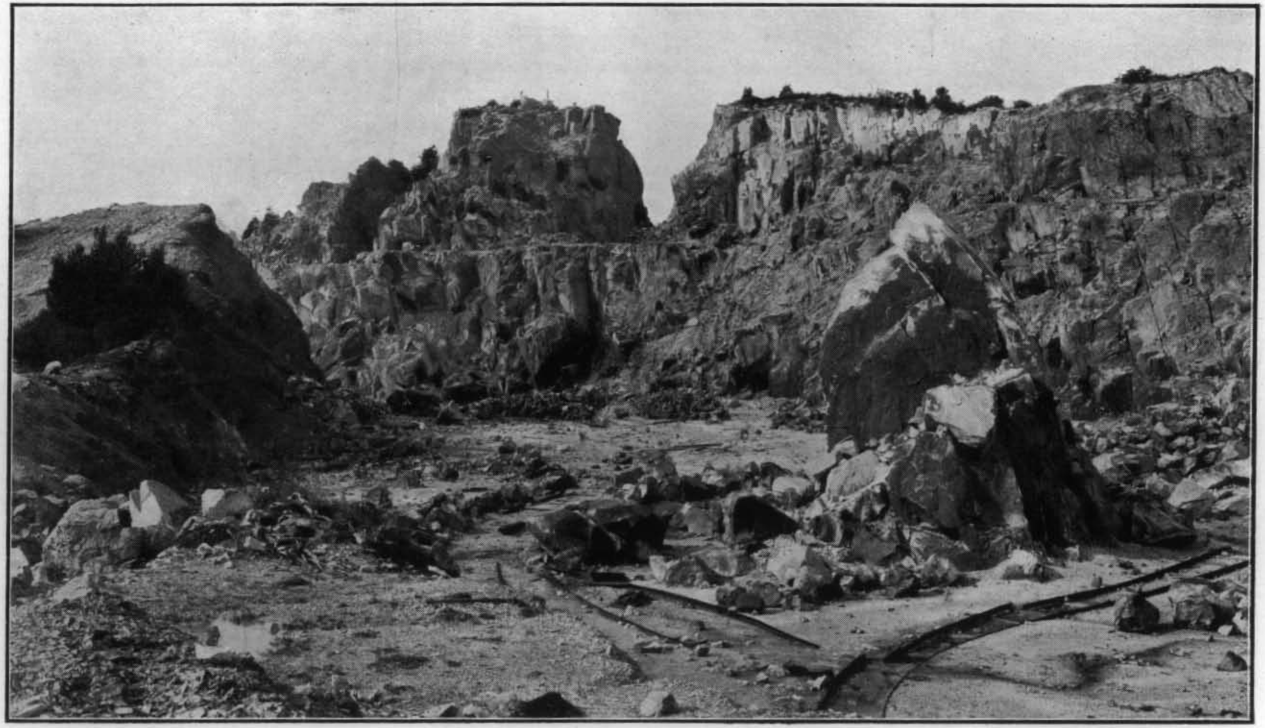
This ore-body was a very prolific source of tin ore, and other flat rich seams may yet be found in sinking below the level of the open-cut.

(*g*) Summit Ore-body.

The open-cut on this ore-body lies directly below the summit of the mountain on the north side, and on Wheal Dyke, a body of porphyry about 12 feet wide. Half-way up the cut a fault, displacing the dyke-rock, occurs. Both the porphyry and the brecciated slates are impregnated with cassiterite, especially along joints and fractures in the rocks. Sulphidic minerals are present only in very small amount. Tourmaline likewise is not prominent. A slight silification of the slate is the only metamorphic effect noticeable. This ore-body is of low grade, but the material is "free-milling" and can be cheaply mined and treated.

(*h*) Stanhope Dyke.

An open-cut 100 feet long, 60 feet wide, and up to 60 feet deep has been formed in the porphyry of this dyke.



To face page 112. Photo. No. 3.—STANHOPE DYKE FACE. [*J. Robinson, Photo.*

Contrary to the general rule, cassiterite here is abundant in pyrite—rich porphyries, but it appears to be always associated with green tourmaline. Thus, the rich tin-bearing porphyry in this dyke, apart from facings on joints, contains green tourmaline pseudomorphs after felspar, and pyrite, cassiterite, and arsenopyrite as well. Extremely fine-grained crystallised pyrite is commonly found partly replacing tourmaline. Cassiterite is usually pseudomorphous after felspar phenocrysts, but it occurs in the interstices also, and is most abundant near joint planes in the porphyry. According to the mine records the porphyry of Stanhope Dyke contains tin in the proportion of 0·2 per cent. The quantity available is very large.

(*i*) Queen Dyke.

Three small open-faces have been cut into this dyke rock, and a large quantity of the material has been excavated by mining from the Queen Vein stopes. The open-cuts have been extended into the sandstone and slate wall-rocks, which are veined with cassiterite and quartz up to 15 feet on both sides. The slates have not been greatly affected by ore-bearing solutions, whereas the sandstones have been converted into quartzites and seamed with silica. There is no appreciable difference between this porphyry than that exposed in Stanhope workings, and the occurrence of cassiterite is essentially similar. The richest part of the rock is that near the footwall, and at the point of contact between porphyry and slate on that side a fairly continuous vein of clean cassiterite, 2 inches wide, is exposed at several points. It is reported that the average content of tin in the porphyry is 0·25 per cent.

(*j*) Western Dyke.

The quantity of ore removed from this dyke is not large, yet in places it is exceptionally rich. Between White Face and the western boundary of the Mt. Bischoff Company's property the dyke-rock contains about 0·2 per cent. tin; beyond those points it is comparatively barren. The rock is a pyrite-quartz-porphyry varying to quartz-porphyry, containing abundant pseudomorphs of green tourmaline. The master planes of the porphyry lie parallel to the strike of the strata, a little east of north. Coursing with the planes across the trend of the dyke are rich veins 2 to 12 inches wide. In some cases the cassiterite replaces porphyry, in others it occurs in veins with pyrite and quartz.

(*k*) Wheal or Giblin Vein.

The Mt. Bischoff Company's portion of this vein was worked originally by the Wheal Bischoff Company. The vein extends through the Wheal section into the Mt. Bischoff Extended Company's property. This vein has been driven on more than half a mile, and has been exposed to a depth of 1000 feet below the outcrop on the west flank of the mountain. It is typical of the tin-bearing veins in this area, and is described in detail in the account of the Mt. Bischoff Extended Company's operations on page 125.

(*l*) North Valley Vein.

The North Valley Vein, from 1 to 5 feet in width, has been exposed in drifts and stopes nearly 1800 feet in length. It traverses slate and sandstone country in a north-westerly direction, and dips to the south-west. This vein was very rich in tin-ore, but it contains pyrrhotite, arsenopyrite, pyrite, sphalerite, and galena in fairly large proportions. Quartz is the most conspicuous gangue mineral. Probably the vein cut in the Stanhope crosscut near the entrance marks its south-easterly extension. It is considered by some that this vein junctions with the Queen Vein, of which it represents the northerly extension.

(*m*) Queen Vein.

This vein, which lies to the north of Brown Face, has a course a little north of west, and underlies at a low angle to the south. It is a true fissure-filling, having well-defined walls, and cutting through slate and porphyry alike without deflection. Its width varied from 1 to 5 feet, and it was worked for a length of 1100 feet and to a depth of 350 feet for 3 to 20 per cent. of tin. In places a solid band of cassiterite 4 to 12 inches thick occurred. This vein was stoped from five levels above Main Tunnel and two below, and its southerly extension was worked by the Stanhope Company through their main crosscut opening. The material consists of gossanous quartz varying to quartz as the dyke is approached, but towards the Stanhope workings pyrite becomes prominent, and ultimately forms the greater part of the vein. This fact is significant in fixing the channel of drainage. Below Main Tunnel (No. 6 level) the vein is strong, but the ore-shoots are comparatively short. No. 7 level is connected with No. 6 by a winze 50 feet deep. Sixty feet north of the winze the drive entered a vugh in quartz encrusted with cassiterite. The vugh was 12 feet wide, and the rich shoot extended 100 feet farther on an average width of 6 feet. South of the winze and elsewhere on this level the vein is wide and continuous, but poor. It consists of gossan and cellular quartz. At No. 8 level the vein is 4 to 10 feet wide, and is contained between hard sharply-defined walls. It consists of gossanous quartz for 100 feet north of the winze, thence it gradually becomes pyritic, until the material consists wholly of pyrite and quartz. Comb-structure of quartz is common, and where pyrite has been removed the vein material consists of cellular quartz. The drainage from the upper levels easily finds an outlet through the vein-openings at this point.

Probably richer shoots of ore will be found as these levels are advanced toward the porphyry dyke. Alternate rich and poor sections may be anticipated.

In the Stanhope workings on this vein the materials consist of perfectly crystallised pyrite fine in grain, white opaque quartz, massive and crystallised, sphalerite and its oxidation products, and the lignitic matter at first thought to be hisingerite. Stalactites of this shiny black substance are at present in process of formation. A particular feature is the occurrence of crystallised quartz of later origin than the other components. Above the east drive porphyry is cut in a rise to a higher level. Very rich tin-ore was found here, and the vein was driven on and stoped to the main workings. Going west the vein becomes less pyritic, and gradually peters to a 4-inch band of quartz. At the level of the crosscut the ore is generally poor.

(*n*) White Face Vein.

A cassiterite-quartz vein in brecciated slate passes along the east side of White Face, and extends to Stanhope Dyke. It courses 10 degrees west of north, and dips west at an angle of 45 degrees. It has been exposed at surface by a trench along the strike, and as it approached the porphyry it turns and ultimately runs parallel thereto. Near the south end the vein has been stoped to surface. It does not exceed 12 inches in width at any point, and throughout its length an average of 8 inches only shows at surface. The cassiterite is coarsely crystallised and represents 3 to 5 per cent. of the vein. As a source of tin-ore it is not important, but it may improve in depth.

(*o*) South-west Vein and North-east Vein.

These apparently represent the filling of one fissure, and are essentially similar in occurrence and composition. At the south-west end a fairly long adit has been driven a little west of north on a crushed quartz vein 12 inches wide. It consists in the main of opaque quartz enclosed by well-defined walls of quartzite and slate. Cassiterite occurs in short shoots of average grade (2 per cent.), and some ore has been stoped. The adit passes through Western Dyke, which here is very pyritic, and in the end exposes only 6 inches of gossanous quartz almost barren of tin.

The eastern section of this vein was worked by the Wheal Bischoff Company many years ago. Two adits were driven on the vein towards the south, and some very rich ore was mined through these openings. Here the ore occurs in short shoots also, and poor material occupies the present working faces.

(*p*) Thompson Vein.

This is a cassiterite-rich vein of quartz and gossan 6 to 12 inches wide coursing in a north-westerly direction towards south-west vein. It is exposed at surface by a long trench, and is seen again on the roadside, where, however, it splits into three veinlets. Southward of the shaft it was exposed 200 feet by trenching along its course. At one time it was considered a part of South-west Vein, but this does not appear so unless they have been displaced by faulting. A shaft has been sunk 64 feet on this vein, exposing rich ore to 40 feet, whence it became poor and pyritic. In the shaft level the material from the north drive is rich, whereas in the south pyrite displaces quartz, and the ore is poor, though the vein there is wide and well-defined. In every respect this body is similar to others of the type already described.

(*q*) Brown Face Vein.

This vein, as its name implies, is associated with the Brown Face ore-body—not directly, but by accident of position. It seems probable that this fissure represents the displaced part of Slaughter-yard Vein, as indicated in the accompanying section. Its course is nearly parallel to Queen Vein, and the dip is in the same direction. The vein consists of gossanous quartz 6 to 12 inches wide, and contains over 1 per cent. tin. Developments consist of short drives east and west from main tunnel and a rise on the west side 54 feet above tram-level.

(*r*) Slaughter-yard Vein.

This is a narrow vein of no great importance exposed in Slaughter-yard Face. A considerable part of the material has been removed, leaving little to be examined. It resembles others of the type described in these pages.

The so-called bore-hole lode cut in drilling from the open-cut is probably identical with this. It consists of white opaque quartz, 12 inches wide, dipping at an angle of 20 degrees and striking north-east. This body was opened from main tunnel level by a winze, 150 feet deep on the dip, and drives 50 feet north and south from the bottom. It is reported that the quartz is tin-bearing to a depth of 50 feet, and that it contains gold near the bottom of the winze.

(*s*) Happy Valley Vein.

This vein occurs between dolomite and phorphyry on the west side of Happy Valley Face. It is a pyrite-quartz body containing tin in the proportion of 1 per cent., and is 3 feet in width. Some very rich material was excavated from the upper level many years ago, but the average grade of the unenriched ore is as stated. A crosscut through the dolomite from the level of Happy Valley Face is now under way. This is one of the more important bodies, and much is expected to result from the development work in hand.

(*t*) No. 1 North-east Vein.

This vein is regarded as the southern continuation of North Valley Vein, but there is no definite evidence in proof, except that their trend coincide. The vein has been opened by a shaft and two adits, and a good deal of exploratory work has been performed on it through these mine openings. At the point where the shaft was sunk the vein is rather " mullocky " at surface, but rich in tin. A few feet below the surface pink-coloured, fluorine-bearing mica 12 to 18 inches thick displaced the mullock, and, with cassiterite, constituted the whole vein. For 50 feet the material was very rich, but at that point the dip changed from west to east, and to the bottom of the shaft (80 feet) the tin-ore component was small.

No. 1 adit was driven from road-level across sandstones and laminated slates near a dyke of porphyry. The only indication of the vein in this adit crosscut is a mineralised bed of sandstone between two soft selvaged walls. No. 2 adit, however, exposes a sharply-defined vein 12 to 24 inches wide, consisting of gossan and quartz. It is contained in slate and sandstone, and separated therefrom by a 3-inch band of white selvage. The width varies from point to point, seldom reaching 2 feet, and pinching to 5 inches at the end of the adit.

The tin-content is not high in this section of the vein.

(*u*) No. 2 North-east Vein.

An 8 to 24 inch vein, coursing 10 degrees west of north and dipping west at 45 degrees, follows the footwall of a porphyry dyke toward Queen Vein, of which it may be the southern extension. The vein material is pyrite and quartz with a variable cassiterite association. It is well defined and persistent, but the tin content is too low to be extracted at a profit. Much selvage occurs on the hanging-wall, which may have been derived from the decomposition of felspar and tourmaline. Although in places these minerals have been removed from the porphyry, green tourmaline is particularly abundant in the rock where the action of the solutions has not been so severe. In the attacked parts cassiterite is more abundant. From this No. 1 drive a branch vein has been followed 50 feet. This vein is pyritic, and is wholly contained in porphyry, which carries a considerable amount of cassiterite. Solutions have strongly attacked the porphyry, leaving it cellular near the walls of the vein. Tourmaline is abundant, and arsenious oxide exudations are prominent.

At the No. 2 level the vein is represented by brecciated slate and quartzite cemented by quartz containing cassiterite. Its general character is similar to White Face lode, with which it may be identical. Some distance in the adit the character of the vein alters to a well-defined body of quartz and pyrite 12 to 18 inches wide, and continues to the end of the adit, where 12 inches of tin-bearing material is exposed.

(*v*) Princess Vein.

This occurs on the footwall-side of Princess Dyke, and consists of 3 to 8 inches of brecciated material veined with tin-bearing quartz. It dips with the dyke to the south, changing to south-west as the vein leaves the wall of the dyke. Near the northern exit of main tunnel the dyke and vein are cut. At this point it splits into two, and becomes pyritic and poor.

These constitute the more important of the many veins that ramify through the mountain. Some of these undeveloped veins were cut in boring to test the downward continuation of the large ore-bodies, a record of which is given hereunder:—

Nature of Strata.	Thickness.	Depth.
Bore Hole No. 1.	ft. in.	ft. in.
Slate, detritus	6 6	6 6
Slate, soft blue	42 1	48 7
Slate blue, with small quartz veins	8 9	57 4
Slate, soft white, with quartz veins	14 3	71 7
Slate (?), soft white, with stones of serpentine	1 7	73 2
Serpentine	3 3	76 5
Slate (?), blue, with serpentine	4 7	81 0
Slate (?), hard, blue	5 9	86 9
Porphyry	17 3	104 0
Bore Hole No. 2.		
Slate detritus	6 6	6 6
Slate, soft blue	12 6	19 0
Conglomerate, soft	8 10	27 10
Conglomorate	21 1	48 11
Schist (?), hard, blue boulders	21 1	70 0
Schist (?), hard	19 0	89 0
Porphyry, white	5 0	94 0
Tourmaline and pyrite	7 10	101 10
Porphyry	7 9	109 7
Bore Hole No. 3.		
Slate detritus	6 6	6 6
Slate, blue	3 0	9 6
Schist, hard, blue	12 8	22 2
Schist, blue, with pyrite seams	14 1	36 3

Nature of Strata.	Thickness.		Depth.	
Bore Hole No. 3—continued.	ft.	in.	ft.	in.
Schist, hard	33	3	69	6
Pyrite and fluorspar	1	0	70	6
Schist and pyrite	46	5	116	11
Fluorspar and pyrite	1	5	118	4
Schist	7	0	125	4
Bore Hole No. 4.				
Detritus	6	6	6	6
Schist (?), hard	6	1	12	7
Schist (?), hard, with siderite	3	3	15	10
Schist (?), hard	11	3	27	1
Schist (?), with siderite	1	0	28	1
Schist (?), hard, with pyrite and siderite	1	1	29	2
Schist (?), hard	64	8	93	10
Schist (?), very hard	4	10	98	8
Pyrite	1	0	99	8
Schist (?), very hard	7	10	107	6
Bore Hole No. 5.				
Clay, yellow and brown, with porphyry boulders, containing pyrite and cassiterite	38	10	38	10
Conglomerate	78	6	117	4
Porphyry	7	0	124	4
Conglomerate	15	2	139	6
Pyrite	1	0	140	6
Porphyry, very hard	1	11	142	5
Bore Hole No. 6.				
Detritus and diluvium, with pyrite	55	3	55	3
Conglomerate, hard	16	5	71	8
Diluvium, blue	7	11	79	7
Conglomerate	22	8	102	3
Bore Hole No. 7.				
Diluvium	109	8	109	8
Clay and stones	19	4	129	0
Conglomerate	6	3	135	3
Clay and stones	6	2	141	5
Conglomerate	8	2	149	7
Bore Hole No. 8 *(horizontal).*			ft.	in.
Slate, hard, blue	...		12	6
Schist (?), very hard, blue	...		6	7
Porphyry leader, carrying tin oxide	...		0	0½
Schist (?), very hard	...		33	11
	...		53	0½

(*w*) Don Alluvial Workings.

The area occupied by these deposits constituted part of the property held under lease from the Crown by the Don Tin Mining Company. After the failure of the original operators the property was bought by the Mt. Bischoff Company, and now forms part of their consolidated lease.

The deposits consist of deep beds of Tertiary age, occupying a narrow channel in slate and porphyry at the southern end of Mt. Bischoff. The uppermost member, which rises above the level of the older rocks, is a 50-feet bed of mud containing bands of lignite and remains of vegetable matter. Underlying this are alternate beds of sandy clay and mudstone, which in turn rest on 20 to 30 feet of gravel and conglomerate. This formation, a little farther to the south, dips underneath sheets of basaltic lava which covers the greater part of the country in that direction. The area of the exposed beds probably does not exceed 2 acres.

The basal member consists of large boulders of conglomerate composed of rounded to sub-angular pebbles of quartz-porphyry, indurated slate, quartz, and quartzite. With these are smaller boulders of brecciated wall-rock, indurated sandstone, and porphyry, and the overlying gravels are composed of similar materials.

These deposits have been tested by a shaft, which was sunk at a point a little to the south of Don Hill to a depth of 120 feet. This mine opening exposed 8 feet of fairly rich tin-bearing gravel consisting largely of the conglomerate boulders already referred to. An attempt was made to reach the bottom wash by crosscutting from the west side of Waratah River Valley, but the ground became so heavy and difficult to excavate that the work was stopped before reaching the objective. The deposits have been exposed in recent years by means of an open-cut, and a fair amount of tin ore has been obtained from the material removed in this operation. The results, however, show that the amount of tin ore that is recoverable from the bottom wash is insufficient to justify a continuance of operations in view of the large quantity of barren overburden to be removed.

(*x*) North Valley Detrital Deposits.

These consist of the waste of the ore-bodies and disintegrated wall-rocks occupying the northern slopes of the mountain. The term "talus material" is more applicable to this loose rock, as the great bulk of it does not represent the disintegrated lode rock in place. For many years this so-called detritus provided a large source of supply for the battery, and very extensive deposits remain to be worked. The great difficulties to be overcome are the cost of removal to the aerial ropeway, and the large proportion of waste rock associated with the tin ore. If a water-supply were available the exploitation of these deposits would prove easy and profitable. By this means the material could be sluiced from top to bottom

(18) *Summary.*

In the foregoing statement an endeavour has been made to present a faithful account of the various activities of the company since its incorporation in 1873. Descriptions have been given of the mine openings, the lodes and veins and the methods adopted for their exploitation. In addition, a new interpretation has been given of the origin of the ore-bodies which heretofore had not been satisfactorily explained. The practical considerations arising out of these investigations will, it is hoped, prove of benefit to the company. In order to complete this report a brief summary will be given of the results obtained, and certain recommendations will be made concerning the future development of the lodes and veins.

It will be noted that the lodes are largely replacement bodies after dolomite and not porphyry, and that the base of all of them is dolomite. The reason why these deposits did not extend far below their original surface is that the tin-bearing solutions, finding easy access at the intersection of fault and lode fissures, and having been arrested in their ascent by the cover of conglomerate, spread out laterally and attacked the rock (dolomite) most susceptible to replacement. In this way the large irregular ore-bodies were formed. Silicification of dolomite outside the range of intense mineralisation has completely masked its original character. As a rule replacement took place along horizontal fractures in the rock producing the layered deposits, and giving rise to the idea that the layers of replaced material represented beds of alluvium. Any ore-bodies below the present working levels will prove to be of this character, but not extensive.

Below Brown Face, in western crosscut from Main Tunnel level, a peculiar body of compact quartz sand is exposed in the " crib " chamber. Under the microscope the quartz appears glassy and of irregular outline, not unlike the sand from crushed sandstone found in the neighbourhood, but its nature in other respects and its position are such as to invite attention. The material is self-supporting in the chamber, but it is very soft, and the particles composing it are detached. It may represent a replaced dolomite, but one would expect to find a crystal development of the extremely fine grains of quartz. To the south of this the dolomite body appears to extend in this direction. The material contains a little fluorine and it is seamed with thin threads of cassiterite. This section should be investigated.

Gossan Face body below the present level deserves attention, especially where the fault and lode fissures intersect. Flat " makes " will spread out from the main fissure here as elsewhere in the dolomite bodies. The end can be seen of all the large ore-bodies, but the tin ore will live in the smaller lodes and veins far below the base of existing workings.

More attention should be given to the veins. Poor sections occur, but rich shoots will alternate with them.

The company possesses a big asset in its enormous deposits of marcasite and pyrite. This material contains 0·25 per cent. of free cassiterite, which could be separated by treatment in the concentrating plant. Now, if a market can be found for the sulphidic minerals these ores could be exploited at a profit to the company. If not, the conversion of the sulphides to marketable products at the mine becomes a matter of necessity. There are two ways in which it is possible to effect this result:—

(1) The conversion of the sulphur constituent of the gases from the calcining plant to the elemental condition; or

(2) The conversion of the sulphides of iron to sulphate of iron.

Of these the latter appears the more attractive. At present the market rate for sulphate of iron is £10 per ton wholesale, and the demand is strong. If the market rate fall the sulphate of iron could be converted into the highest grade iron oxide pigment simply by a process of reduction, and the formation of sulphuric acid as a by-product of the operation would add to its value.

(B)—Mt. Bischoff Extended Mine.

(1) *Area, Situation, &c.*

The Mt. Bischoff Extended Company's holdings now consist of mineral lease 3964-M, of 433 acres, and timber lease 7850-M, of 80 acres. The mine workings are situated on the south-west slopes of Mt. Bischoff at an elevation of 1200 to 2200 feet above sea-level, and the property adjoins that leased by the Mt. Bischoff Tin Mining Company.

It was in the bed of Tinstone Creek, which flows through this property, that James Smith discovered tin ore in 1873. Until 1879, when Wheal or Giblin lode was discovered, it was considered that the most important deposits of tin ore would be found in the detrital or talus material covering the mountain slopes. A number of shafts were sunk through the detritus to bedrock, and it was then found that the proportion of tin oxide in the material was so small that operations could not be conducted with profit to the company. Attention has since been concentrated on Wheal lode, from which a large quantity of tin ore has been produced. Hitherto all attempts to exploit these deposits failed, and but for the high market rates for tin, and the employment of the most up-to-date appliances, the Mt. Bischoff Extended Company would not have been successful in their operations.

(2) *Geologic and Structural Relations.*

The ore-deposits are of the true vein or fissure type. Only one of the fissures which they fill has thus far proved of commercial importance, the subsidiary parallel ones being narrow and comparatively poor. In general they follow the direction of transverse faulting. Much of the faulting is earlier than ore-deposition, as is shown by the fact that the fault breccias are cemented by ore. Minor movement subsequent to ore-deposition is indicated, but the similarity of the wall-rocks over considerable thicknesses makes it difficult to determine its amount.

The rocks in which the ore-bodies are encased are sandstones, slates, quartzites, &c., of the Bischoff series. They have been affected by intense folding on a small scale and by the intrusion of irregularly defined dykes of quartz-porphyhy. Fissuring took place subsequent to the intrusion of the porphyry, for the lodes pass through this rock without interruption.

(3) *The Ore-bodies.*

Wheal or Giblin Lode.

This is the only lode thus far developed on this property that has proved of economic importance. The northern portion was at one time worked by the Wheal Tin Mining Co. through adits which extend to the boundary and junction with the Mt. Bischoff Extended Co.'s workings. These companies have opened the lode a distance of 2000 feet along the strike, and deep workings have intersected it 1000 feet below the outcrop. It pinches and swells along the strike and the dip, varying in width from 8 inches to 8 feet, generally maintaining an average width of 2 feet. In its passage through the rocks (slate, sandstone, quartzite, and porphyry) no striking change is apparent in the size nor in the content of tin. It is noticeable, however, that the quartz increases and the pyrite decreases in amount as the lode approaches the porphyry.

As a rule the vein materials adhere firmly to the wall-rocks, and there is very little evidence of movement subsequent to their formation into lodes. Apparently the ore-bearing solutions had little effect on the wall-rock, the only change noticeable being due to silicification.

The mineral components in approximate order of abundance are quartz, pyrite, cassiterite, arsenopyrite, sphalerite, wolfram, chalcopyrite, tourmaline, topaz, fluorspar, and bismuthinite, in addition to another group, of later formation, consisting of galena, stibnite, siderite, &c.

Of the deleterious impurities contained in the minerals listed above, lead, arsenic, and sulphur only are present in sufficient quantity to require special treatment for their removal. According to Gudgeon[21] the average composition of the concentrate produced during the past four years is:—

	Per cent.
Tin	70·75
Lead	0·37
Sulphur	0·34
Arsenic	0·11
	+

Lead is the most troublesome of these impurities, and in the untreated concentrate is contained in the proportion of 3 to 6 per cent. In the form of galena it occurs from the lowest level to the surface as blebs and pockets

[21] Gudgeon, C. W.: The Giblin Tin Lode of Tasmania, Trans. Inst. of Mg. and Met., 1919.

in the body of the ore, and also as a separate vein-filling on the footwall side of the fissure.

Wolfram and its oxidation product, tungstite, are found in pockets usually on the hanging-wall side of the lode, but their occurrence is sporadic and in very small quantity.

In addition to the primary minerals referred to, a number of unimportant secondary minerals occur commonly as encrustations on the walls of adits, drifts, and winzes. These are malachite, arsenious oxide, and iron and zinc sulphates.

Banding is well developed where the vein is wide, and in such places also comb structure is usual. Where the vein is narrow cassiterite and pyrite frequently occur as interstitial minerals in compact quartz, clearly indicating the predominance of silica in the ore-bearing solutions and its early deposition during the period of mineralisation. In open spaces, where the quartz is well crystallised, cassiterite is often found implanted on the crystal faces. This relation does not necessarily indicate a later period of deposition, for these minerals occur in intimate association in the body of the ore—rather does it suggest that deposition was continuous and contemporaneous. In places, however, clean bands of massive dense cassiterite occur 2 to 3 inches wide, encased in quartz, and occasionally on the hanging-wall side of the vein. These bands may continue unbroken 100 feet or more in length, and extend a like measure on the dip. A noteworthy feature of these deposits is that in the tin-rich sections of the ore-bodies quartz is the predominant gangue mineral, and in the poor sections the mineral associate is either pyrite or its oxidation product, limonite.

Reference to the longitudinal section appearing herewith shows that the ore-body as a whole pitches to the south at an angle of 50 degrees. The line of pitch corresponds in position, direction, and magnitude to the fault passing on the north side of Brown Face deposit in the Mt. Bischoff Mine. The result is a progressive shortening of the ore-body with increase in depth. For instance, at the No. 9 level, its length is only a fraction of its lineal extent at surface.

The shoots of ore in this ore-body on the contrary pitch to the north at an angle nearly normal to the main fault, and correspond to the other group of transverse faults observed in the Mt. Bischoff ore-body. In consequence of this complexity of faulting, rich and poor shoots of ore are found in alternate sections, the rich ore occurring on the hanging-wall side of the faults at points of easiest access for solutions. The vein-fissure courses north 18 degrees west—almost at right angles to the fault fissures—and dips westerly at angles varying from 44 to 56 degrees. Evidence is available of differential slipping of the vein-fissure walls, both prior and subsequent to the deposition of ore. The effect of the former is seen in the swelling and pinching of the ore-body, both along the strike and the dip, where the walls converge, and the angle of dip becomes greater, the tin content of the ore is richer than it is where the vein is wide and flat, the proportion being fairly constant; but there is no appreciable variation in the amount of tin ore in the vein material. In other words the proportion of tin ore in the material varies inversely with the width of the vein.

(4) *Developments.*

The West Bischoff Mining Company, floated in 1878 with a capital of £50,000, commenced operations on Wheal lode in 1879. The early operations, consisting of the sinking of Hammond's shaft, and the driving of Nos. 1 and 2 levels on the lode, revealed a rich and extensive ore-shoot. It was decided then to erect a battery of 15 stamps, and the necessary concentrating machinery. This work was completed in March, 1882, and the plant was kept in continuous operation until the end of 1884. During this period 7102 tons of lode matter containing 3·02 per cent. tin was treated, and 306·6 tons of tin ore, valued at £18,850, was obtained. The cost of production was so great that operations by the company were suspended, and the mine was let on tribute to one, White, who in two years obtained 110 tons of tin oxide. In the following year tributor Root produced 34 tons of concentrated tin ore. Production ceased until 1892, when the New West Bischoff Co. was formed. Between the latter end of 1892 and 1894 this company mined 2520 tons of lode material containing 2·76 per cent. tin, and obtained 120 tons of ore in the process of treatment. This company, however, fared no better than its predecessors, and the mine ultimately came into the possession of the Commercial Bank of Tasmania.

During the following decade exploitation of the ore-body was carried on in a desultory fashion by several parties of tributors, none meeting with marked success. In 1907 the Mt. Bischoff Extended Tin Mining Company purchased the mine, and by means of long adits and cross-cuts exposed the ore-body to a depth of 1000 feet below the collar of Hammond's shaft. A brief description of the ore-body in the several mine openings follows:—

Nos. 1 and 1 Intermediate Levels.—At the time of the recent investigation these workings were not accessible. From information obtained it appears that the nature of the ore and its mode of occurrence was similar to that of the lower levels.

No. 2 Level.—Huge pillars of high-grade pyritic ore left by the early operators were removed by the Mt. Bischoff Extended Company. Ore, in alternate rich and poor sections, has been opened up by a drift over 1000 feet long.

No. 3 and No. 3 Intermediate Levels.—No. 3 level adit follows the lode from its outcrop a very great distance. Rich and poor shoots alternate here as in other parts of the mine. Just beyond the "jump-up" from the footwall to the hanging-wall "makes" a very rich shoot of ore was stoped above this level on the hanging-wall side. This ore followed a dyke of porphyry.

Nos. 5 and 5 Intermediate Levels.—Between the No. 3 and the No. 5 Int. 80 feet below, a shoot of rich ore 100 feet long and 30 inches wide, consisting largely of gossanous quartz and fluorspar, was mined. Near that body a vein of fairly clean galena, 18 inches wide, rises 40 feet above the level. The boundary line crosses No. 5 level drift 15 feet from the north end. A band of clean cassiterite, 2 inches wide, shows in the rill face just over the boundary, and the southern continuation of this shoot has produced a large quantity of high-grade material. From the crosscut the ore for 40 feet north and 200 feet south was wonderfully rich. This shoot rose on the rill southward up to No. 3 level. Beyond the rich section north a 200-feet shoot of average grade ore occurs; and, after passing through a mullocky barren section average quality material comes in south and extends a long distance.

Intermediate Levels A, B, and C, between Nos. 5 and 6 Levels.—From No. 5 level a winze (No. 3), was sunk on the footwall "make" to A Int. on a lode consisting of galena, sphalerite, pyrite, and a little cassiterite. On the north side of the winze at A Int. the first section of

300 feet was barren. This was succeeded by a very rich shoot of ore, 20 inches wide, containing over 20 per cent. tin, and extending 200 feet. Very rich ore was found between this and No. 5 level where the lode passes through western dyke.

At No. 6 Int. B the hanging-wall "make" contained the richest ore. For 200 feet north of the winze the lode material was mullocky and poor, then the rich shoot, 200 feet long, worked from A Int. was cut. At this level galena and sphalerite are prominent in some sections of the ore-body. In the north-end the lode is poor, pyritic and broken. This drift exposed the upper part of the big dyke of porphyry, which here is very pyritic, dense, and hard.

Above Int. B a body of ore, 12 inches wide, containing tin in the proportion of 30 per cent. was stoped 20 feet in height. This probably corresponds to a similarly rich shoot found in the level of C Int. It gave place abruptly to pyrite. A short distance north of the main pass to No. 9 level, the lode passes through a dyke of porphyry. Near this point the ore-body consists of an 8-inch band of brecciated wall-rock, resting on a 10-inch vein of galena, under which is a 14-inch vein of tin-bearing quartz.

South of the main pass average quality material continued for a long distance, and ultimately gave place to soft, yellowish-brown gossan, poor in its content of tin.

At No. 6 C level near No. 10 rise a very rich body of ore 6 to 8 feet wide, was cut and followed 300 feet southward. This material near the next level gives place to 24 inches of lower quality ore with 12 inches of galena on the hanging-wall side. At the south end of the drift, barren gossanous slate marks the continuation of the fissure. The north end likewise is barren of tin, and the lode consists of similar material. Between C and B Ints., near the porphyry in the north section of the lode, a band of stone containing 1 inch of clean cassiterite, 30 feet in length, was found adhering to the hanging-wall.

No. 6 Level.—The workings at this level are very extensive, especially on Giblin lode. They consist of a long crosscut, and drifts north and south therefrom. Where Giblin lode was intersected by the crosscut the ore was of exceeding richness, and the shoot extended nearly 200 feet to the south. In the north end, a short distance from the crosscut, the ore is split into numerous small veinlets and is valueless. Going south a footwall "make"—the main one in all cases—contained a 1-inch vein of clean cassiterite for 80 feet along the drift. Thirty feet above this level the vein junctioned with the hanging-wall "make." It has not been followed under foot. Continuing south the drift passes through barren material off the line of lode, thence through a porphyry dyke, and on to the footwall "make" again, which contains tin in the proportion of 4 per cent., but is too small to prove profitable. The drift ultimately enters the main lode channel and continues along its course until the ore becomes poor and the vein narrow. The richer part of this section of the ore-body has been stoped. At the point where the lode intersects it the porphyry has been completely silicified.

Farther eastward the crosscut intersects another ore-body, probably identical with Eastern lode. The south drift on this body exposes pyritised slate resting on the slickensided surface of a 4-inch galena-pyrite vein which extends 60 feet to a porphyry dyke. Beyond that point the lode channel is indistinct, and the hanging-wall is brecciated. North of the crosscut a 2- to 10-inch vein of gossanous quartz has been followed. Samples of this ore containing up to 1 per cent. tin have been obtained but the average quality is very low. This lode dips in a north-easterly direction. The eastward extension of the crosscut passed through several narrow veins of quartz-pyrite, and near the end a lode of antimonial ore. No exploratory works have been performed on these.

Between Nos. 6 and 9 levels comparatively little ore has been stoped. No. 2 rise from 9 level connects with No. 6 level at the point where the main lode was cut towards the south end of the drift. Below this point at No. 7 Int. level a very rich shoot of ore, 50 feet long, was stoped. No other rich shoots were found at that level, and it is evident that the ore is gradually petering with increase in depth. In the No. 1 rise from No. 9 level poor ore extends 70 feet below No. 6 level, and from that point the tin-bearing material is displaced by galena.

No. 9 Level.—A crosscut, 1700 feet long, driven from the level of the ore-bins at the concentrating plant intersects the several veins. About half-way a galena-sphalerite-pyrite vein, dipping at an angle of 60 degrees in a direction 30 degrees east of north, was intersected and explored along its course a distance of 100 feet. Two more were cut farther on, neither of which were of any importance.

The evidence obtained at the No. 9 level clearly indicates that the downward limit of profitable mining has been reached. Owing to the southerly pitch of the ore-body it is possible that the No. 9 level crosscut passes to the north of the lode, but apart from that consideration altogether a progressive shortening of the ore-body and decline in value of the ore has been noticeable below No. 6 level.

Porphyry Dykes.—Western dyke, the post persistent off-shoot of the main porphyry body which passes through the Bischoff leases in a north-easterly direction, consists of slightly topazised quartz-porphyry. It is 30 feet in width and continues right through the property. The dip, where discernible, is at an angle of 87 degrees toward the north-west. Cassiterite is occasionally found in the body of the porphyry, but usually it occurs filling cracks in the rock. On the adjoining Mt. Bischoff property the porphyry of Western dyke contains an appreciable amount of cassiterite, especially on and near the walls. In addition to Western dyke a large, irregular body of porphyry has been exposed in these workings. The composition of this rock varies according to its distance from the ore-channels. In places it has the appearance of a silicified quartz-porphyry, in other parts it is pyritic, and at some points it has suffered topazisation.

It was considered at one time that the these dykes of porphyry contained tin in profitable amounts. In order to determine the value of this material a large number of samples were taken from both dykes, the averages being:—

0·17 per cent.
0·09 per cent.

A high tin content was not found in any particular section of the porphyry, but tin was detected in every sample taken, showing a fairly even distribution.

In addition to the ore-bodies already described several other parallel formations are known. Of these the

Haulage, Eastern, and No. 6, appear the most important. Eastern lode has been developed by adits on the adjoining Mt. Bischoff property; but the others have received little attention, and little is known of them. These are the only possible resources now possessed by the company, consequently the future depends upon the results of their development.

(5) *Milling and Concentration.*

The original milling and concentrating plant was erected in 1881 on the right bank of Arthur River. It consisted of a battery of 15 stamps with jigs, classifiers, and buddles driven by an overshot water-wheel. This milling-plant was burnt and a new one was erected nearer the mine in 1908.([22]) It consisted of a jaw-crusher, ore-bin, Challenge feeders, battery of 10 stamps (1050 lb. weight, 50 revs. per min.), double Callow (belt) screen, two 2-compartment jigs, grinding-pan, one 3-compartment hydraulic classifier, two Callow tanks, three No. 5 Wilfley tables, one Wilfley slime table, and canvas strakes. The battery screens were coarse (12-mesh linear), and the Callow screen was a 30-mesh. The undersize from the screen passed to a hydraulic classifier which separated it into three grades—coarse, medium, and fine—each being conveyed to its particular concentrating table. The oversize was conveyed to jigs, the heading of which was clean, and the tailing was sent to the grinding-pan, thence to the classifier that received the screen undersize. Material overflowing from the classifier was successively thickened in two 8-feet Callow tanks and a large V settler, and fed partly to three Wilfley tables and partly to the Wilfley slime table. Tailing from all tables received further treatment in passing over strakes.

Later a belt conveyor was placed between the breaker and ore-bins, and within twelve months there were added a small Merton furnace, two Wilfley tables, one Phœnix-Weir table, two classifiers, a settling-tank, and a mixer for calcined concentrate. In 1910 a much larger furnace was erected in order to cope with the increase of pyrite in the concentrate. Callow screens were replaced by two spitzlutte; and another grinding-pan, two double-belt

([22]) Herman, Hyman: Proc. Aus. Inst. Mg. Eng., 1914, p. 368.

vanners, another classifier, and a dressing jig were added to the plant. Since that time no radical change has been made in the process of treatment, except perhaps the addition of a caustic soda plant for the extraction of lead from the concentrate.

The ore contains 0·95 per cent. tin and 11 per cent. pyrite, sulphides of lead, zinc, and antimony, and wolfram. Ten-mesh battery screens are used. The grading analyses are given in the subjoined table:—

—	(a)	(b)	(c)
	Per cent.	Per cent.	Per cent.
+ 10	—	—	0·00
+ 20	13·51	0·0	0·32
+ 40	22·42	6·9	5·70
+ 60	13·62	24·8	9·70
+ 80	5·63	18·0	15·00
+ 100	7·24	3·7	8·50
+ 120	2·98	6·4	10·20
— 120	34·60	40·1	51·20
—	100·00	99·9	—

The pulp from the grinding-pan shows the analysis (*b*) above.

The object aimed at is to save as much of the sulphidic ore as possible, and at the same time save the fine tin oxide. Jig headings, and first and second-grade materials from the concentrating tables and vanners are sent to the calciner. The average value of this concentrate is 17·5 per cent. tin. A single compartment jig receives the calcined material.

The ore is concentrated to 69·5 per cent. tin. A grading analysis is shown in column (*c*) of the accompanying table. The plant is driven by steam from boilers generating 75 horsepower.

(6) *Production.*

A complete record of the output of tin ore from this mine is not available. All the information at hand is given in the subjoined table, and in some places estimates have been entered where the record is deficient:—

Producer.	Period of Operation.	Crude Ore Treated.	Tin Recovered per Ton of Crude Ore Treated.	Tin Oxide Obtained.	Value of Product in Pounds Sterling.
		Tons.	Percent	Tons.	£
West Bischoff Co.	1882-84	7102	3·02	306·6	18,850
Tributor White	1884-86	...	...	110·0	11,000*
Tributor Root	1887	...	...	34·0	3400*
New West Bischoff Co.	1892-94	2520	2·76	120·0	12,000*
Sundry Tributors....	1895-1907	...	...	80·0*	8000*
Mount Bischoff Extended Tin Mining Co.	1907-18	130,768	0·94	1741·92	184,720
		Estimated Total		2392·52	237,790

* Estimated.

During the period 1882 to 1907 the operations of the several companies and tributors were not successful, but better results attended the enterprise of the Mt. Bischoff Extended Tin Mining Company, and a considerable sum was distributed in dividends from the profits of their operations. The grade of the ore extracted has depended on the possibility of profitable treatment. In the early days only very high-grade material could be profitably mined—later a much lower grade was treated.

Gudgeon supplies the following information relative to the tenor of the ore at various levels:—

Vertical Depth.	Level.	Distance Sampled.	Tin Content.
Feet.	No.	Feet.	Per cent.
355	3	2368	0·79
454	4	289	0·70
484	5	168	1·12
678	6	2814	1·20
734	7 Int.	119	1·41

These figures represent the proportion of tin in the lode, but not the material milled. In mining the ore part of the wall-rock is broken with it, thereby reducing the grade in proportion to the quantity of waste included.

(7) *Ore-reserve.*

In 1918 the superintendent estimated an ore-reserve of 41,000 tons, containing 1·01 per cent. tin. Since that estimate was made the reserve has not been appreciably reduced. It is proposed to pay attention to the most promising of the parallel lodes (Haulage, Eastern, and No. 6), in order to augment the supply.

The dyke of porphyry near Tilley's Rise and No. 6 lode have been sampled at the outcrop and analysed.

The subjoined table contains the analyses of samples taken in 10-feet sections:—

Porphyry near Tilley's Rise.

Width Sampled. (Feet.)	Tin Content. (Per cent.)
2·5	0·24
1·5	0·29
3·0	0·21
2·5	0·19
2·7	0·27
2·7	0·12
2·5	0·31
2·0	0·09
3·0	0·03

Trench Along Outcrop of No. 6 Lode.

Width Sampled. (Feet.)	Tin Content. (Per cent.)
1·0	0·45
1·3	1·12
1·5	0·90
1·5	0·86
1·3	0·36
1·2	0·24
1·5	0·47
1·5	0·47
1·5	0·47

Trench Along Outcrop of No. 6 Lode—continued.

Width Sampled. (Feet.)	Tin Content. (Per cent.)
1·5	1·21
1·3	0·45
1·3	1·23
1·4	0·47
1·0	0·29
1·6	0·09
1·0	0·11
1·0	0·41
1·3	0·35
1·4	0·74
1·5	0·73
1·7	0·76

(C)—Weir's Bischoff Surprise.

(1) *Area, Situation, &c.*

In the valley of Waratah River on the northern side of Mt. Bischoff an extensive deposit of alluvial material shed from the main ore-bodies has been worked for its content of tin ore. The property owned by the company comprises the following leases:—1892-M, of 20 acres, 4400-93M, of 10 acres, 4426-93M, of 6 acres, 1264-M, of 2 acres, and 1265-M, of 1 acre, all of which are situate in the bottom of the valley.

(2) *The Deposits.*

The deposits consist of Quaternary and Recent gravels and sands from 300 to 600 feet in width, and 8 to 12 feet in depth. Apparently the 2-feet band of gravel immediately above the bed is the only profitable section of the deposit. Rounded pebbles and boulders of porphyry and quartzite constitute the bulk of the material, which varies in size from fine grains to pieces 2 feet in diameter, although the greater part is from 2 to 4 inches. These gravels have been so firmly cemented by iron oxide solutions from the large ore-bodies that they now have the consistency of conglomerate. The cassiterite content varies from the finest particles to pieces 4 inches in diameter, and is sufficient under ordinary circumstances to allow of profitable operation; but the conglomerated mass is very difficult to disintegrate by the methods usually employed, and recourse is had to other means of effecting this result.

(3) *Development*.

The material is excavated in open-cuts, and trucked to a small milling and concentrating plant for treatment. The milling plant consists of three batteries of light stampers (nine in all), driven from a geared water-wheel, 16 feet in diameter. A Wilfley table and a fixed buddle are employed in the concentration of the crushed material. In the quarrying operations a three-ton crane is used to remove large boulders and the overburden.

Material of exceptional richness only could be operated at a profit to the company. The means employed are not considered satisfactory.

(D)—Bischoff-Taylor.

This is a sub-basaltic deposit of Tertiary age situated on the eastern side of the valley of Waratah River, and two miles north-east of Mt. Bischoff. It belongs to the tin-bearing gravels exposed in the Don workings of the Mt. Bischoff Mine, and elsewhere in the neighbourhood, and, like them all, is of no commercial importance. At the Bischoff-Taylor the section exposed is as follow:—

Basalt, 100 feet.
Light sub-angular gravels and drift, 13 feet.
Dun-coloured muds full of organic matter, 30 feet.
Angular to sub-angular gravels containing a little tinstone, 22 feet.
Grey and blue slates.

The gravels directly underneath the basalt consist largely of quartz, hardened sandstone, and quartzite pebbles not often exceeding 1 inch in diameter, and also a little porphyry. They occur in distinct layers, and contain very little cassiterite. Underlying these are muds seamed with thin bands of Tertiary coal, and containing leaves and other organic matter in a fair state of preservation. Underneath this member is the tin-bearing gravel, which consists of pebbles of all sizes up to 1 foot in diameter. These pebbles are of quartzite, hardened sandstone, and porphyry. They show little sign of attrition by fast-flowing waters. The materials are similar to those composing the formations of Mt. Bischoff, and, probably, they have been derived largely from that source or from the northern extension thereof. Half a mile south of the mine grey slates crop out higher than the Tertiary sediments, and as the surface of this bed-rock rises on the north side also, it seems that this deposit represents an old stream bed. A little work was performed on these beds, on both sides of the ridge dividing Hellyer and Waratah Rivers, by a Queenstown company about 15 years ago. In the preparation of this work a water-race (3 miles long) was excavated from Taylor Creek, and half a mile of steel piping was erected to convey the water across a break in the ridge of the hill. This work was put in hand before the value of the deposit was ascertained, and, after a trial run of three weeks, it was found that the tin content of the gravels was too low to allow of its separation at a profit to the operators.

The sub-angular condition of the gravels indicate that the sorting and concentration of the tin ore by streams did not take place in any great degree. The deposit would have to be phenomenally rich to compensate for the cost of removal of so great a depth of overburden, especially as the quantity of water available is quite inadequate for this purpose.

(E)—Jones or Webster's Prospect.

This prospect is situated 5 miles from Waratah, and half a mile south of Corinna-road. It consists of tin-bearing gravels and detritus from 6 inches to 3 feet deep, covering a button-grass flat 5 chains wide and 50 long. Through the centre of this flat flows a tributary of the Coldstream, one of the head streams of Huskisson River. In the creek the "wash," as a rule, is shallow, but it contains a fair proportion of coarse tinstone or cassiterite. A few tons of tin has been obtained in working an area of 5 square chains, and outside this ground prospects indicate an average tin content of one pound per cubic yard. The associated material consists of quartz-tourmaline, quartz, and granite fragments all derived from the bed-rock. This is a fine-grained, grey granite, with porphyritic felspar, abundant biotite, and a little muscovite. In it are veinlets of cassiterite up to a quarter of an inch thick, which, doubtless, in the process of disintegration shed the cassiterite contained in the wash. The quantity of tin ore available in this area is not considerable, nor is the proportion sufficiently high to prove attractive.

(F)—Bischoff Alluvial Tin Mining Company.

About 30 years ago this company was formed to test the sub-basaltic deposits south of Mt. Bischoff. A number of bore-holes were sunk through the basalt and the Tertiary sediments to the slate bottom, and the tin ore in the gravels was carefully estimated. The results in all cases were disappointing, and showed conclusively that the exploitation of these deposits could not be conducted with profit to the operators.

Information relating to the nature of the rocks passed through in boring is given hereunder.

Nature of Strata.	Thickness.		Depth.	
Bore Hole No. 1.	ft.	in.	ft.	in.
Basalt soil	6	6	6	6
Basalt, decomposed	19	5	25	11
Basalt boulders	39	2	65	1
Basalt, hard	7	0	72	1
Mudstone	35	11	108	0
Slate, blue	4	3	112	3
Bore Hole No. 2.				
Basalt soil	6	6	6	6
Basalt, decomposed	12	6	19	0
Basalt boulders	9	10	28	10
Basalt boulders, hard	6	2	35	0
Basalt, soft	10	3	45	3
Clay, brown, with a few stones at 80ft.	74	9	120	0
Clay, brown, containing decomposed wood	72	7	192	7
Gravels and sand	19	5	212	0
Slate, blue	2	1	214	1
Bore Hole No. 3.				
Basalt	31	0	31	0
Clay, black	94	6	125	6
Clay, white, with stones	29	6	155	0
Mudstone	24	7	179	7
Sandy clay, white, with boulders	11	1	190	8
Sandy clay, white	11	2	201	10
Sandy clay, white, with boulders	8	11	210	9
Mudstone	4	0	214	9
Clay, blue, with boulders	9	3	224	0
Conglomerate	20	8	244	8
Hard, blue rock (not identified)	9	2	253	10
Conglomerate	7	4	261	2
Slate, blue	2	7	267	9

Nature of Strata.	Thickness.		Depth.	
Bore Hole No. 4.	ft.	in.	ft.	in.
Soil	21	0	21	0
Basalt boulders, hard	33	4	54	4
Clay, brown and blue	14	6	68	10
Clay, black	107	1	175	11
Clay, white	35	7	211	6
Clay, black, with decayed leaves	18	11	230	5
Clay, blue, with stones and gravel	17	1	247	6
Clay, white, sandy, with decayed woo	12	10	260	4
Gravel, fine	6	8	267	0
Slate	1	6	268	6
Bore Hole No. 5.				
Soil	34	0	34	0
Basalt, decomposed, with boulders	11	6	45	6
Clay, blue, sandy, with stones	19	6	65	0
Clay, black, with stones	9	0	74	0
Clay, black, with decayed vegetation	106	5	180	5
Clay, white	27	11	208	4
Clay, black, with decayed vegetation	25	6	233	10
Clay, blue, with stones	15	6	249	4
Clay, black, with vegetation	10	5	259	9
Clay, blue, with stones	22	3	282	0
Slate, blue	0	8	282	8
Bore Hole No. 6.				
Basalt boulders	46	6	46	6
Basalt boulders	2	8	49	2
Clay, yellow	5	0	54	2
Clay, black	42	9	96	11
Clay, white, with vegetation	29	6	126	5
Clay, black, with vegetation	23	7	150	0
Clay, blue, with stones	25	1	175	1
Schist (?)	4	3	179	4
Clay blue, with stones	5	4	184	8
Clay blue, with gravel heavily charged with pyrite and galena	11	3	195	11
Clay, blue, with gravel and schist (?) boulders	22	1	218	0
Slate	2	0	220	0
Bore Hole No. 7.				
Soil	17	0	17	0
Clay, black	62	1	79	1
Clay, white, sandy	26	6	105	7
Clay, black, with vegetation	24	7	130	2
Clay, blue, with stones	27	3	157	5
Clay, black, with vegetation	2	0	159	5
Clay, blue, with stones	10	7	170	0
Slate, blue	11	0	181	0

(G)—MOORE PROSPECT.

This prospect is situated 15 chains west of Cundy's on a plateau occupied wholly by granites. It was discovered some years ago by J. Walsh, of Waratah, who, with E. Pryde, erected a small milling plant to crush the ore. Some sections of the lode were profitable, but, as a whole, the ore-body was disappointing.

In many important particulars this deposit is similar to that of Pryde Prospect, but it differs in some respects. In some parts it consists of cassiterite-lepidolite bodies in aplite, in others it is composed almost wholly of quartz, and the wall-rock appears to have been greisenised. Twenty feet from the lode, which varies from 1 to 5 feet wide, the containing granite is a hard, dense, fine-grained rock consisting largely of orthoclase felspar and quartz, with subsidiary biotite. A little farther from the lode on both sides biotite granite prevails.

Developments consist of a shaft 30 feet deep, and a deep trench south of it along the course of the lode. Four bulk samples of the lode-material were taken in this trench. The results, given hereunder, show that the cassiterite is erratically distributed:—

No. 1, taken from north end of trench, contained 0·15 per cent. tin.

No. 2, taken from middle section of trench, contained 0·55 per cent. tin.

No. 3, taken from the eastern wall, contained 1·35 per cent. tin.

No. 4, taken from south end of trench, contained 0·05 per cent. tin.

As stated, these results do not lend encouragement to further exploration by the owners. Where lepidolite is prominent tin ore is correspondingly abundant, but these rich bodies are inextensive, and are widely separated.

(H)—CAMPBELL PROSPECT No. 1.

This prospect is situated near the source of Wombat Creek, about 20 chains to the south of Corinna-road. It consists of shallow trenches on a pyrite-quartz body in aplitic material. Analyses of samples reveal a low tin content. An improvement in the value of the ore is not anticipated.

(I)—Campbell Prospect No. 2.

Between the 6- and 7-mile pegs on the Corinna-road a shaft has been sunk on a 2-feet gossan lode to a depth of 20 feet. This lode, which courses a little east of north, is contained in Cambro-Ordovician slates near the point of contact with granite. A sample of ore taken from the shaft contained tin in the proportion of 0·56 per cent. The result of the analysis would justify further attention.

(J)—Campbell Prospect No. 3.

This is a griesen ore-body consisting largely of quartz and black tourmaline outcropping on the north side of Corinna-road near the South Bischoff turn-off. It is exposed 10 chains further north in shallow trenches. Samples of the material from the two outcrops yielded:—

0·15 per cent. tin.
0·07 per cent. tin.

The prospect is not encouraging.

(K)—Cundy Prospect.

(1) *Area, Situation, &c.*

This prospect is situate 8 miles to the south-west of Waratah. The track to Mt. Ramsey, which connects with Corinna-road at the 6-mile peg, passes through the property. This ore-body was originally worked on a small scale by W. Cundy, and later by tributors. Their operations resulted in the production of £3500 worth of tin.

(2) *The Ore-body.*

The deposit is a short lens-shaped body of pegmatitic material enclosed in biotite granite. It is composed of arsenopyrite, molybdenite, pyrite, chalcopyrite, sphalerite, and cassiterite set in a gangue consisting largely of green, fluorine-bearing mica. Sphalerite, cubic pyrite, and arsenopyrite are found, in coarsely crystallised form, intermingled with quartz in distinct veins and bunches embedded in the mica gangue.

From the mouth of the adit to a point within 10 feet of the lode the rock is a normal biotite granite, the components of which are equi-dimensional and of fine grain size. Near the lode muscovite takes the place of biotite and the rock is much softer.

Samples taken by the writer from the ore-body yielded little more than traces of tin. Not one contained tin in profitable proportion.

(3) *Developments.*

Development work consist of two small open-cuts and an adit. It is reported that rich lenses of ore were found in the open workings, but they were very small. The adit is driven on a course south 70 degrees west to the ore-body 111 feet from the entrance. Drives on the ore were carried 20 feet on both sides of the crosscut, and in the end of the south one a winze was sunk 40 feet on the lode. The lode became very poor at the bottom of the winze.

Lodes of this kind are rich, but as a rule are short and irregular both along the strike and dip.

(L)—Wombat Alluvial.

(1) *Area, Situation, &c.*

This property of 40 acres extent is now held under Lease 8572-M by A. E. Palmer. It is situated between Cundy Prospect and the Waratah Tin Sluicing Company's Mine, and is accessible by way of the Mt. Ramsay track to Waratah. Between 40 and 50 tons of tin has been produced by the several operators engaged in sluicing this deposit during the past 15 years.

(2) *The Deposit.*

The deposit is 6 to 20 feet deep, and consists of the waste of granites in pebbles up to 8 inches in diameter. The bulk of the material is not larger than 4 inches, and a large proportion consists of drift. These gravels extend nearly the full length of the section, and are from 100 to 200 yards wide. One of the serious difficulties to be overcome in their exploitation is the removal of thick jungle, the roots of which intertwine and form a thick cover to the deposit. Fifteen chains below the track the alluvial ground is nearly 200 yards wide and 5 feet deep. The actual depth of gravel is only 3 feet, and the bottom gravel only is rich, containing 2 lb. of tin ore per cubic yard of material.

In the bed of Walsh Creek, a tributary of Ramsay River, tin-bearing gravels containing also abundant monazite lie on Tertiary consolidated muds and beds of poor lignite. The depth of gravel is only 2 feet. It consists of quartz, quartz-tourmaline, indurated slate, diorite porphyry, and a little granite.

Downstream the alluvial material becomes much narrower but retains the average content of tin. The heavy vegetable cover greatly detracts from the value of this deposit.

(M)—Waratah Tin Sluicing Company.

(1) *Area, Situation, &c.*

The properties leased from the Crown by this company consist of Sections 7245-M, of 40 acres, and 1214-M, of 10 acres. They are situated 12 miles to the south of Waratah, and are accessible from the 6-mile peg on Corinna-road by way of a pack and sledge track.

The lode was discovered by W. and E. Pryde in 1914, and a local company was formed in 120 shares of £10 each, 20 shares going to the discoverers for their 40-acre section. The company erected a 3-head battery of stamps and two Wilfley tables to crush and concentrate the lode material. By this means they produced £2000 worth of tin ore, and then preparations were made for the erection of a new concentrating plant. After spending £3000, the mine was closed before the completion of these works. In 1920 the Waratah Tin Sluicing Company secured a 12 months' option of purchase, and during that period drove 360 feet on the ore-body. In June, 1922, the option was exercised, and since that time active operations have been carried on.

(2) *The Ore-body.*

The ore is contained in a lenticular body of micaceous material encased in medium-grained granite porphyry. The rock is aplitic, with pseudo-porphyritic crystals of quartz, and occasionally of orthoclase. The average course is 10 degrees west of north, and the dip is westerly at 65 degrees. In the No. 2 adit the lode is well exposed for examination, and is typical of the deposits. On the footwall is a 2-inch band of gossanous kaolin, which is succeeded by a 12-inch band of light bluish-green tourmaline with blebs and veinlets of pyrite and the bulk of the cassiterite. Chalcopyrite and its alteration product malachite are prominent. Succeeding thin band quartz-free kaolin 8 to 18 inches wide occurs. The tin-bearing rock remaining on the hanging-wall side is a fine-grained granite consisting essentially of quartz and felspar with minute scales of secondary muscovite. It is striking that everywhere in or near the muscovite is of much finer grain size than the other component minerals of the rock. The footwall is well-defined, hard, and unbroken; whereas the hanging-wall is not definitely marked, but the rock on this side occurs in horizontal layers, the division planes of which dip at right angles to and toward the footwall. Evidently the hanging-wall planes provided a means of ingress for later solutions which formed the later kaolin band on that side. The bluish-green tourmaline is pseudmorphous after orthoclase and is fluorine-bearing. The main ore-body exposed in this tunnel is the middle one of three lenticular masses occurring in an aplitic dyke rock trending in a north-westerly direction toward Pryde Prospect.

The following analyses of samples represent the grade of the lode material:—

Distance from Entrance to Adit.	Width of Lode.		Tin Content.
	feet	inches	per cent.
309	1	9	3·04
326	3	2	5·03
336	6	0	1·31

This ore-body is only 45 feet long. It apparently pitches north at an angle of 70 degrees.

Besides the No. 2 adit there are two more openings on the ore-body—No. 1 adit and an open-cut. From the open-cut 20 tons of tin-ore was obtained. Samples of lode material from the upper workings yielded tin as follows:—

Locality.	Width of Lode.		Tin Content.
	feet	in.	per cent.
Rise from No. 2 adit	3	6	3·92
No. 1 adit, 100 feet from entrance	4	10	0·84
South of open-cut	3	6	0·62
Hanging-wall of lode at surface ...	7	0	0·20
North of stope on hanging-wall ...	7	0	0·74

The other ore-bodies referred to have not been developed. One near the old mill is rich, but the shoot is short.

(3) *Developments.*

The plan of the old company was to drive 750 feet through a low hill to get 40 feet below No. 2 adit level. This would entail an outlay of £2000 for very little gain. The Nos. 1 and 2 adits will provide openings for mining the ore while a main shaft is being sunk. No. 2, the lower one, is only 70 feet below the surface, and fully half of the ore above it has already been taken out. If development work proves satisfactory a shaft will be sunk on the underlay of main lode.

Two dams of one and two million gallons capacity supply 10 sluice-heads of water for power purposes. The milling-plant consists of two batteries of stamps of three heads, each weighting 450 lb.; and the concentrating plant consists of two Card tables and one Wilfley table.

(4) *Alluvial Deposit.*

A deposit of tin-bearing gravel, 20 chains long, by 3 chains wide, and 5 feet thick, occurs on the east side of the mine workings. The gravels are made up largely of fine pebbles of granite intermixed with finer drift composed of similar material. It is reported that these gravels contain from $1\frac{3}{4}$ to 3 lb. of tin ore per cubic yard of gravel. Dish prospects confirm this estimate. The gravel rests on a soft bed of aplite. It is proposed to work this deposit by means of a hydraulic elevator operating under a head of 100 feet.

(5) *General Remarks.*

This is a small mine and will never develop into a big one, but under judicious management the operations of the company should prove profitable. Ore-bodies of this kind, however, are notoriously erratic. The shoots are short and are lenticular in form, consequently their persistence in depth cannot be anticipated. The only safe course to follow is to concentrate attention on mine development until sufficient ore is proved to warrant the erection of costly machinery.

(N)—Pryde Tin Syndicate.

This property some years ago was leased by the Summer P.A. Syndicate who recovered 4 tons of tin oxide in working the gravels in the bed of the creek. The operations of the syndicate were not successful, and the mine was let on tribute to a party of miners from Waratah who obtained one ton of ore from workings in the same locality.

Two years ago W. Pryde, with the assistance of some residents of Waratah, formed a syndicate for the purpose of working the alluvial ground higher upstream, and exploring the tin-bearing dykes of aplite to the westward. The preparations for these works are now proceeding.

(1) *Area, Situation, &c.*

The property held by this syndicate consists of five 40-acre leases, which include not only the alluvial ground but the higher country to the west in which tin-bearing lodes are found.

The lease numbers are:—8813-M, 8812-M, 8814-M, 8815-M, and 8837-M, all charted in the name of P. J. O'Connor.

Situated two miles south of the 7-mile peg on the road from Waratah to Corinna the mine is easily accessible. The connecting link is a well-graded pack-track which, providing an easy way of transport in summer, becomes almost impassable for horse traffic during winter.

(2) *The Ore-deposits (Alluvial).*

The tin-bearing alluvial material extends over 15 acres of flat country covered with dense jungle. The clearing of trees and scrub and the removal of the peat covering form the chief obstacles to the successful sluicing of these gravels. It is considered that the beds of gravel, 3 to 5 feet deep, contain 2 to 3 lb. of tin oxide (cassiterite) per yard. Tests were made by sinking holes in all quarters of the flat, and it was found that the ore extended through the "wash" from the peat covering to the bottom, where the richest material occurs. The gravels consist largely of rounded pebbles of quartz, quartz-tourmaline, and granite, varying in size from the finest particles to stones 6 inches in diameter. As a rule the tin ore is of pin-head size, but it occurs also in much finer and coarser grains. Associated with it is a large amount of ilmenite and titanite, which are difficult to separate in streaming. The country is too flat to be favourable for ground sluicing. In order to work the deposits to the best advantage it is proposed to erect a hydraulic elevator, but it is doubtful whether the grade of the material warrants this expenditure of money in the purchase of such plant.

The alluvial deposit is too shallow and too small in extent to attract investors, but there are decided possibilities of finding ore-bodies in the aplite dykes. There is room here for the profitable employment of a small party only at the present time.

(3) *Aplite Dyke.*

The property is wholly occupied by granitic rocks, the disintegration of which has provided the materials of the alluvial deposits. Of these the aplite variety has produced the bulk of the tin ore, and in the body of this rock small rich deposits of cassiterite can be seen. The normal type of granite, almost barren of tin, is a medium-grained rock consisting of quartz, biotite, orthoclase, and plagioclase. Through this a dyke of aplite, 100 to 200 feet wide—one of the several parallel formations—courses in a north-westerly direction at an angle of 45 degrees to the trend of the main mass. Probably this aplite is the northern extension of the dyke penetrating the granite on the Waratah Tin Sluicing Company's property a mile to the south. The rock consists of fine, equidimensional grains of orthoclase, quartz, and muscovite, the orthoclase predominating and the muscovite prominent only near the walls. In places complete disintegration of the rock has been brought about by the kaolinisation of the orthoclase, the soft dyke rock contrasting strongly with the hard, fresh, biotite granite encasing it. Tin ore in the aplite is invariably associated with lepidolite which occurs in short irregular lenses, usually crossing the dyke. The lepidolite occurs as minute green scales, and probably is an alteration product of green tourmaline with which it is frequently associated. Veinlets of cassiterite up to one half-inch thick are of common occurrence; but bulk samples of the ore as a whole are disappointing, and samples of clean aplite contained traces only of tin. Titanite is a common associate of cassiterite and lead sulphate in minute crystals is abundant. This latter mineral has been mistaken for monazite here.

(4) *Developments.*

Exploratory works only have been performed on the aplite ore-bodies. These consist of deep trenches into the soft rock where indications have been favourable. No. 1 trench exposed a body of gossanous material seamed with veinlets of quartz and containing a little brown tin ore. A few chains south of this is No. 2 trench, 5 feet deep and 30 feet long, in soft aplite between hard granite walls. In this trench are exposed two veins of greenish mica, 8 to 12 inches wide, containing 0·25 to 0·5 per cent. tin. Fine and coarse-grained resin-coloured cassiterite is found in the alluvium nearby. Seven chains north of this is No. 3 trench in this dyke rock, which here consists almost wholly of orthoclase felspar and lepidolite (green mica). Fine-grained brown tinstone is studded through this material. A little farther uphill the rock becomes muscovite-bearing and poor in tin. The other trenches have exposed similar formations, none of which contains tin in commercial quantity. The presence of lepidolite may be taken as a sign of the occurrence of tin ore, as these minerals are invariably associated here, and probably as exploration goes on larger and richer bodies of ore will be found in the aplite dykes in this association.

(O)—Palmer's Prospect.

This consists of an alluvial deposit and a tin-bearing greisen formation, and is situated half a mile north-westward of the Wombat Mine. It was discovered many years ago and the alluvial deposit was worked successively by J. Walsh, A. Palmer, and W. Pryde. In these operations over £1000 worth of tin ore was obtained.

This property is not held under lease at the present time.

The deposits occur near the slate contact at a deep embayment in the granite. Protruding through the slate are fairly large bodies of greenish-black diorite porphyrite which is so commonly found as a differentiate fringing the granite mass. Associated with biotite granite are bodies of pegmatite and granitite; a little to the west is an aplite dyke, and on the east side of the valley of Palmer Creek granite porphyry containing molybdenite is found. On the western side of the valley large boulders of quartz-tourmaline containing much cassiterite are strewn over the surface. These are found in association with greisen, but attempts to discover the source of this material have thus far failed. It is evident, however, that they were shed from veins in the granitic rocks nearby. They represent greisenised granite, and consist of opaque and pellucid quartz with black tourmaline and cassiterite, the latter in considerable proportion where tourmaline is not abundant. The cassiterite is of fine grain size, and occurs in intimate association with the quartz.

It is not considered that these deposits will prove of commercial value. Greisen veins although continuous are notoriously erratic in their content of tin.

(1) *Alluvial Deposit.*

In the bed of Palmer Creek a small deposit of tin-bearing alluvial material has been formed from the disintegration of the rocks over which the creek flowed. The creek bed has been worked for tin oxide a distance of 30 chains and to a depth of 2 feet. The "wash" or alluvial material consists of granite waste, quartz-tourmaline, diorite porphyrite, slate and limonite pebbles and sands. Many of the quartz-tourmaline pebbles contain cassiterite, and were derived from the greisen veins to the westward.

Very little alluvial ground remains to be worked in this locality, and the deposit may be considered of no further importance.

(P)—The Cleveland Mine.

(1) *Area, Situation, &c.*

This mine is situated on the western foothill of Magnet Range, half a mile southward from the settlement of Luina, on the banks of the Whyte River. Outside the boundaries of the leases that enclose the Cleveland Mine no important tin-bearing ore-bodies have been found in this area. In its isolation there is a resemblance between it and the Mt. Bischoff occurrence.

This mine is now held under leases 8740-M, of 65 acres, and 8741-M, of 30 acres, by J. Luck and C. Thompson, of Devonport.

These ore-bodies were discovered 25 years ago, and the area was leased at first by S. C. Coundon, of Waratah. The gossan outcrops were considered to be the cappings of silver-lead lodes until the late Harcourt Smith, Government Geologist, on a visit of inspection in 1900, detected tin oxide (cassiterite) in the gossan. Subsequent exploratory work revealed the presence of this mineral in profitable proportion. Many years passed, however, before an attempt was made to exploit the deposits for their content of tin. The first to undertake this work was the Cleveland Tin Mining Co., N.L., formed in 1908. From the beginning this company had been beset with difficulties. The initial expenses of the undertaking were so great that the company was taxed to the limit of its resources before the enterprise had been fairly launched. Under the circumstances it is not surprising to learn that the enterprise failed.

The property is now easily accessible by road and tramway, the land has been cleared of heavy forest, a water-supply has been obtained, and the several ore-bodies have been explored by open-cuts and adits; therefore, the expenses in connection with these works will not be incurred by future operators.

(2) *Access.*

The property is accessible from Waratah by way of Corinna Road to the 8-mile peg. From that point a tramway, 2½ miles long, connects with the mine. Nearly all the heavy machinery was transported to the mine in the early days by way of Luina. This route is not followed now, owing to the difficulty experienced in passing the steep grades and the sharp curves of the road. The cost of transport from Luina to Waratah is 30s. per ton, and by the other route 20s.

(3) *General Features.*

Boundaries of these leases pass over the summit of Crescent Hill, a long spur jutting out from Magnet Range. This hill is largely occupied by Cambro-Ordovician strata, consisting of grey, blue, purple, and red slates and cherts, intercalated with thick beds of tuff and sheets of lava. All of these rocks have suffered alteration by the action of hot ore-bearing solutions, and in places some have been completely transformed into hard resistent quartzites. These stratified rocks have a general north-easterly trend and dip to the north-west at angles varying from 60 to 80 degrees. They have been intruded by dykes of peridotite.

pyroxenite, gabbro, and also by quartz-porphyry and syenite. The basic intrusives are much more prominent, and, like the stratified rocks, have a north-easterly trend. Only very small protrusions of porphyry occur. These have been greatly altered by the metasomatic action of ore-bearing solutions, so much in places that their original nature has been completely masked.

(4) *The Ore-bodies.*

The ore-bodies of this area belong to the replacement-fissure type, and are of two kinds, namely—

(*a*) Pyrrhotite-chalcopyrite;

(*b*) Pyrite-quartz.

The pyrrhotite-chalcopyrite bodies are large irregular replacements of chert and tuff, extending 20 to 30 feet on both sides of fissures. Many of these fissures, which are narrow and irregular, are filled with tin-bearing pyrite and quartz, and it is not unusual to find that oxidation of the vein material extends far below the replacement sulphides. As a rule the fissure filling contains a greater proportion of tin than the replacement bodies, and this material being more amenable to treatment, is usually attacked first.

In order of quantitative importance the mineral constituents of the lodes are pyrrhotite, chalcopyrite, pyrite, quartz, arsenopyrite, and cassiterite. Calcite, which is a prominent constituent of the tuff gangue-rock, is always abundant. The ores are characteristically fine-grained, and because of this fineness microscopic study is necessary in order to determine the textual relations and the association of the minerals. The texture is usually fine-granular; the structure is ill-defined and ramifying, and the shape conforms to the irregular outline of the original calcite of the replaced rock. The intercrystallisation of these minerals clearly indicates a contemporaneous deposition. Inasmuch as these ores are worked as a source of tin chief interest lies in the mode of occurrence of the compounds of that metal. Under the microscope cassiterite in extremely fine grains has been detected in the pyrrhotite ore; but stannite, although proved to be present by analysis, has not been recognised.

The pyrite-quartz ore-bodies are commercially the more important, not only because they contain as a rule a higher proportion of cassiterite, but because this class of ore is more readily oxidised, and the tin oxide it contains is thereby set free from the encasing pyrite. Well-defined crustification, developed by deposition of these minerals on the walls of fissures or in irregular open spaces, is not unusual. They occur also as replacement minerals after felspar-porphyry, also after calcite in tuff, and in some few cases after pyroxenite. In association with these minerals cassiterite is more coarsely crystallised than in the essentially pyrrhotite ore-bodies, and is easily discernible by eye. Quartz is the dominant mineral component of these ore-bodies, followed in order of abundance by pyrite and cassiterite. Fluorspar and tourmaline are sporadic. In some places they constitute 20 per cent. of the lode material, in others these minerals are not common.

The fissures strike in a general north-east direction parallel to the trend lines of the strata in which they occur. They dip, however, in different directions and at various angles. Thus, the easterly group dip to the north-west at angles of 45 to 60 degrees; the westerly group dip to the south-west, and some of the short irregular bodies between them appear to be vertical. On this evidence the converging ore-bodies should meet at depth and form one main ore-channel. Apparently the main body of granite from which the tin-bearing solutions were derived lies at a great depth at this point. It is noticeable that there has been considerable folding and not a little faulting in this area. The strata have been bent into sharp, broken anticlines, the axial trend of which is to the north-east with a pitch to the south-west. The folding is very irregular, owing to the variation in the competency of the chert, tuff, and slate rocks to withstand compressive strain.

(5) *The Effects of Oxidation.*

In the ore-bodies contained in chert, and consisting largely of pyrrhotite and chalcopyrite, the rate of oxidation has been slow, and these minerals occur unaltered within a foot or two of the surface. Near fractures and joints in the partly silicified slate, however, the chalcopyrite and pyrrhotite have suffered alteration, the former into malachite and the latter into limonite.

Oxidation of the pyrite ore-bodies has been much more rapid and extensive. In these pyrite and silica have been deposited contemporaneously, and occur in intimate association. The soft porphyry in which these minerals are sometimes contained is easily decomposed and disintegrated by the action of percolating solutions, and the pyrite rapidly oxidises to sulphate and ultimately to oxide of iron. A considerable proportion of the sulphate is carried away in solution, leaving the associated silica in the form of cellular quartz. On fresh faces of ore sulphate of iron crystals are very common, and where arsenopyrite occurs white arsenious oxide is found. Although bunches of pyrite occur in the present working faces, partial oxidation has taken place below that level.

The oxidation effect of percolating meteoric waters is shown by the following reactions. The initial effect of the action of water on pyrite (iron sulphide) is to convert it into ferrous sulphate and sulphuric acid; thus—

$$FeS_2 + H_2O + 7O = FeSO_4 + H_2SO_4.$$

Ferrous sulphate will further readily oxidise to ferric sulphate—.

$$2FeSO_4 + H_2SO_4 + O = Fe_2(SO_4)_3 + H_2O,$$

or to ferric sulphate and ferric hydroxide—

$$6FeSO_4 + 3O + H_2O = 2Fe_2(SO_4)_3 + Fe_2(OH)_6.$$

The hydrolysis of ferric sulphate may first give a basic ferric sulphate which subsequently breaks down, forming ferric hydroxide and sulphuric acid—

$$2Fe_2(SO_4)_3 + 6H_2O = 2Fe_2O_3 + 3H_2SO_4.$$

(6) *Erosion of the Ore-bodies*

There has been relatively little erosion of the ore-bodies This is due in some measure to the hardness of the cherts and tuffs in which the ores are contained. However, erosion in some places has kept pace with oxidation, as evinced by the occurrence of pyrrhotite-chalcopyrite ore-bodies within a few feet of the surface. For long periods protection had been afforded by the covering of Tertiary sediments and basaltic lava; but no trace of these formations has been found on the property, and since their removal the tuffs, slates, and chert have been reduced at least 200 feet. The occurrence of alluvial material containing cassiterite in the Whyte River valley, west of the mine, and the presence of a considerable amount of tin-bearing wash in the bed of Deep Creek, show that the ores extended far above the outcrops near the summit of the hill. It is interesting to note, however, that only very small outcrops of porphyry are exposed, and that the ore-bodies occur in fan arrangement dipping toward a common centre. These facts suggest that the ore did not extend far above the present level, and that their continuance in depth may be safely anticipated.

(7) *Development.*

The nature, extent, and value of these ore-deposits have been exposed at a number of points on the surface by open-cuts, quarries, and trenches; and underground by means of long adits, winzes, and shafts. The underground works are fairly extensive, and will prove of use in the further development of the lodes. Quarrying and open-cutting methods of excavation have been applied to the large pyrrhotite replacement ore-bodies, and mining methods to the comparatively narrow vein formations. The ore-bodies, it will be observed, are irregular both in their occurrence and their character, hence the apparent lack of system in the design of operations. Mine or quarry openings have been made in the rich ore shoots, leaving untouched the poor and barren sections between them.

The natural conditions are very favourable for economic development by means of adits and open-cuts. As the workings gain cover the adit system only should be employed. In fact, it is doubtful whether the open-cut method is preferable under any conditions, for the extensive bodies of ore consist largely of pyrrhotite—a difficult ore to treat—and the vein fillings are as a rule richer in tin and are pyritic. After very close observation it is considered advisable to confine attention in future to the comparatively narrow lodes in which pyrite predominates over pyrrhotite. The main object to keep in view is the exploitation of the lodes to the best advantage to the company, and not necessarily to produce a large quantity of material in order to show a low working cost per ton of crude ore. Successful mining depends upon the excavation of as little waste material with the ore as it is possible under suitable working conditions.

No. 3 or Mill Workings.—This lode was discovered shortly after the milling plant had been erected. It passes underneath the mill in a south-westerly direction, and extends unbroken 200 feet to the north-east. It has been opened by means of two adits and a winze, and has been stoped to surface. The adits are 110 and 160 feet in length, and are 20 feet apart. According to reports received, the material removed from these workings contained tin in the proportion of 4 per cent. In the north end of the lower workings the ore-body is 3 feet wide, and consists of partly replaced white and grey slates, with a white slate footwall and blue slate hanging-wall. The original pyritic lode matter now consists of limonite associated with cellular quartz, dark-green tourmaline, and fluorspar. The tourmaline is more abundant on the hanging-wall side and fluorspar in the centre of the lode. This tourmaline has been formed by the action of boron-bearing solutions on slate. Malachite occurs on the walls and in cracks, and chalcopyrite is commonly found as blebs and veinlets. It is reported that a 60-feet winze, sunk from the floor of these workings, exposed ore containing 6 per cent tin.

Sample No. 25, from the end of drive, contained 1·59 per cent. tin.

Sample No. 4, from the same drive, contained 1·74 per cent. tin.

Sample No. 3 was taken from the Smithy lode, and contained 1·84 per cent. tin.

No. 2 *Workings.*—Close to this lode are two parallel formations of similar nature which have been opened by adits and open-cuts. From the entrance to these workings to a point 12 feet from the end the adit has been cut through chert. There it gives place to tuffs heavily charged with pyrite and pyrrhotite, especially the latter. In the end of the north-east drive the tuff is seamed with quartz dipping at 40 degrees to the north-west.

Sample No. 2, consisting of 12 feet of mineralised tuff at the end of the crosscut, contained 1·06 per cent. tin.

No. 1 *Workings.*—This consists of a small open-cut into the hillside. The ore-body is indicated here by the presence of pyrite, pyrrhotite, arsenopyrite, and chalcopyrite, which occur as disseminations and as reticulating veinlets in altered slate.

No. 4 *Workings.*—This is a short drive on the Smithy lode, which is poor at this point. The lode at the outcrop near the Smithy is 5 to 6 feet wide, but it appears irregular and bunchy. Here the ore consists of cellular quartz filled and lined with pyrite and other minerals. Pyrite is the dominant sulphide, but arsenopyrite and chalcopyrite are not uncommon associates. Pyrrhotite is conspicuously subordinate. In places the lode material consists largely of pellucid, pink, green, and purple fluorspar, but quartz is the more common gangue rock. Fine acicular crystals of green tourmaline and the massive variety are prominent. In the cavernous quartz clusters of perfectly crystallised grey cassiterite (tin oxide) of pin-head size are very common.

Sample No. 5 represents the value of the material in the adit.

Sample 5 contained 0·81 per cent. tin.

The country-rock here is folded and faulted, and the richer ore-bodies—the fillings of irregular fractures—appear to peter out at a shallow depth. It must be remembered that the fissures represent the true lode channels, and that the disseminated ores are replacements of the wall-rocks. Care should be exercised in the location of the true lode channel, for this is the medium through which the ore-bearing solutions found access. In places the dip of the lode changes to a very flat angle following the line of junction between the two dissimilar formations, chert and tuff. This has given rise to the belief that they do not persist in depth.

No. 11 *or Main Open-cut Workings.*—The ore-bodies already described extend in a north-easterly direction half a mile. They have not been proved to continue unbroken, but rich bodies occur along the course at intervals. One of these occurs 600 feet from, and 250 feet higher than, the Mill Workings. It has been exposed in an open-cut 220 feet long, 20 feet wide, and 30 feet deep, from which a large quantity of ore has been taken. The ore consists of silicified and mineralised grey slates and cherts, overlain by a soft grey slate hanging-wall, dipping 80 degrees to the north-west. A band of unaltered grey slate occupies the centre of the ore-body. The replacement portion of the ore-body consists of pyrrhotite and chalcopyrite, with also a little quartz and arsenopyrite. The quartz is frequently found with idiomorphic outlines in the pyrrhotite ore, which is extremely hard and dense. Pyrite is usually found filling joints or associated with the quartz-rich ore in fissures. The saccharoidal quartz and pyrite fillings of the two fissures that traverse this ore-body contain in association much coarsely crystallised tin oxide.

Sample No. 16 represents the quality of a 4-feet band of pyritic material on the footwall of the ore-body, and sample No. 17 a 6-feet body on the hanging-wall side.

No. 16 contained 1·44 per cent. tin.

No. 17 contained 1·87 per cent. tin.

Samples of the pyrrhotite ore from this ore-body were not as rich.

No. 13 contained 0·43 per cent. tin.
No. 12 contained 0·23 per cent. tin.

No. 12 Workings.—This is a small open-cut on the eastern side of the same lode channel, about 250 feet farther to the north-east. The ore here is essentially similar to that exposed in the main open-cut, and is extremely hard. It consists of a dense pyrrhotite-chalcopyrite replacement of chert. No fissures were observed.

Sample No. 14 contained 1·28 per cent. tin.

No. 13 Workings.—Two hundred feet due north of No. 12 Workings is an open-cut on the main ore-body. The cutting is 150 feet long, 40 feet wide, and 60 feet deep. Passing along the sides are two lode channels containing ore of more than average quality. Specimens of the ore were obtained showing fine-grained crystallised cassiterite (tin oxide) implanted on crystals of quartz and filling interstices in the quartz matrix. Associated minerals are pyrite, fluorspar, and gilbertite, likewise of later formation than the quartz. Arsenopyrite and pyrrhotite are prominent replacement minerals outside the lode channels. Between the fissures is a large mass of unreplaced chert and slate. In the pyrite-quartz lodes a considerable amount of tin oxide can be detected by eye. These bands unfortunately do not continue unbroken for any considerable distance. Their richness has been recognised by the operators, who have persistently followed them in preference to the pyrrhotite bodies.

Sample 18 represents the quality of the 6-feet lode on the hanging-wall side of the open-cut; Sample 21 was taken from two bands of soft pyritised material 3 feet wide; Sample 22 indicates the tin content of a 3-feet band of pyrite-quartz lode matter on the south side of the cut.

Sample 18 contained 1·59 per cent. tin.
Sample 21 contained 1·31 per cent. tin.
Sample 22 contained 0·67 per cent. tin.

Mining methods should be employed instead of open-cutting, because the vein-fillings only contain tin in profitable amounts.

Traces of this ore-body have been found in tin-bearing arsenopyrite veins and in tin-bearing detritus several hundred feet farther on. No exploratory works have been performed to test their value.

No. 10 *Workings*.—The ore-bodies exposed in these workings are probably the most important on the property. Like the eastern group already described, they have a general north-easterly trend, and follow the ridge of Crescent Hill; but, unlike them, these dip to the south-east. They occur over a width of 50 feet, and consist of the fillings of two fissures and the partial replacement of the intervening tuff and chert. The ore consists almost wholly of limonite and quartz, the former largely derived from pyrite by oxidation. Tourmaline is abundant and in places forms a considerable part of the gangue rock.

The ore-body was sampled in 10-feet sections over the full width.

Sample 1 consisted of gossanous chert and tuff with black tourmaline; Sample 6 was of similar material; Sample 7 consisted of gossanous quartz in decomposed tuff and chert; Sample 8 contained disseminated blebs of finely crystallised zinc blende associated with cubic pyrite and fine particles of chalcopyrite in a chert and tuff matrix; Samples 9 and 10 were taken from the end of the main drive; Sample 11 from the north crosscut.

Sample 1 contained 0·35 per cent. tin.
Sample 6 contained 1·80 per cent. tin.
Sample 7 contained 0·88 per cent. tin.
Sample 8 contained 0·45 per cent. tin.
Sample 9 contained 0·43 per cent. tin.
Sample 10 contained 0·28 per cent. tin.
Sample 11 contained 0·38 per cent. tin.

No. 16 *Workings*.—The same ore-body has been exposed in an adit and a winze about 200 feet to the south-west. In the adit a 12-feet body of gossanous material has been driven on a distance of 90 feet. Its value at the end of the adit is indicated by the following analysis:—

Sample 15 contained 1·08 per cent. tin.

In the winze workings, 30 feet lower, the ore-body has been further explored by driving 200 feet along its course. Here the ore, which is essentially similar to that in the upper level, is not of average grade.

Sample 19, from the north end, contained 0·73 per cent. tin; and Sample 20, from the south end, contained 0·35 per cent. tin.

A winze underlying to the south-east connects this level with No. 8 workings. This part of the workings was not accessible owing to the collapse of the roof. It is reported that some of the richest ore in the mine was taken from this section of the lode. A considerable amount of ore has been stoped in the northern part of the No. 8 workings.

Workings 6, 7, 9, *and* 15 expose small irregular ore-bodies of no great importance, according to surface indications.

Sample No. 23, taken from No. 6 workings, contained 0·10 per cent. tin.

Sample No. 24, taken from No. 7 workings, contained 0·18 per cent. tin.

The line of the western group of ore-bodies has been intersected 600 feet to the north-east by the Khaki Company's workings. A little tin was found, but no defined lode channel exists.

(8) *Milling and Concentration.*

([23]) In 1908 a 10-head battery of stamps and concentrating machinery was erected by the Mt. Clevelend Tin Mining Co. to treat high-grade non-pyritic ore. As mine development progressed it was found that the material consisted of a mixture of gossan and sulphide ores, and that it contained tin oxide in the proportion of 1 per cent. only. Ore of such low grade and complex nature is difficult to treat in a plant except one specially designed for that particular class of material, therefore good results could not be expected of the original plant. Careful sampling and testing showed that the loss of tin oxide in the process of concentration was excessive, and that operations under such conditions could not be conducted at a profit to the company. The necessary alterations to the plant were made, and better results were obtained.

The following is a brief description of the process:—

* The ore is conveyed from mine bins in half-ton buckets along an aerial ropeway, self-dumping over a grizzly to the stone-crusher floor. The original plant did not include a rock-breaker, the large lumps of ore being spalled to a

([23]) Herman, H.: Australian Tin Lodes and Tin Mills, Trans. Aus. Inst. Min. Engrs., Vol. 14, 1914.

* NOTE.—Part of the plant was recently destroyed by fire, and part has suffered from rust and decay.

size suitable for feeding to the stamps. The expenditure incurred in breaking the ore and feeding the battery by hand amounted to half the cost of milling and concentration. Wire battery screens of 25-mesh (linear) were used in the mill, and the concentrating plant, besides hydraulic classifiers and spitzkasten, included two Card tables, one Wilfley, and four slime tables of the rotary type, 16 feet in diameter—two with a surface slope of 9/16 inch per foot, two with a slope of 1 inch per foot.

The following sizing tests of the feed and tailing indicate the efficiency of the plant at this stage:—

* *Gossan Ore Crushed to Pass Through* 25-*mesh Screen.*

Feed.

	Proportion of Battery Pulp.	Free Tin Oxide.		Occluded Tin Oxide.		Free and Occluded Tin Oxide.	
		Estimated as Metallic Tin.		Estimated as Metallic Tin.		Estimated as Metallic Tin.	
		(a)	(b)	(a)	(b)	(a)	(b)
Bulk.	100	1·02	67·33	0·49	32·67	1·51	100
+ 30	1·0	Trace	...	0·82	0·54	0·82	0·54
+ 40	6·3	0·01	0·42	0·90	3·08	1·00	3·50
+ 60	11·2	0·03	2·22	0·88	6·51	1·18	8·73
+ 80	9·6	0·88	5·61	0·93	5·90	1·81	11·51
+ 100	2·9	1·58	3·02	0·57	1·09	2·15	4·11
+ 150	7·8	2·28	11·74	0·45	2·32	2·73	14·06
− 150	60·5	1·11	44·33	0·34	13·48	1·45	57·81
	99·3	...	67·34	...	32·92	...	100·26

Columns (*a*) show the proportions of tin (free, combined, and occluded or total) in the various-sized products ; columns (*b*) the proportion of the total tin in the ore that each sized product contains.

* Probably part of the occluded tin occurs in combination with sulphur in the pyritic ore.

Tailing.

	Proportion of Tailing.	Free Tin.		Combined and Occluded Tin.		Total Tin.	
		(a)	(b)	(a)	(b)	(a)	(b)
Bulk.	100	0·1	25·0	0·3	75·0	0·4	100
30	1·35	Nil	..	0·693	2·34	0·693	2·34
40	5·10	,,	...	0·784	10·00	0·784	10·00
60	10·10	,,	...	0·812	20·50	0·812	20·50
80	8·75	,,	...	0·735	16·08	0·735	16·08
100	3·70	,,	...	0·507	4·69	0·507	4·69
150	5·40	trace	...	0·285	3·85	0·285	3·85
150	65·60	0·154	25·25	0·094	15·50	0·248	40·75
	100·00	...	25·25	..	72·96	...	98·21

At this stage, as the ore delivered to the mill was becoming very sulphidic, it was decided to erect a small roasting furnace. A single-hearth furnace with two Leggo mechanical rabbles was built. The capacity of this furnace was 5 tons per week of concentrate containing 7 per cent. of sulphur. Alterations and improvements brought the capacity to 18 tons per week (of seven days). The sulphur contents having meanwhile increased to 30 per cent., reduced the capacity to 15 tons per week, the sulphur content of the concentrate being reduced to 0·1 per cent. The roasted ore was re-treated on the Wilfley table, and a recovery of 93 per cent. was obtained.

On referring to the sizing test of the tailing, the losses are found in the coarser sizes to be wholly combined or occluded tin, and the slimes to be principally free tin. This pointed to the necessity of grinding finer and adding more efficient slime-saving appliances. Accordingly, a Bigelow positive pan, Callow revolving screen, two Card tables, and a double-belt vanner were erected. The addition of this machinery reduced the tailing loss from 0·4 per cent. to 0·13 per cent. tin (by vanning assay). The battery screens were changed from 25 to 8 mesh, the pulp went direct to the Callow screen (50-mesh), screen undersizes to hydraulic classifiers, oversize to the grinding pan, and from the pan back to the screen; all the ore being finally ground to pass 50-mesh.

The heading from the Card and rotary tables contained 12 per cent. tin, 30 per cent. sulphur, and from 8 to 9 per cent. copper, the last derived from the chalcopyrite-pyrrhotite ore-bodies. After treating the roasted ore the concentrate contained from 0·1 to 0·4 per cent. copper.

Power was supplied by Pelton wheels working under a head of 290 feet, and employed as follows:—

One 4-feet diameter, with $1\frac{1}{4}$-inch tip, driving the battery, pan, screen, elevator, and breaker.

One 3-feet diameter, with half-inch tip, driving tables, calciner, and vanner.

One 2-feet diameter, with half-inch tip, driving generator for lighting.

The water for these Pelton wheels was conveyed in a line of pipes, 800 feet long and 13 inches in diameter, from a race connecting with Deep Creek. In summer the water-supply was too small to be of use for power purposes, and an auxiliary steam plant was employed instead.

Very little of the existing plant is of any use now, the ironwork having been seriously damaged by fumes from the calcining plant.

A better site for the milling and concentrating plant could be found on the western fall of the hill.

(9) *Production.*

The period of active production of tin ore from this mine extended from 1908 to 1917. The mine was operated by the company until 1914, when it was let on tribute to different parties for each succeeding year until 1917. Although the collapse of the tin market directly brought about the cessation of operations, the erratic nature of the ore-bodies and the inefficient methods employed in the transport and treatment of the ore contributed largely to the failure of the company.

The results of the analysis of the samples taken during this investigation clearly indicate that, as a rule, the pyrrhotite replacement ore-bodies are unprofitable, and that attention in future should be directed to the pyrite-quartz lodes.

Details of production are given hereunder:—

Year.	Crude Ore Milled. (Tons.)	Tin Oxide Recovered.				Tin Oxide Recovered from Crude Ore Milled.	Value of Crude Ore per Ton.			Net Value of Output.		
		Tons.	Cwt.	Qrs.	Lbs.	Per Cent.	£	s.	d.	£	s.	d.
1909	4500	36	0	0	0	0·8	0	14	5	3278	14	7
1910	8757	75	6	0	21	0·86	0	13	8	5985	16	3
1911	6976	58	7	2	1	0·836	0	15	11	5574	4	4
1912	5848	56	6	2	22	0·963	1	0	5	5965	14	7
1913	5245	44	2	0	27	0·84	1	1	7	5675	14	9
1914	4140	25	10	1	12	0·616	0	13	4	2758	6	3
1915	845	10	18	2	7	1·29	0	18	8	789	10	6
1916	...	20	10	1	24	...	...			1990	10	6
1917	...	16	12	1	7	...	...			1794	0	6
	Total output	343	14	1	9	...	Valued at...			£33,812	12	3

It has been estimated that 45 per cent. of the tin content of the crude ore was lost in treatment. Although the loss was undoubtedly heavy, this estimate was not based on reliable data, and, consequently, cannot be accepted as even an approximation.

(10) *Ore Reserve.*

Insufficient data are available upon which the quantity and value of the reserve of ore can be estimated. Development has not been kept ahead of mining, and therefore, according to the recognised rules, there is no reserve, despite the fact that profitable ore occurs in many of the workings. On the resumption of operations all expenditure at the beginning should be applied to exploration underground, in order that a large reserve may be established. If it is found that the ore is not of profitable value, the mine may then be abandoned at any stage of development without incurring undue loss. Except under unusual circumstances mining development should always precede surface expenditure.

(11) *The Future of the Mine.*

At the present market rate for tin the free-milling oxidised ore opened up in Nos. 10, 8, and 16 workings could be worked at a profit to the operators. These resources should be tapped while development works are in progress in other parts of the mine. Based on the information obtained during this investigation it may be stated that the geological conditions are decidedly favourable, and that the prospects for the future success of the enterprise are much better now than they were when the Mt. Cleveland Company was operating the mine. An adequate working capital is the first essential to success, but a large outlay will not be necessary in plant. At the present stage of development the mine cannot be regarded as a large one. This fact should be borne in mind when consideration is being given to the design of future operations.

Outside the boundaries of the Cleveland properties a considerable amount of exploratory work has been performed by some of the early companies operating in this area. Some of these works are the Crescent, Khaki, Coundon's, and Behr's adits, all of which crosscut the strata, but none of which has been productive. The Cleveland ore-bodies gradually peter out to the north-east, but tin ore has been obtained beyond Coundon's high on the hillside. This most likely was shed from a replacement-fissure lode near the crown of the hill. None of these workings has penetrated so far.

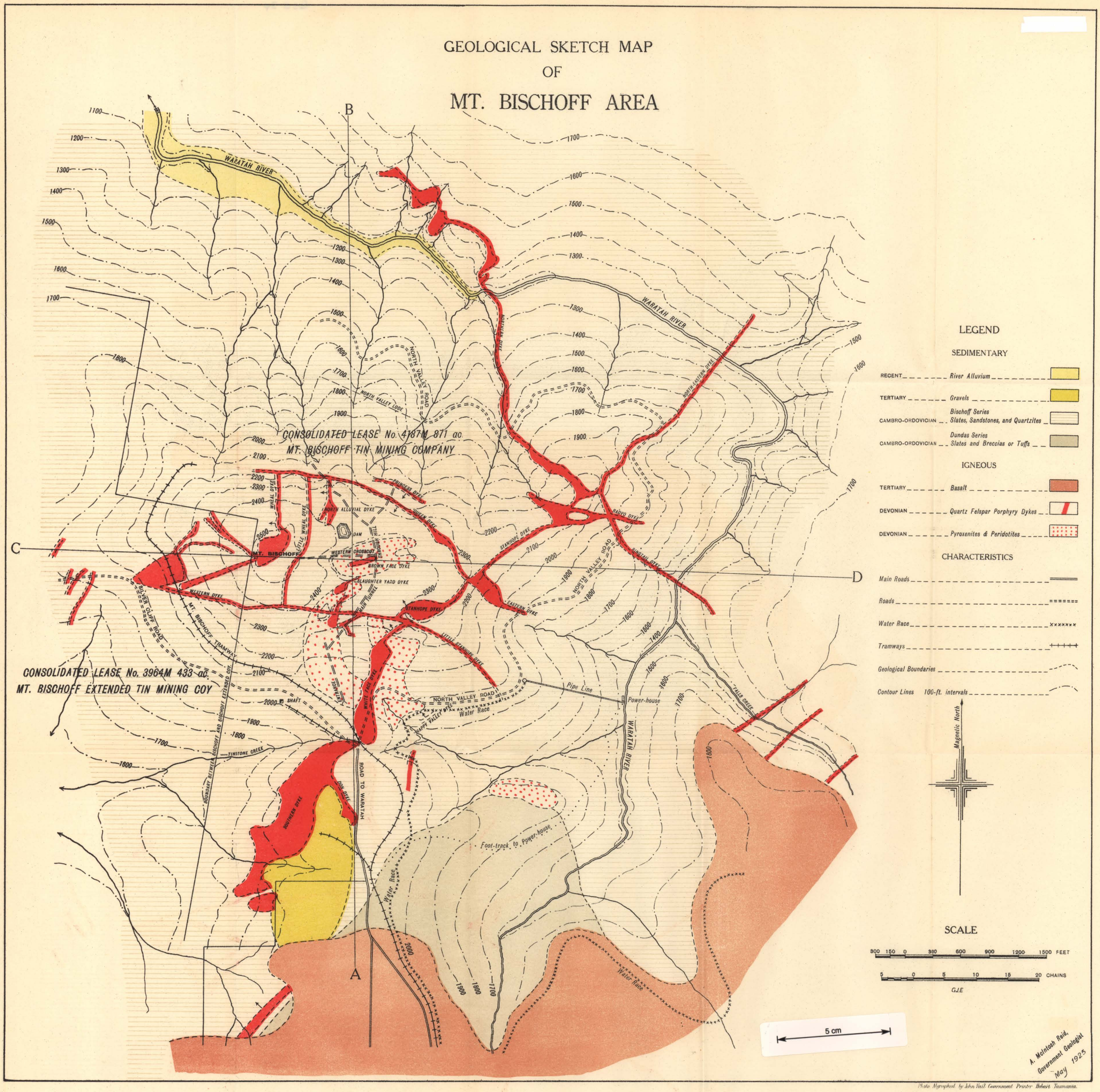
(Q) Whyte River Tin Mine.

About half a mile along Godkin track from the settlement of Luina a deposit of tin-bearing alluvial material occurs on the left bank of Whyte River. Here the river flows through a broad valley, and has now entrenched itself in its old bed. Its present channel follows closely the base of Crescent Hill, toward which the tin-bearing gravels and clays have been deposited. On the other side of the river the gravels are unproductive, and the rich ground on the east side is not very extensive, although traces of cassiterite (tin oxide) have been found as far as the Gregory Mine. A number of holes in the old river-bed expose 4 to 8 feet of gravel resting upon decomposed serpentine. The gravels, ranging in size from fine sand to water-worn pebbles 6 inches in diameter, are composed largely of chert, with also quartz, gabbro, tuff, and occasional pebbles of quartz-porphyry. In this "wash" cassiterite is found in grains of all sizes up to pieces nearly 1 inch in diameter, but the bulk of this material is of pin-head size. It is estimated on the basis of the tests made that these gravels contain cassiterite at the rate of nearly two pounds per cubic yard over an area of 10 acres. At the foot of Crescent Hill, and a little to the east of the alluvial deposits, is a large body of tin-bearing clay, evidently derived from the decomposition of underlying basic rocks. Skirting the hill are protruding dykes of basic character, varying from gabbro to serpentine. These rocks have been attacked by mineralising solutions and completely altered. The tin ore in them is not alluvial; it is part of a replacement ore-body. In places there is 10 feet of this clayey material, resting upon altered serpentine, and up the hillside as much as 14 feet and more occurs. The included stones are angular, not water-worn, and the cassiterite or tinstone is crystalline, with the angles only slightly smoothed, and adhering often to sharp vein-quartz. Several large lumps of lode-quartz, rich in tin, have been found, but no tin ore has been observed in any of the numerous quartz veins that traverse the rock.

This ore-body was worked originally by the Whyte River Tin Mining Co. about 1897, and since then several parties have continued the operations in a desultory way without success. The tin-bearing material has been shed from a dolomitised pyroxenite ore-body on the east side of the dyke at the foot of the hill. The clayey gangue represents the ultimate decomposition product of the original pyroxenite or serpentine. Nearby a narrow dyke of porphyry occurs; this rock, evidently, was the source of the tin-bearing solutions, and probably it will be found to contain tin as well as the altered basic rock of the ore-body. It projects in two small masses only, and may be easily overlooked.

Both the old river-bed deposits and the tin-bearing clayey material have been shed from the one ore-body, which is worthy of careful investigation, and should not be difficult to locate.

A. McINTOSH REID, Government Geologist.



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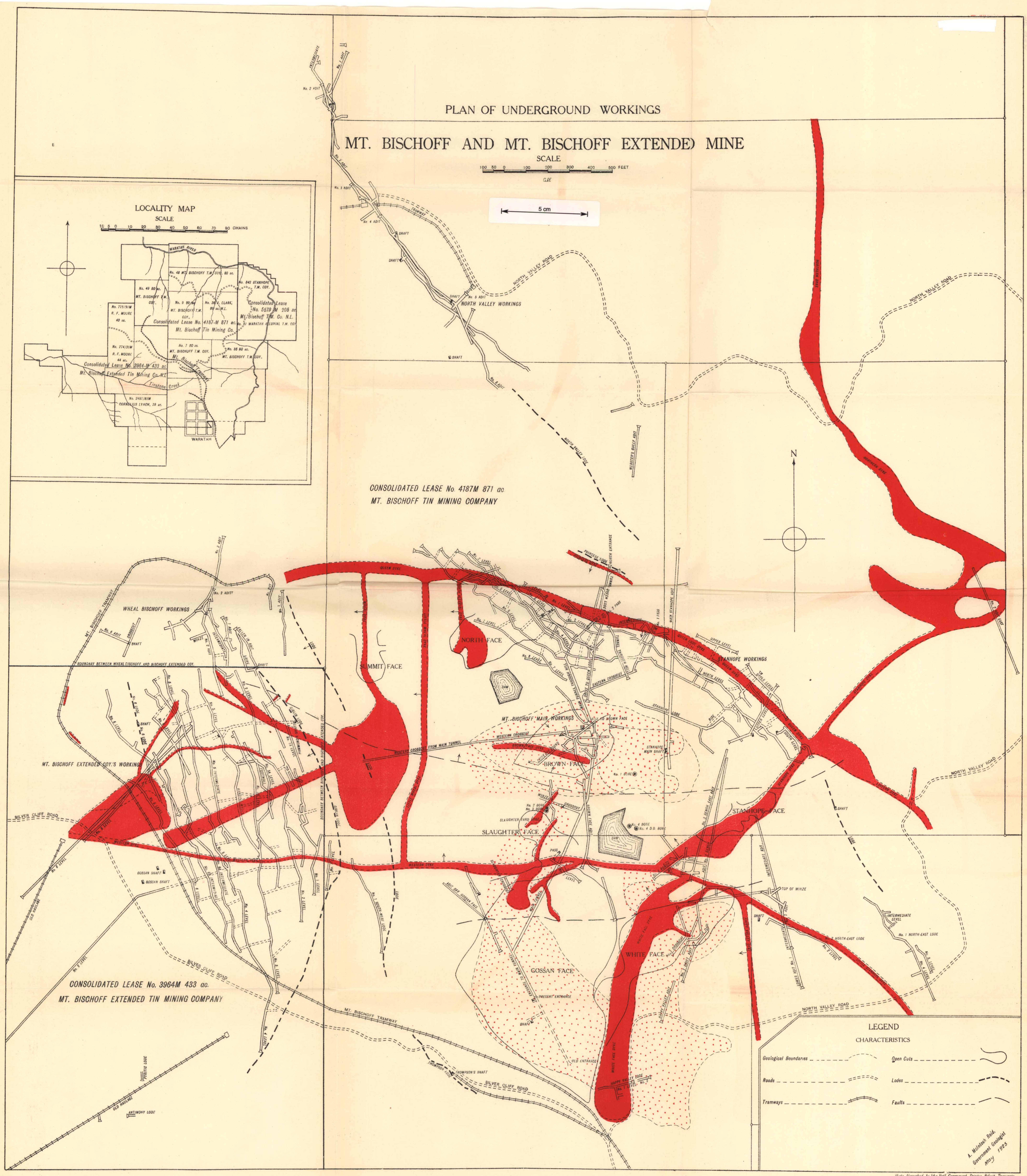
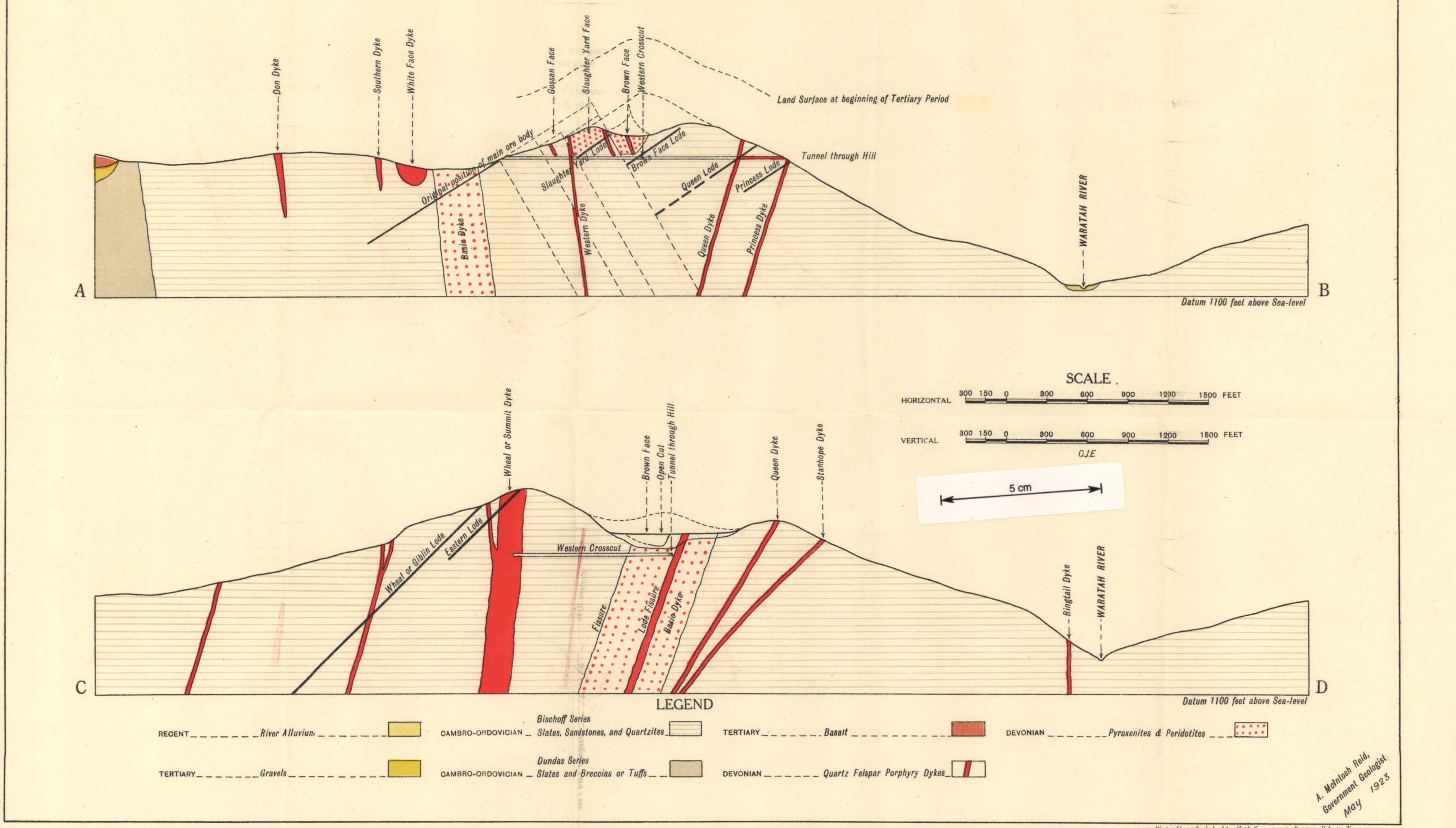


PLAN OF UNDERGROUND WORKINGS
MT. BISCHOFF AND MT. BISCHOFF EXTENDED MINE
SCALE
100 50 0 100 200 300 400 500 FEET
5 cm
LOCALITY MAP
SCALE
10 5 0 10 20 30 40 50 60 70 80 CHAINS
WARATAH RIVER
Consolidated Lease No. 4187-M 871 ac.
Mt. Bischoff Tin Mining Co.
Consolidated Lease No. 5579 M 205 ac.
Mt. Bischoff T.M. Co. N.L.
Consolidated Lease No. 3964-M 433 ac.
Mt. Bischoff Extended Tin Mining Co. N.L.
Tinstone Creek
WARATAH
NORTH VALLEY WORKINGS
NORTH VALLEY ROAD
CONSOLIDATED LEASE No. 4187M 871 ac
MT. BISCHOFF TIN MINING COMPANY
N
WHEAL BISCHOFF WORKINGS
BOUNDARY BETWEEN WHEAL BISCHOFF AND BISCHOFF EXTENDED COY.
NORTH FACE
SUMMIT FACE
STANHOPE WORKINGS
MT. BISCHOFF MAIN WORKINGS
MT. BISCHOFF EXTENDED COY.'S WORKINGS
SILVER CLIFF ROAD
BROWN FACE
SLAUGHTER FACE
STANHOPE FACE
WESTERN CROSSCUT FROM MAIN TUNNEL
WHITE FACE
GOSSAN FACE
CONSOLIDATED LEASE No. 3964M 433 ac.
MT. BISCHOFF EXTENDED TIN MINING COMPANY
MT. BISCHOFF TRAMWAY
THOMPSON'S SHAFT
LEGEND
CHARACTERISTICS
Geological Boundaries
Open Cuts
Roads
Lodes
Tramways
Faults
A. McIntosh Reid.
Government Geologist
May 1923

GEOLOGICAL SKETCH SECTIONS
OF
MT. BISCHOFF AREA



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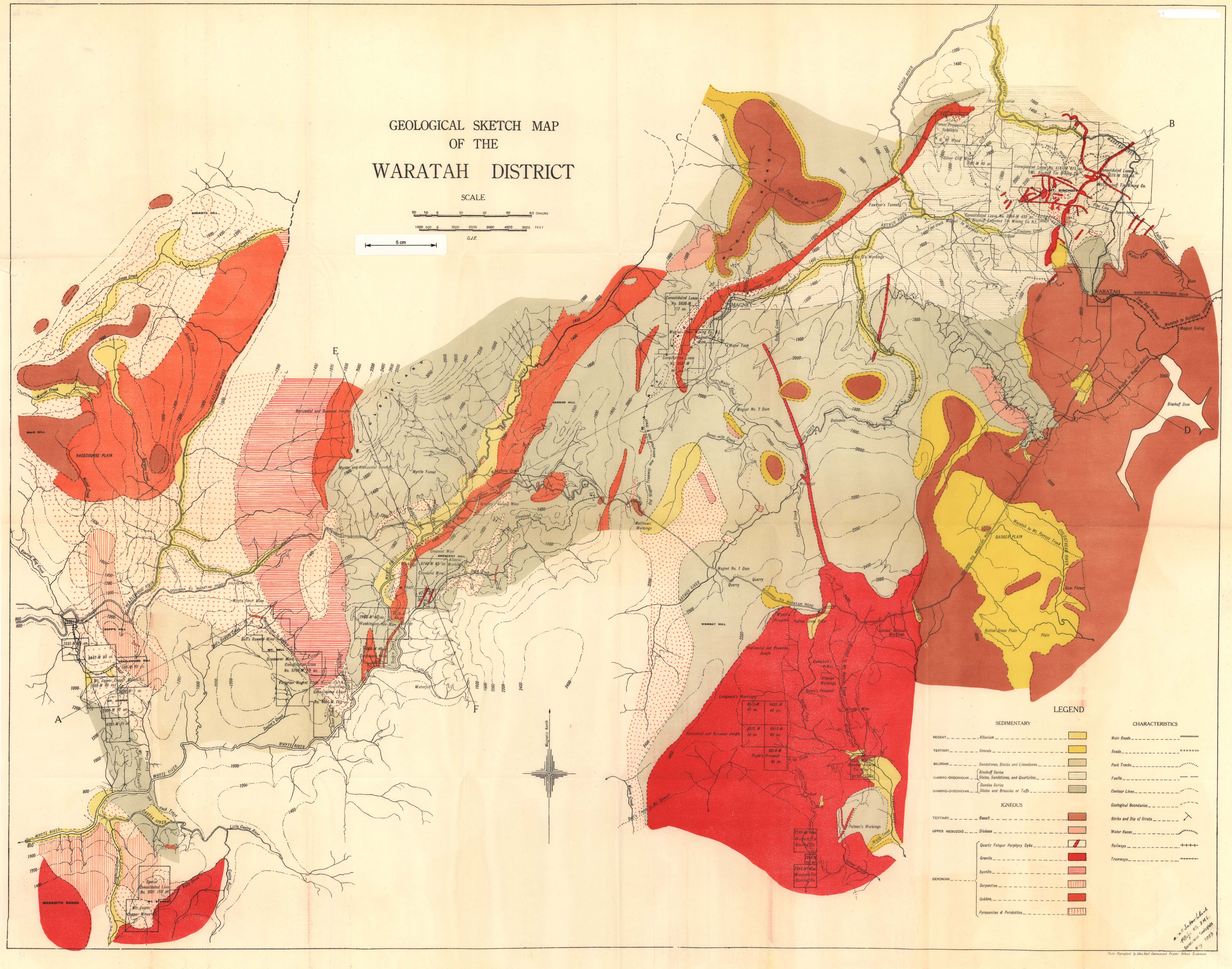

GEOLOGICAL SKETCH MAP
OF THE
WARATAH DISTRICT
SCALE
CHAINS
FEET
5 cm
LEGEND
SEDIMENTARY
RECENT — Alluvium
TERTIARY — Gravels
SILURIAN — Sandstones, Shales and Limestones
CAMBRO-ORDOVICIAN — Bischoff Series Slates, Sandstones, and Quartzites
CAMBRO-ORDOVICIAN — Dundas Series Slates and Breccias or Tuffs
IGNEOUS
TERTIARY — Basalt
UPPER MESOZOIC — Diabase
DEVONIAN — Quartz Felspar Porphyry Dyke
Granite
Syenite
Serpentine
Gabbro
Pyroxenites & Peridotites
CHARACTERISTICS
Main Roads
Roads
Pack Tracks
Faults
Contour Lines
Geological Boundaries
Strike and Dip of Strata
Water Races
Railways
Tramways
WARATAH
MAGNET
MT. BISCHOFF
BADGER PLAIN
RACECOURSE PLAIN
BALD HILL
MEREDITH RANGE
WOMBAT HILL
ARTHUR RIVER
WHYTE RIVER
Magnetic North
Government Geologists
1923
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