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The North Pieman and Huskisson and Sterling Valley Mining Fields

BY

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[*Frontispiece.*

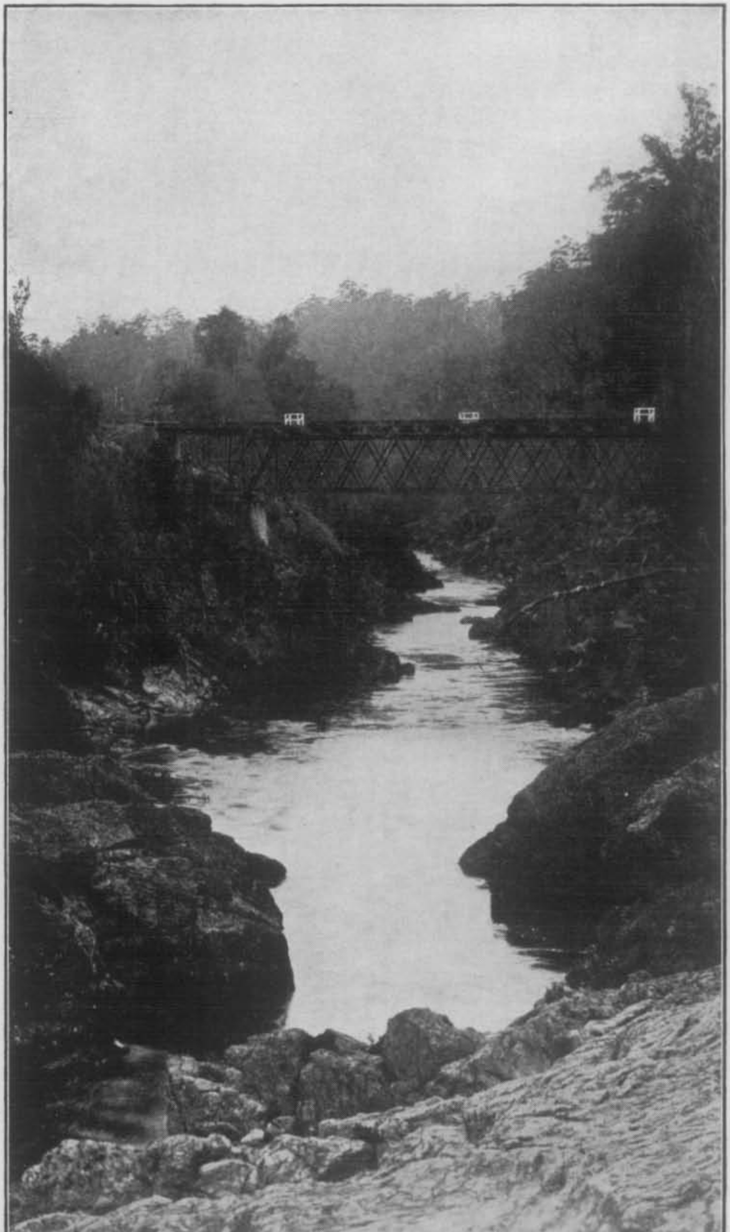

Photo. 1.—PIEMAN RIVER GORGE. [*H. W. Judd Photo.*

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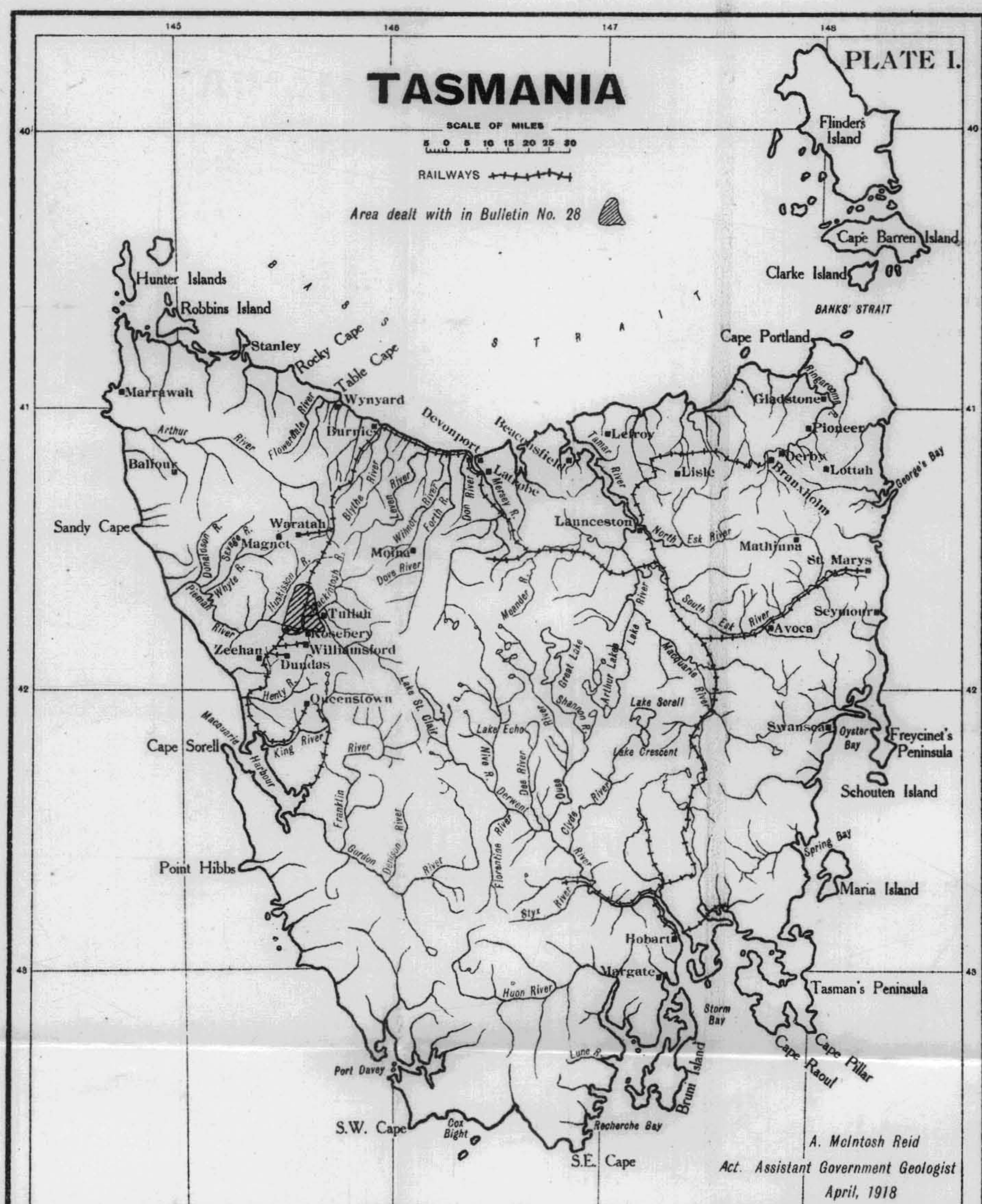

LOCALITY MAP

Photo-lithographed by John Vail, Government Printer, Hobart, Tasmania.

The North Pieman and Huskisson District.

I.—INTRODUCTION.

(1)—Preliminary Statement.

During the past few years the portion of the North Pieman country on the Read-Rosebery mineral belt has been attracting considerable attention, more especially at and in the vicinity of the Chester and Pinnacles Mines. The very large pyritic deposits of the Chester Mine, which a few years ago were considered of no economic value, have been developed and exploited for the recovery of the pyrites content to supply material for the sulphuric acid works of the Mount Lyell Company at Yarraville. The Pinnacles Mines have also received attention at different times during the past 20 years. Prospectors and mining syndicates have been operating there almost continuously since the discovery of the deposits, and have done much to develop these zinc-lead and copper lodes. In later years these mines have attracted the attention of investors following the development of the very large Read-Rosebery zinc-lead deposits, but chiefly on account of the reported successful direct treatment by electrolytic* methods of the complex ores of that district, and the consequent enhanced value placed upon those mines.

In view of these facts, the writer was instructed by the Department to examine the North Pieman country, and prepare plans and reports of that district. Advantage was taken of the occasion of this visit to examine also the Sterling Valley country, 5 miles south of Tullah.

(2)—General Statement.

The work outlined in this report was carried out during the period extending from the 17th November, 1917, to the 17th January, 1918, and is the continuation of that completed during the summer of 1914 in the adjacent area to the south (the Read-Rosebery district) by Mr. Loftus Hills [1]. The geological map accompanying this

(1) Geological Survey of Tasmania, Bulletin No 23.

bulletin includes the major portion of four mineral charts, viz., the Murchison, Mount Farrell, North Dundas, and the North Pieman and Huskisson. The main object of this arrangement is to present further information concerning the distribution of the various formations, and also to include on the one map the small isolated area in the vicinity of the Sterling Valley Mine, described also in this report. This work was carried out with the aid of the mineral charts of the districts, drawn to a scale of 20 chains to one inch. The topographic features are shown more accurately on those parts occupied by mineral leases; the location of the more prominent features beyond the surveyed area was determined by prismatic compass and chain, and may be taken as substantially correct. Some difficulty was experienced in the location of the Silver Falls Mine, the sections of which are charted as being $2\frac{1}{2}$ miles due west of the Pinnacles, whereas the more correct position is $2\frac{1}{2}$ miles distant on a course 15° west of north. The lack of complete field maps of this mountainous region, the almost impenetrable growth of horizontal and bauera scrub covering the western section, and the comparative inaccessibility owing to the condition of disrepair of the few foot-tracks traversing the district, made it impracticable to carry out in detail a complete geological survey of such an extensive tract of country in the short space of time allotted for the work; therefore the most westerly portion, near the Huskisson River, not having received the attention required, will not be discussed in this report.

The study of details was confined chiefly to those areas where lodes are located or where mining development is being carried on. There are very few places where good stratigraphical sections are exposed. The cuttings of the Emu Bay Railway present opportunities for geological examination not obtainable under natural conditions; but the general course of the railway line, and also that of nearly all the creeks, is meridional, the approximate trend of the strata, and therefore only a short cross-section is available here for examination. The surface of the land is covered either with a clayey soil supporting dense forest growth, or with peaty soil upon which only button-grass and allied plant life can subsist, and outcrops of strata are few.

In some cases the names of creeks and mountains have been altered. This practice is apt to lead to confusion, and so has been discountenanced in this report, the original nomenclature in all cases having been retained. In the uncharted areas some streams of considerable size—tributaries of the Huskisson River—have been named by the writer after the early explorers of these districts.

The mileage pegs along the Emu Bay Railway, which formerly were marked from Guildford Junction, have been recently adjusted to commence from Burnie; accordingly these alterations are recorded on the geological map.

The heights above sea-level have been calculated from aneroid readings based on the level of the contour pegs at the Chester Mine.

For the purpose of reference the old numbers of forfeited mineral leases have been retained in this report, and appear on the geological map.

(3)—Acknowledgments.

The writer desires to express his appreciation of the courtesy and hospitality extended to him by many residents of the district during his two months' visit. The assistance rendered by Messrs. J. H. Astell, A. Midson, J. Fulford, A. E. Bruce, S. Smith, D. Snowdon, F. Grubb, and P. Waller greatly accelerated the work of the investigation.

The writer wishes also to gratefully acknowledge his indebtedness to Messrs. Basil Sawyer, G. Barker, L. Williams, A. C. Gordon, A. Goldstraw, and A. D. Sligo for much valuable information received.

The writer was accompanied on this expedition by Mr. Edward Higgins as field-assistant. It is a pleasure to acknowledge and to place on record the splendid and efficient services rendered by him.

(4)—Location and Area.

The district to which this report relates is in the south-eastern corner of the County of Russell, north of and adjoining the district of Rosebery, between the Huskisson and Murchison Rivers. The major portion of this area lies on the north side of the River Pieman. The nearest settlements are Tullah, 6 miles to the eastward, and Rosebery, 7 miles southward. The main centre of population is Zeehan, 28 miles by rail to the south-west; the seaport of Burnie is 63 miles distant in a north-easterly direction.

The area described is 80 square miles in extent, and is 8 miles wide in an east-west direction, and 10 miles from north to south.

II.—PREVIOUS LITERATURE.

Although mineral discoveries were made as far back as the year 1891, no detailed description of the ore-deposits or the geology of this important field has been published up to this time. The first official record of mineral discoveries of economic importance in this area is contained in a report written in 1891 by Mr. A. Montgomery to the Secretary for Mines. (2) This report briefly describes the country traversed by the route of the proposed Waratah-to-Zeehan Railway, and reference is made to the discovery of galena by J. Lynch in Ross Creek, a tributary of the Huskisson. Writing in the early part of the year 1892, Mr. Montgomery states that very few prospectors have been at work in this area owing to the difficulty of access and to the financial depression at that time.

Attention was again drawn to the district in 1896 by the discovery of a large pyrites outcrop by Messrs. Kershaw and Sanderson. Mr. J. Harcourt Smith(3) writes an account of his visit of inspection to this mine in July, 1897. In this report he refers also to the Cutty Sark group of sections, and to the Hawkesbury sections on the south side of the Pieman, which are included within the compass of this discussion.

In the year 1900 Mr. W. H. Twelvetrees(4) paid a hurried visit to Kershaw's blocks (Chester Mine) and the Cutty Sark group, near the Pieman River, on his return journey from an examination of the Mt. Farrell area. At the time of Mr. Twelvetrees' visit very little developmental work had been done. The ore had been exposed in one trench only, and a tunnel, 50 feet below the trench, was being driven to cut the lode. A short description of the mines and some of the geological features which he observed *en route* is contained in a publication of that year. Very little work of any importance has been done on these mining properties, except at the Chester (Kershaw's) and Pinnacles Mines, since those reports were written, and the descriptions of them are, in the main, applicable to-day.

(2) *Vide* A. Montgomery: "Report on the Country Traversed by the proposed Waratah-to-Zeehan Railway," 1891.

(3) *Vide* J. Harcourt Smith: "Report on the Mineral Fields in the neighbourhood of Mt. Black, Ringville, Mt. Read, and Lake Dora," 1891.

(4) *Vide* W. H. Twelvetrees: "Report on the Mt. Farrell District," 1900.

III.—HISTORY.

The nearest settlement to the North Pieman and Huskisson district in the early prospecting days of the western division was Waratah. This town was made the base of operations for all expeditions, not only to the neighbouring districts, but also to such remote parts as Zeehan and Heemskirk. In later years the coastal areas were more conveniently reached by means of the vessels trading to the ports of Strahan and Trial Harbour, but Waratah remained the starting point of expeditions to the North Pieman and Huskisson country until the coming of the Emu Bay Railway, which, passing right through the area from north to south, brought the district into easier communication with Zeehan.

In the history of this area the year 1890 was signalised by the discovery of silver-lead ore at Ross Creek, a tributary of the Huskisson River. The discovery was made by Mr. Jack Lynch, who was a member of the party engaged on the construction of the Huskisson valley pack-track from Waratah to Zeehan, and was named by him the Silver Falls Mine. The district did not benefit immediately by this discovery, as the nature of the deposit was such as to preclude the possibility of its turning out a payable mine at that time. This area was visited by Mr. A. Montgomery in 1891(5), who remarks, *inter alia*:—

> "The country to the north of the Pieman has been as yet very little prospected. Until opened by the pack-track down the Huskisson valley, and by Meredith's cattle-track (now being marked through), it was almost inaccessible, and since the completion of these works a cessation of prospecting, owing to the prevailing financial depression, has taken place, so that up to the present time very few prospectors have been at work. A fair amount of success has, however, been even now attained, several groups of sections having been taken up in the vicinity."

Mining interests in the district remained dormant for several years, until in 1896 two men named McGuiness reported the discovery of rich copper ore at the Pinnacles Hills, which was almost immediately followed by the dis-

(5) "Report on the Country Traversed by the proposed Waratah-to-Zeehan Railway."

covery of the big pyrites mine (now known as the Chester) at Mount Kershaw by F. Kershaw and H. Sanderson. Previous to 1896 this area was little known, but in that year the district came into prominence more on account of the alluvial gold discovery in Strong's Creek than by the development of the more important known lodes or the discovery of new ones. These developments gave a great stimulus to prospecting work, the scope of which was extended as far west as the Huskisson River. The several small companies which had subsequently been formed to develop their holdings at Pinnacles, amalgamated their interests under the name of the Tasmanian Pinnacles Proprietary Company Ltd. Mr. Alex. Peoples was placed in charge of the mining operations, which were conducted under the direction of Mr. A. T. Brown of the Intercolonial Options Development and Purchase Mining Company. The results of this work, although in many respects decidedly encouraging, were considered unsatisfactory, and active operations ceased.

At this time Kershaw's blocks were placed under offer to Mr. John Godkin, who had certain prospecting work performed, including the sinking of a shaft on the ore-body some distance south of the main workings. These works failed to expose copper or zinc-lead sulphide ore in payable quantity, and soon after the leases were forfeited.

A pyritic lode containing pockets of galena was uncovered on sections west of Kershaw's blocks charted in the names of A. C. Gordon and W. G. Pybus.

Between 1897 and 1900 the Emu Bay Railway, connecting the mining centres of the western division with the seaport of Burine, was built, thus providing transportation facilities to the mines of the district. Naturally the completion of this line was the direct means of giving a decided impetus to mining in this area, especially to certain properties near the Pieman River crossing. Moreover, a number of lodes were exposed in the railway cuttings at several points between the 59 and the 66 mileage-pegs. These lodes contained enough copper and iron pyrites, although not in sufficiently payable quantity, to encourage prospectors to further effort. During the next few years, for a number of reasons, the mines were abandoned. Since the year 1899, very little development work had been carried on at Kershaw's Iron Blow, until in 1908 Mr. T. O. Thomas, the lessee, recognising the prospective value of this enormous deposit as a pyrite producer, decided to offer the mine for sale to the Mount Lyell Company. The arrangements for the purchase were made and completed in that year. The mine at this time received the name "Chester." Exploratory work, under the supervision of Mr. Luke Williams, was begun by the Mount Lyell Company in the summer of 1908 by cutting a series of long parallel trenches across the ore-body. The preliminary work showed the existence of a promising body of ore of considerable dimensions, and more extensive operations were begun, including the open-cutting of the ore-body at selected points, and the further exploration by diamond-drilling. During the period extending from 1909 to 1913 inclusive development and exploration were carried on systematically, and a considerable tonnage of first-grade lump-ore, carrying over 37 per cent. sulphur, was shipped to the sulphuric acid works at Yarraville. The development work is regarded as having proved the ore-body to be continuous over 1500 feet in length and 300 feet in depth. In 1913 the working costs had increased so much, owing to the necessity of removing large quantities of second-grade material to get at the first-grade ore, that active operations were discontinued.

In the early part of the year 1917 a lease of the property was secured by Mr. A. E. Bruce, on behalf of Messrs. Cuming, Smith, and Company, who, profiting by the difficulties experienced heretofore, decided to subject the ore to preliminary treatment. This company is now engaged upon the erection of a concentrating plant to treat the lower-grade ore dumped and the unmined ore of second-grade.

About the year 1908 the Pinnacles properties came into prominence again. Mr. Richard Watkin, representing the Trimetallic Syndicate Ltd., carried out extensive exploratory work on the properties, and uncovered the lodes at several points. In 1911 an option over the properties was secured by the Mount Lyell Company. Under the direction of Mr. Luke Williams the ore-bodies were carefully sampled, and further exploratory and developmental work was carried out.

At the time of the writer's visit all operations had ceased. The shafts were full of water, and some of the tunnels were impassable because of the fallen rock and the accumulation of hydrous oxide of iron sediment. The development may be regarded as the result of the work of a few men extending over a long period of years.

IV.—PHYSIOGRAPHY.

(1)—Topography.

(a)—*General Description.*

The area under review embraces one of the most rugged portions of the west coast division—a series of high hills and deeply dissected valleys, heavily clothed with dense forest growth, follow one another seemingly in endless succession.

The topography generally is one of high relief, and may be regarded as the physiographic continuation of the adjacent areas. The most prominent topographic features of this area are due to the occurrence of erosion-resisting porphyroids standing out slightly above the upland surface, and to the bold configuration resulting from the corroding effect of the Pieman River. The area is almost wholly occupied by pre-Silurian sediments, tuffs, and felsitic lava flows, which constitute part of the old peneplanated surface recognised by earlier writers in neighbouring districts. In Pleistocene time, glaciers invaded the district, and occupied the main depressions—which were both widened and deepened—leaving much evidence of their action in vast accumulations of glacial debris. The general effect of the glacial activity on the topography has been to widen existing valleys, and to obliterate any inequalities on the land surface, leaving only subdued hills in the place of rugged mountains.

Periodic changes in post-glacial time have brought about alternate stages of alluviation and degradation as exhibited in the successive variations in the composition of the fluviatile terraces observed on the hill sides, far above the present bed of the Pieman River. The nature of the terraces and fluviatile deposits affords some evidence of the successive movements operating to produce the present topographical features. At the railway bridge, the bed of the river is 110 feet below the broad flood-plain extending one-half mile on either side, and 250 feet below an earlier flood-plain, the remains of which are seen as terraces of fluviatile material in the railway cuttings towards Farrell Siding. The earlier flood-plain is occupied by river-wash, composed mainly of quartz pebbles, varying in size from very fine particles to pieces 6 inches in diameter. The bulk of this mateiral is coarse gravel. The formation of this deposit indicates a period of gradual subsidence. After a short period of stability, a gradual uplift of the region followed, giving renewed power to the river, which soon carved its course through the loose wash, and more gradually through the bed-rock, until it reached the level of the later broad flood-plain. The river at this level had reached the limit of its erosive power, and spread over a considerable area. The succeeding uplift was the commencement of the present cycle of erosion. The river soon passed through the alluvium, and is now deeply entrenched within its former channel. The bold escarpments and the deep precipitous gorges are further proof of the comparatively recent elevation of this area. This elevation of the country is not restricted to the particular region in question, for there are raised beaches at several points on the West Coast. Mr. Ward, in his report on the Mount Farrell Mining Field(6) in 1908, refers to the river terraces of the Mackintosh Valley as providing evidence to prove that the uplifting of the region was not effected by one simple movement, for there are still traces of two river terraces left in the undenuded river-wash at a point a little north of the town, and west of the Mackintosh Mine. At Strahan, the Tertiary beds are known to form raised beaches, and numerous terraces of gravel are recorded. Raised beaches of recent sediments have been recorded at Cox's Bight by Mr. Twelvetrees(7), and it may be that some parts of western Tasmania are still undergoing elevation.

The age of the alteration of level in the North Pieman and Huskisson area cannot be exactly determined, but it can be placed within narrow divisions of time. The first uplift was certainly Pleistocene, for the glacial debris has been dissected by the major water courses; the second uplift brought about by the present erosional cycle which has resulted in the rivers becoming deeply entrenched in the bedrock below the flood-plain, and probably took place in late Pleistocene time.

(*b*)—*The Peneplain*.

This is a part of the terrain which has been recognised by other geologists as a peneplanated surface of erosion(8).

(6) Geol. Survey of Tasmania, Bulletin No. 3, 1908.

(7) Proc. Roy. Soc. of Tasmania, 1893.

(8) W. H. Twelvetrees: "The Ore-bodies of the Zeehan Field," 1908: Geol. Survey of Tasmania, Bulletin No. 8.

L. K. Ward: "Tin Fields of North Dundas," 1909: Geol. Surv. of Tasmania, Bulletin No. 6.

L. L. Waterhouse: "Stanley River Tinfield," 1914: Geol. Surv. of Tasmania, Bulletin No. 15.

Looking westward towards the sea from a prominent hill as a vantage point, a remarkably even horizon is presented. A closer observation shows that this elevated surface, which at one time stood at a much lower elevation, is dissected by numerous youthful streams, giving a very irregular topography. These streams, flowing generally in a southerly direction toward the major drainage channel, the River Pieman, have carved deep channels from 500 to 1500 feet in depth. Here and there above the surface of the peneplain, a few rounded summits, such as Mounts Ramsay, Parson's Hood, Livingstone, and Stanley—all occupied by the more resistant granite rocks—stand out as residual peaks of erosion or monadnocks. All that remains now of the old peneplain are the numerous narrow ridges lying between the waterways. The elevation of the highest of these ridges in this area is 1800 to 1900 feet above sea-level, and from 850 to 1200 feet above the present drainage level.

That the dissection of the peneplain had commenced prior to the glacial invasion in Pleistocene time, there is material evidence to show(9); but the great rejuvenation of the streams, which are still far above the basal level of corrosion, resulted from the series of uplifts occurring in Pleistocene and Post-Pleistocene times, probably during the glacial period. From a number of aneroid readings taken at the level of the main flood-plain, and at the most elevated terrace, it has been ascertained with some degree of accuracy that the first uplift in Pleistocene time was about 400 feet; the amount of the second uplift cannot be determined in this manner, as the river, after having corroded its present bed 110 feet below the flood-plain, has not yet reached a stage of maturity.

(c) *The Mountains.*

The mountains of this area consist of the highest erosion residuals of the old peneplain, and are better described as a series of roughly parallel ridges divided by deep, narrow valleys. Few of these mountain ridges attain to 2000 feet above sea-level or 1200 to 1300 feet above the piedmont. The outstanding topographic feature presented here is the bold outcrop of felsitic rocks occupying the eastern portion of this area. This igneous belt outcrops unbrokenly for over 30 miles, and forms the geographical axis of the most prominent peaks of the West Coast Range. The fel-

(9) Prof. J. W. Gregory: Royal Society Paper, 1904.

sites and keratophyres, being more resistant to erosion influences than the surrounding sedimentary rocks stand out in prominent relief, and present rugged, precipitous ridges, which trend in a general north to south direction.

Besides these larger features of relief, there are many hills of lesser importance arranged generally in rough alignment on an approximately meridional course.

The Pinnacles range of hills is the geological and geographical continuation of Mt. Kershaw, now separated by Hollway Rivulet. The higher peaks of this range consist of a series of curved pinnacles of rock from which taluses with steep slopes, practically uncovered by forest growth, descend, gradually merging with the more gentle, buttongrass-covered slopes of the piedmont. The summits of these peaks are very narrow, due to the highly resistant qualities of the felsitic rocks composing them to the effects of erosion.

The whole area is a complex of narrow ridges divided by deep gorges through which the streams flow in a succession of cataracts.

(*d*) *Drainage*.

The present valley system has been developed subsequent to the formation of the glaciers, excepting such a valley as that represented coursing in a northerly direction on the eastern side of the Emu Bay Railway line, now occupied by glacial morainal material. Since the retreat of the ice, these great masses of conglomerate morainal material have been little altered by erosive agencies owing to the resistant qualities of the hard conglomerate boulders of which they are partly composed, and also to the protection afforded by a thick covering of peat. These vast accumulations of glacial debris in the old river-courses had the effect of raising the bed to such a height that the course of the river was diverted westward. The old valley has now only a local watershed—from Boco Plain, which is at the divide, the small streams follow the old channel, one flowing northerly, another in the opposite direction. The present cycle of erosion had commenced, following the uplift of the old peneplain, before the invasion of the area by glacial ice in Plesitocene time. After the retreat of the ice, the streams once more began their work of erosion with renewed life and energy.

The Pieman River, which receives the drainage of the whole area, and has been the major sculptor in determining the present configuration of the country, is formed at Tullah by the junction of the Murchison and Mackintosh Rivers, which have their sources in the central highlands. The river, already of considerable magnitude, flows rather rapidly westward through a deep, broad valley. Below the flood-plain the Pieman River has become entrenched in the bed-rock to a depth of 110 feet, and is confined in a narrow, deep gorge with almost precipitous walls. It flows at right angles to the trend of the strata, while the tributary streams enter from the north through narrow, steeply-inclined valleys. The main tributary streams are the Huskisson River, which forms the western boundary of the area under discussion; the Marionoak River, which enters the Huskisson River near the point of confluence with the Pieman; and Boco, Chester, and Main Creeks, all flowing directly to the major stream Ross, Higgins, and Lynch Creeks are streams of lesser size, and are affluents of the Huskisson. All these streams, having a general southerly course, following closely the direction of the bedding-planes (10) of the strata, have carved narrow, steep-walled valleys from 700 to 1000 feet deep. A striking feature of the Marionoak River valley are the elevated terraces occurring 850 feet above the bed of the river, the flood-plain of which at this point is ¼ mile wide. The stream here is slow-flowing, and has not cut deeply into the Pieman flood-plain, a little to the south; farther north the valley narrows, and rises at a rapid rate until at the Pinnacles, where the river is split up into a number of small creeks, it merges gradually with the older topography. The old terrace referred to suggests an earlier, almost mature water-course, which has been greatly modified by later glacial agency.

Boco Creek and its affluents have their source in the highlands separating the watershed of Marionoak River, whence they flow eastward to the Emu Bay Railway line, thence turning abruptly southward to the Pieman River. The only other stream of considerable magnitude is the unnamed stream which, for convenience of description, has been called Main Creek. This stream has its source near the Boco divide in the old pre-glacial valley coursing northward. Main Creek carries the drainage of the most eastern portion of the area southward to the Pieman River.

The gradient of the Pieman River between Tullah and the sea averages 25 feet per mile. The tributary rivers

(10) The erosive power of streams is far greater when flowing with than when flowing across the bedding planes of the strata.

have much steeper gradients, often reaching as much as 150 feet per mile; and the lesser streams upwards of 250 feet per mile. Neither the Pieman nor the tributary streams are suitable for the generation of power. The tributary streams are too small during the summer months, and the conservation of the comparatively small amount of power available from the Pieman River would cost so much that it could not be considered a profitable undertaking.

(2)—The Relation of Topography to Mining.

(a) Prospecting and Exploitation.

It does not always follow that a district of high relief is necessarily of very great advantage to mining. That, in the main, the topographic features within this area are of decided advantage is due not only to the pronounced high relief, but also to the position of the ore-bodies in relation thereto. Although the igneous rocks occupying the eastern part of this area present a more rugged, bolder outline than that occupied by the Ordovician sedimentary group, there is very little difference in the heights of the ridges, and therefore the main topographic features have not been determined by the difference in the geological formations. It has been already mentioned that since the uplift of the old peneplain, the streams have been given a greatly increased corroding power, and have carved deep, narrow channels in the upland surface. The Pieman River, as the parent stream, has been mainly instrumental in this work, but the numerous tributary streams flowing southward to this great drainage channel, have contributed largely, though in a lesser degree, and have exposed numerous sections of the strata for examination. The rate of corrosion is in the main proportional to the hardness of the rock, and the course of the stream in relation to the strike of the bedding-planes. Thus, at Higgins' Creek, the resistant properties of the conglomerate beds striking obliquely to the course of the stream having been less eroded, present an unbroken wall of rock 90 feet high, over which the stream falls; again at the Silver Falls the ore is contained in dolomite near its contact with the quartz-felspar-porphyry, and is exposed in the face of a waterfall 110 feet high. This dolomite porphyry contact belt is the host of all the important lodes of the district, and standing out prominently above the more easily corroded sedimentary rocks, present every facility for mining by open-cut or tunnelling methods. The Chester Mine, for instance, occurring on the eastern fall of Mt. Kershaw, which rises 1000 feet above the piedmont, is ideally located for economic mining by open-cut methods. The slope of the hill gradually increases from 20° near the foot to 45° near the summit.

In effect, the topographic features of the district may be regarded as decidedly favourable to mining.

(b) *Water-Supply and Power.*

The rainfall of this region is comparatively heavy and fairly evenly distributed throughout the year, but owing to the extremely high relief, the water is quickly returned to the sea. Not one of the tributary streams of the Pieman passing through this area has a sufficient catchment to ensure a supply equal to half its normal flow after a fortnight's fine weather.

In the whole area, there is only one locality where the natural conditions are suitable for the conservation of water. This is at the dam site, 20 chains north-east of the Chester main workings at an elevation of 400 feet above the piedmont. It was the intention of the Mount Lyell Company at one time to utilise this almost land-locked basin for the storage of water for power purposes, but it was found that the flow of the Hollway Rivulet, from which the supply was to be drawn, fell in volume to 3 sluice-heads or 72 cubic feet per minute during the summer months. This rivulet will be drawn upon to supply wash water for the milling plant now in course of erection at the Chester Mine.

In considering the question of water-power it is well to bear in mind the fact that the initial cost is usually so great that the interest on the capital outlay would pay the running costs of a modern suction producer-gas plant of equal power in localities where wood supplies are abundant.

Ross, Lynch, Boco, and Higgins' Creeks are all sufficiently large to provide water for treatment purposes, and during the winter months may be even applied to power-generation. The summer flow of each of them is from 2½ to 4 sluice-heads. The Marionoak River at Pinnacles is very small in the dry season, in fact, it does not assume the proportions of a river until the broad valley is reached two miles to the southward.

For power purposes then, the streams are negligible, but are large enough to supply wash water to treatment plants

(3)—GLACIATION.

Some very interesting features have been revealed, during this examination, concerning the extent and character of glacial deposits, and much detailed information regarding the effect of glacial action upon the configuration of the country has been obtained. Although there has been no regional glaciation, the valleys of the higher mountain areas have been occupied by local glaciers, some of which were of considerable extent. The most prominent peaks of the Eldon and West Coast ranges were the main centres of such glaciation, and probably there were many smaller glaciers which did not extend beyond the mountain gorges. Along the ridges and the slopes of the hills and mountains bounding the main glacial valleys lateral moraines are common features. Terminal morainal deposits of great extent occupy all the pre-glacial valleys, and are composed almost wholly of very large, worn, conglomerate boulders derived from the conglomerate beds, the remnants of which still cap parts of the West Coast Range. Beyond the limits of the definite morainal deposits, erratic conglomerate and keratophyre boulders are strewn over the surface of the greater part of this area up to an elevation of 1700 feet above sea-level. The origin of the glaciers, and the direction of their movements is clearly indicated by the nature and position of the erratic blocks.

Along the hillside cuttings of the railway line north of Boco Siding, well-rounded pebbles and boulders, set in a dark argillaceous groundmass mark the remains of a lateral moraine. The lateral morainal material extends northwards for several miles beyond this point, but the limit in that direction was not determined.

The ice, occupying all the major depressions, was, in its movement, controlled largely by the irregularity of the course of the valleys. Where the valley confines were less elevated, the glaciers spread over the hills modifying their outlines by the removal of irregularities, and leaving behind them enormous glacial erratics as evidence of their movement. The writer has no further evidence to put forward as to whether these glaciers reached the sea. The very large terminal morainal deposits left behind during the retreat of these glaciers suggest that they were only of mountain type, and were melted before reaching the sea.

(*a*) *The Pre-Glacial Waterways.*

The most important and the best preserved of the pre-glacial river-courses in this area is that occupied by terminal morainal deposits, commencing from the Mackintosh Valley, following the Emu Bay Railway route, mainly on the eastern side, northwards towards the sea. This great, flat, button-grass-covered deposit, composed of large conglomerate erratics—some of them of gigantic size—has withstood the effects of erosion so well that it is little altered since the time of its formation. The elevation of the old water-course is 650 to 700 feet above the bed of the Pieman River at the bridge. The general evidence suggests that this terminal morainal deposit marks the course of a pre-glacial river flowing from the Mackintosh Valley, and that these waters were divided from those of the Pieman by the barrier of igneous rock traversing the district. The head waters of the Mackintosh River are in the interior plateau; at Tullah, this river junctions with the Murchison, forming the Pieman, which passes completely through this range of igneous rock. The narrowness of the gorge of the Pieman River below the township of Tullah, and the sharp outline of the high, enclosing hills, suggest that the course of the main glacier of the Mackintosh Valley was northward, and that a through valley was formed westward by lateral glacial action. The Pieman River terraces, on the western side of this igneous belt, are mainly of fluviatile origin. The distribution of very large conglomerate and felsite boulders in the fluviatile deposits covering the flood-plain, may be due to the denuding effect of water loosening the support, and carrying down the glacial erratics to the river valley; however, it is quite certain that glacial action was largely responsible for the dissection of the ranges, and the alteration of the river course westward, and that the main Pieman Valley was occupied by glaciers.

The only other deposit of appreciable size occurring in this district occupies the basin 1536 feet above sea-level, on the western side of the igneous range between the Pinnacles and Silver Falls Mines.

(*b*) *Erratics.*

Glacial erratics—almost invariably conglomerate boulders—are found strewn over the greater part of the district. These boulders vary greatly in size; some are less than 1 foot, while others exceed 20 feet in diameter, and are hundreds of tons in weight. One particularly fine isolated specimen reaching 35 feet above the surface occurs ¼ mile west of Chester open-cut. Completely rounded small boulders are not generally seen, commonly they are flattened, irregularly shaped, imperfectly worn rocks, rarely showing striæ on the worn surfaces; but glacial transportation of the large boulders results in a more or less rounded condition, and the complete effacement of the striæ on their surface. A very large boulder of felsite, near the smithy on "B" bench at Chester Mine, shows well-preserved striæ in lines parallel to the major axis. On the hillside, near the entrance to Brown's Tunnel, Pinnacles Mine, a very highly-polished boulder of conglomerate, showing faint striæ was observed. The rock presents a perfectly sheared flat surface, smooth and highly polished. The conglomerate does not possess the requisite texture for the preservation of striations which almost invariably have been effaced by exposure to the weather.

(c) *Boulder Clay.*

The best example of boulder clay was observed at Boco Siding, near the outer limit of the pre-glacial valley. The boulder clay of Boco Siding is a mixture of rock fragments, varying in size from that of a rock 20 feet in thickness, to the finest particles. The heavy conglomerate and felsite boulders are embedded in a soft, stiff clay, varying in colour from yellowish-grey to brown. Boulder clay deposits also occur at other points, both on the northern and southern sides of the Pieman River.

(d) *Age.*

The glacial deposits of this area have been regarded as belonging to the Pleistocene.

> "The glacial deposits of Farrell, Rosebery, and Dundas, may be assigned to the action of a Pleistocene glacier, which followed north-westward from the ice-sheet of the Central Plateau. Moreover, the erratics found by Sprent in the Mackintosh Valley, at a locality only some six miles from Farrell, may be safely attributed to the Pleistocene, and not to the Carboniferous glaciation. The only direct evidence as to the latest date at which the glacial deposits of North-Western Tasmania were formed, is derived from their condition of preservation. The maximum

age of the deposits is given by their stratigraphical relations. They are not only later than the formation of a great peneplain, which is one of the most conspicuous features in North-Western Tasmania, but they were formed after the dissection of this peneplain had begun; for some of the glacial deposits in the valley of the Queen River at Queenstown are but little above the present floor of the valley."[11].

(4)—Meteorology.

The rainfall at Chester (the only settlement of the North Pieman and Huskisson district) is about equal to that of Tullah and Rosebery, but much less than that of Zeehan, Waratah, and Queenstown. The annual precipitation of over 85 inches is spread over 250 wet days, not confined to any particular season of the year; but more rain falls in the winter than in any other period. The months of July, August, and September, in particular, are characterised by most boisterous climatic conditions often culminating in very severe gales. The heaviest gales, and the coldest winds come from the south and the south-west; winds from the east and north invariably bring fine weather. It is a remarkable fact that although there may be great variation in the periods of excessive rainfall, the yearly average is fairly even, and always exceeds 80 inches. Hailstorms are frequent, especially during the winter months, and snow falls sometimes, though it is melted almost at the rate it falls, and even after a continued snowfall of two days' duration, it seldom remains on the ground longer than three to four days. The water runs off the steep barren slopes very quickly, consequently the change from rise to fall of the rivers is very rapid. A considerable portion of this area is occupied by glacial morainal deposits covered with peaty soil, which completely protects the underlying rock from the erosive effect of flowing water, and acts as a reservoir from which the streams draw their supplies of water during the driest summer months. The steep hill slopes are generally covered with talus material, but this can retain only a small proportion of the large quantity of rain-water, the bulk of which soon finds its way down to the fast-flowing streams below.

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[11] "The Glacial Geology of Tasmania." Quart. Journal, Geol. Soc., Vol. IX, 1904, pp. 37-53, and pls. VII. and VIII.

The amount and frequency of the rainfalls is an important factor in mining operations that are largely carried on by open-cut methods. The open-cut workings at Chester, although situated near the summit of Mt. Kershaw, are partly protected from the south and south-west winds. The residential quarter is situated on the eastern side of Mt. Kershaw, almost surrounded by hills that afford considerable shelter in all weathers. The climate compared with the less-protected townships of Zeehan and Rosebery is mild and free from sudden changes of temperature. The average temperature of the district is about 60° Fahr. Extremes of summer heat rarely exceed 90° Fahr., while the temperature in winter seldom falls below 30° Fahr.

The Pinnacles portion of this area is in a more exposed position, and suffers the full effects of the south-westerly gales. The accompanying table compiled from the monthly rain maps supplied by the Commonwealth Meteorologist, gives an idea of the annual rainfall of the North Pieman and Huskisson district, and also a comparison with that of neighbouring districts:—

Rainfall for Year 1913.

(Rainfall in inches.)

Month.	Chester.	Rosebery.	Tullah.	Zeehan.
January	5·85	5·52	5·86	7·27
February	2·81	3·03	2·66	4·52
March	6·23	5·81	5·45	7·35
April	2·41	2·71	2·14	3·90
May	5·78	6·70	5·47	7·82
June	4·81	5·12	4·43	6·42
July	8·58	9·12	8·41	13·02
August	12·11	11·32	10·91	13·42
September	10·32	10·70	10·26	12·38
October	6·52	5·91	5·60	6·95
November	13·49	15·97	15·18	14·07
December	6·12	6·96	5·33	7·05
Total for Year	85·03	88·87	81·70	104·17

(5)—Agriculture and Timber.

Agriculture and grazing possibilities are not likely to operate in a large way in the development of these areas for many years, mainly because the difficulties confronting the prospective farmer in clearing these heavily wooded lands impose so great an expenditure of time, labour, and money, in preparing the land for use that it would not be justified by the estimated returns. The forest resources are, therefore, far more significant to the early development of the area, but unless mining development is such as to warrant the construction of steel-rail tramways to provide cheap transport, the more accessible forests near the railway lines will be attacked first. The most fertile tract is that west of the Marionoak River, particularly the Lynch and Higgins Creek valleys, and the ridges between them.

The forests vary in kind according to the altitude, and also to the nature of the soil resulting from the decomposition of the various rock types. Thus the eucalypt "stringy bark," musk, and pear tree, are invariably found on rich clayey soils, while celery-top pine and myrtle prefer that of a sandy nature, and horizontal and bauera apparently the poorest and shallowest soils.

In the eastern portion of the area, the hills are almost bare of soil, and, excepting that part occupied by igneous rocks, do not encourage forest growth; in the western portion, there is evidence of deeper rock decay, for a heavy mantle of soil covers the hills, and the valleys are buried in talus. The dark chocolate-coloured clayey soil supports a most luxuriant vegetation, not only in the valleys, but also on the ridges where magnificent eucalypts find their habitat. The only parts unoccupied by forests are the Pinnacles Hills, and the flat plains and old waterways covered with glacial morainal deposits, which afford sustenance only for the so-called button-grass and allied rush plants. During the warm summer months, cattle are run on the button-grass plains; although this plant is not very nourishing, the cattle keep in good condition.

There exists in the districts a great variety of timber eminently suitable for all mining purposes, and in quantity sufficient to supply all the mines in the vicinity for many years. The forests of the district consist chiefly of nine species, all of which possess some peculiar quality that makes them adaptable for particular uses; the other species are shrubs and the like, of little or no value. The more important trees are the various eucalypts, myrtle, celery-top pine, leatherwood, sassafras, musk, pear-tree, tallow-wood, and horizontal. The "stringy bark" eucalyptus is perhaps the most useful, and one of the most widely distributed trees. This tree grows to enormous dimensions, upwards of 150 feet tall, with the barrel clear of limbs for 100 feet, and often individual trees exceed 20 feet in girth 10 feet above the ground. The best growth is found on the rich chocolate-coloured soil east of the Huskisson River, and also along the narrow belt occupied by igneous rocks. This timber is sawn into weatherboards, joists, studs, &c., and is also suitable for splitting into palings and laths. Celery-top pine and myrtle grow in profusion on the poorer soils of Mt. Kershaw, the north-western slopes of Mt. Black, and near the Marionoak River Valley. The celery-top pine is very highly prized for its many fine qualities. Its non-shrinking quality when cut green makes it eminently suitable for flooring-boards; and on account of its ability to resist the effects of changes of weather, its long life, and its capacity to resist continued shock, it is prized above all other timbers for railway sleepers. These trees seldom exceed 120 feet in height, and 10 feet in girth.

Horizontal and bauera scrub occupy all the poorer parts of the area, and are especially thick on the old terrace of the Marionoak River. These horizontal thickets are almost impenetrable without the aid of a slash-hook, and even then, present a formidable barrier to progress.

V.—TRANSPORTATION AND COMMUNICATION.

The district is accessible by means of the Emu Bay Railway, which connects Burnie with the State Railways at Zeehan. The Emu Bay Railway is conducted by a company, the head office of which is in Melbourne, and acquired its rights from the Van Dieman's Land Company by virtue of an agreement with that company, dated 27th August, 1897. The construction of the Burnie-Guildford extension from the latter town commenced in October, 1897, and was completed to Zeehan at the beginning of 1900. The line is of 3 feet 6 inches gauge (the standard for Tasmania), and has a maximum grade of 1 in 40.

The district is well served by this line, which passes through the area from north to south, and not only connects the ports of Burnie and Strahan, but links up the western with the main railway system of the State. Stations are provided at Boco Siding, 58¼ miles; at Chester Siding, 63 miles; and at Farrell Siding, 64 miles from Burnie A narrow-gauge tramway, one mile long, connects the Chester Mine with the siding. The mines at Sterling Valley are reached from Tullah by a two-feet gauge wooden-rail tramway line of 5 miles, laid down on the road formation connecting Tullah with Rosebery; and from Tullah a steel-rail, narrow gauge tramway, of 6 miles, connects with Farrell Siding. Boco Siding is conveniently situated to serve the Pinnacles group of mines.

The port of Burnie is more centrally situated, offers far better harbour facilities, provides a much safer approach, and can accommodate much larger vessels than the western port of Strahan; and, in consequence of these advantages, secures the major portion of the trade of the district.

There are no public roads in this district. Where the developments warrant greater transport facilities, tramways are laid down in preference to roads owing to the very heavy cost of upkeep of the latter, due to the extremely heavy rainfall, and the rugged nature of the country. Those parts unsupplied with tramway communication receive access by means of foot-tracks. The most important of these tracks is that constructed by Atkinson, commencing at Boco Siding, passing through the north end of the Pinnacles section, thence due west across the Huskisson Valley towards the Stanley River area. The first section of this track is over gently-inclined open button-grass country, until the fall towards Higgins Creek is reached; from this point onwards the track follows a zig-zag course in and out of the deep valleys, and finally gradually ascends to connect, near the Lindsay Mine, with the track to Stanley River. The foundation of this track is solid, except on the parts crossing Boco and Pinnacles Plains, and it is well-graded and constructed. In places it is completely overgrown with bauera and ti-tree scrub, and in the heavily-wooded country is blocked by fallen trees, but if these adjustments were made, the track could be used for horse traffic during the summer months. The clearing is about 12 feet wide; the formation is 6 feet wide on the flats, but only 3 along the steep sideling country, near the Huskisson River.

A branch track connecting with Atkinson's on the west side of Marionoak River leads to the Silver Falls Mine. The " track " is nothing more than a lightly-brazed trail. It is sketched on the geological map for the convenience of prospectors who might experience some difficulty in locating this mine.

Berry's track was constructed five years ago under the direction of Mr. Hartwell Conder, late State Mining Engineer. This work was decided upon to give access to a strip of unexplored country immediately north of the Pieman River, and east of the Huskisson. Commencing at the point of confluence of the Pieman and Huskisson Rivers, and coursing north-easterly, it traverses a series of ridges and valleys, and connects with an old unnamed track, one half-mile west of the Chester Mine.

Meredith's cattle-track from Waratah, marked out in 1892, passes through the Pinnacles country, thence three miles north of and parallel to Berry's track, to which it gradually converges, meeting at the Pieman River crossing. A branch from this track passes southward through the Pinnacles and Chester areas, thence to the Pieman River ford, one quarter mile east of the railway bridge.

Many of the tracks are constructed without regard to grade in a more or less direct line, in defiance of the topography; but some are adjusted to the topography of the country, and if widened in certain places, and maintained in good order, would be suitable for horse traffic. All of these tracks, overgrown with scrub and blocked by fallen trees, are very difficult to follow.

The Pinnacles group of mines is easily accessible from Boco Siding. A tramway, about 3½ miles in length, could be constructed to connect at this point with the Emu Bay Railway at a comparatively small cost. The route is over cleared country on an ascending grade to the Pinnacles not exceeding 1 in 20, the load being with the grade from the Pinnacles saddle to the railway siding.

Telegraph and telephone communication can be had at Tullah and Rosebery, and until quite recently similar facilities were provided at Chester. The post and telegraph office was temporarily closed at Chester, in 1913, at the time of the cessation of operations by the Mount Lyell Company.

VI.—GEOLOGY.

(A)—General Statement.

The geological examination of the district has revealed many interesting features, and has supplied further information concerning the interpretation of the petrologic problems exhibited by the eruptive rocks of this area. The additional evidence produced here, taken in conjunction with that obtained in the detailed examination of the neighbouring districts, will go far to elucidate the difficulties experienced in arriving at the correct solutions of the problems in question. This work is designed to supplement that of earlier writers, and as far as it is applicable, is confirmatory of the hypotheses already propounded. Much further research is necessary, however, to establish the exact relationship of the various transitional types comprising the igneous complex.

In an earlier chapter of this bulletin which dealt with the relation of topography to mining as applied to this area, the statment was made that there does not exist any outstanding physiographic feature that can be considered the topographic expression of any particular geological formation; but that the igneous rocks, occurring on the eastern side, are slightly more prominent than the sedimentary which they conformably overlie. Such is not the case in the Sterling Valley area to the south-west where the physiographic features exhibited by the igneous rocks are in marked contrast with those of the sedimentary. The igneous rocks present a more rugged, precipitous appearance, and stand out as prominent mountains above the sedimentary formations occupying the foothills and the plains at the bottoms of the valleys. This great eruptive complex, which is about 4 miles wide, extends in a perfectly straight meridional line from Mount Darwin in the south beyond the northernmost limits of the area under review—a distance of over 33 miles—and forms the backbone of the most prominent peaks of the West Coast Range. The district, which has a close tectonic relationship to the Read-Rosebery and Mount Farrell areas is occupied on the western side by a number of different sedimentary formations identical with the Dundas series. To the south, the mining districts of Read, Lyell, and Darwin, which have a more or less closely related mineralisation, form one connected mountainous belt of extrusive and intrusive igneous rocks. These districts, in addition to those already mentioned, make up the main part of the West Coast mining region.

(B)—Geological Map.

The geological map (Plate VIII.), accompanying this report includes portions of three adjacent districts introduced primarily to convey a clear conception of the distribution of the various rock types, and of their relationship one to the other.

The igneous rocks, represented by extrusive felsites and keratophyres, and intrusive quartz-porphyries and felspar porphyries of pre-Silurian age, have been so metamorphosed and distorted, and occur in such irregularity that it is quite impossible to delimit their boundaries. As these formations are contemporaneous, and are only structurally different types, they are grouped together. The only other igneous rock represented in the district is that of a narrow dyke of diabase of Upper Mesozoic age intruding the porphyroids.

The sedimentary rocks of Pre-Silurian age have been divided into three groups—the Read-Rosebery schists; Dundas slates, breccias, &c.; and the Farrell slates. The Read-Rosebery schists lie adjacent to the felsite, and are the repositories of the main lodes of the district. They differ in appearance considerably in that the degree of schistosity developed is much less at North Pieman than in the Read-Rosebery area, but in other respects they are identical. The Dundas group comprises a number of widely different formations easily distinguishable one from the other, but the limitations of the map preclude a separation being made.

The exact relationship of the Farrell slates to the other sedimentary groups is not known, but they have been referred indefinitely to the Pre-Silurian in conformity with the other Palæozoic strata already mentioned.

The only other sedimentary formations occurring in this district are the Quaternary unconsolidated sediments, consisting of Pleistocene and Recent members, which are lithologically nearly identical, and in some instances grade into each other. It has been found convenient to separate these formations so that the distributions of the glacial deposits may be followed.

The accompanying map shows also that the economic deposits of iron, lead, zinc, and copper sulphides are distributed mainly along the boundaries of the porphyroid belt.

It will be noticed that in the lodes contained in porphyroid rock, the dominant mineral is chalcopyrite, while in the sedimentary rocks near the contact, zinc-lead sulphide and pyrite predominate. The relationship of the different ores to the rock-types is pointed out in the discussion of the origin of the ores.

The map shows the location of the mining properties, the positions of the more important lodes and faults, the directions of the strike and dip of the structurally-important strata, and the general physical features of the region. Features that are not sketched are represented by conventional signs.

(C)—Table of Formations.

Sedimentary.

Recent ... ...Fluviatile and Glacio-fluviatile deposits.
Pleistocene... ... ...Glacial morainal deposits.

Unconformity.

Pre-Silurian	Sedimentary schists Pyroclastic schists	Read-Rosebery group.
	Slates Sandstones Quartzites Conglomerates and breccias	Dundas Group.

Igneous.

Intrusive and Extrusive.

Upper Mesozoic... ... ... Diabase.
Pre-Silurian... ... ... Felsites, keratophyre, porphyries

(D)—Igneous Rocks.

(1) *The Porphyroid Group.*

The great igneous complex so abundantly developed in the adjacent districts to the south and east is the dominant feature, both structurally and petrologically, of this district. The igneous types represented range from fragmental rocks to felsites, keratophyres, and porphyries. The various elements are so irregularly associated that it is at once apparent that the exposed rocks of the group belong to one igneous mass of contemporaneous lava flows, pyroclastic breccias, tuffs, and intrusive dykes and sheets. Variations in texture from felsites through felspar porphyry to quartz felspar porphyry take place transitionally, and show that these rocks are differentiation products of one magma.

The term porphyroid, which is a convenient field name, has been applied to rocks of this type, both schistose and massive, and includes the intrusive as well as the extrusive forms. This term was suggested by Mr. G. A. Waller in his report on the Mount Farrell Field[12] as a provisional group-name for the schistose varieties of these igneous rocks. It has been adopted by the Geological Survey, but is applied in a wider sense to include the massive forms as well and a number of closely allied but more basic igneous rocks occurring in other localities. Rocks of similar type and similar variations of type occur at Mount Balfour, Gunn's Plains, Riana, North Dundas, Mount Claude, and Middlesex, and all are described as porphyroids. The name was originally applied to certain schistose porphyries in Europe, which were subsequently shown to be peculiarly rich in soda, and were termed keratophyres.

All the members of the porphyroid group are similar in composition in that the dominant felspar component is albite, and, with quartz, is an essential constituent. Magnetite is an accessory component; secondary minerals due to metamorphism are sericite, epidote, chlorite, pyrophyllite, calcite, and actinolite.

The prevailing colour, dark green to greenish-grey, is due to the development of chlorite, but the felsitic members are usually greyish-white. The grains of the component minerals are ordinarily of medium size, but they vary greatly in different localities. Large phenocrysts of idiomorphic felspar and quartz, closely packed together, occur at Silver Falls. The quartz has suffered corrosion to such an extent that the crystal outlines are quite obliterated, and they present either a spheroidal or a much embayed appearance. The structure of the rock-mass varies from a dense felsitic rock made up of felspar and quartz microlites to a typical porphyritic rock with phenocrysts of spheroidal quartz and of felspar set in a ground-mass composed of like minerals. In some instances quartz pheno-

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(12) *Vide* G. A. Waller: "Report on the Mt. Farrell Mining District," 1904.

crysts are entirely absent, and the rock takes the form of felspar porphyry. The phenocrysts are almost invariably arranged in parallel formation or flow alignment, indicating the volcanic origin of the rock. A remarkable characteristic of the keratophyres(*) and porphyries is the development of schistose structure, which, in certain localities, as at Sterling Valley, is intensified so much that the rock presents a peculiar gneissose appearance. Here also the schistose porphyroids have been folded into wavy lines like enlarged corrugations, 6 to 8 inches in diameter.

Evidence of the durability of these old porphyroid rocks is afforded in many places where long exposure to the influence of weathering has caused in some varieties little disintegration of the surface. The weathering effect varies in proportion to the felspar constituent. At Pinnacles the felspar porphyry has become completely kaolinised; near Farrell Siding so-called fragmental rocks exhibit a deeply pitted appearance, showing the siliceous interstitial material standing out in high relief. With the exception of these latter instances, the rock is fairly well preserved, though alteration has taken place owing to constitutional rearrangement.

(a) Tuff Facies.—The tuffs present a rude stratified arrangement of successive beds directly overlying the uppermost sedimentary formation, and again, as intercalated beds between lava flows.

These lower beds of tuff and larger volcanic ejectamenta are usually mixed with much sedimentary material, and merge by imperceptible gradation into true sedimentary rocks. The original pyroclastic texture of the tuffs is usually obscured on account of subsequent alteration, making the dividing-line between pyroclastic and clastic formations extremely difficult to determine. The schistose structure induced by dynamic force, resulting in a complete rearrangement of the mineralogical constitution, is most marked at Chester, and, because of this alteration, the former character of the rock has in most cases been obliterated; but in some other parts they are recognisable by their texture and mineral content, as of igneous origin. These tuffs have, in part, been laid down on a submarine

(*) The name "keratophyre" is applied to the older rocks intermediate between porphyries and porphyrites, and differing from either in having as the principal felspar albite, or any felspar having a pronounced soda constituent instead of the soda-lime felspars. "Keratophyre" is usually applied only to Pre-Tertiary rocks of this kind.

floor, but deposition was certainly continued under sub-aerial conditions. At Pinnacles Hills, the tuffs are composed of white felsitic fragments embedded in slightly schistose, fine-grained pyroclastic material. These extrusives are further represented by stratified rocks exposed in cuttings at several points along the railway-line, and again in a cutting one half-mile from Farrell Siding on the Farrell Tramway and at a point still farther eastward towards Tullah. The succession of tuffs and lava flows followed irregularly but at very short intervals, these latter being commonly separated by tuffaceous material. Contemporaneous dykes, for the most part identical in mineralogical composition with the other members, intrude the tuffs and lavas, causing a most irregular arrangement of the several formations.

Subsequent alteration, due to chemical and structural changes, has rendered the identification of the various types very difficult, and they are distinguishable only in favourable localities. The tuffaceous character is recognisable only on the weathered surfaces of the hard, compact varieties, the more resistant components of which, standing out in high relief, emphasise the fragmental nature of the rock.

(b) Intrusive Facies.—The intrusive members of the porphyroid formations, being the product of magmatic differentiation at a depth, differ considerably in structure and slightly in composition with the extrusive members. The intrusive rocks are generally much more felspathic than the extrusive, and they have suffered more from the effects of chemical and dynamic change. The contact between the intrusive and extrusive members is discernible only under the most favourable conditions, and those are usually found near the sedimentary contact where dykes jut out beyond the igneous into the sedimentary formations. It is impossible to trace the boundaries of these intrusive masses owing to the surface covering of button-grass and peat and the large area occupied by glacial deposits which completely obscure the underlying rock. Near Silver Falls the porphyritic igneous sheets at the contact with the schists appear to have been intruded between older flows. Some of the felspar crystals attain ½-inch in length, and display a perfect idiomorphic outline. There is undoubted evidence of fluxion or flow structure in the rock, which shows a parallel arrangement of the closely packed felspar and quartz phenocrysts with the major axes

of the crystals parallel to the strike of the strata nearby. The felspar has undergone almost complete kaolinisation. The ground-mass also contains evidence of a former crystalline structure in fresh specimens, but the original constitution has been destroyed by kaolinisation.

When examined under the microscope the felspar porphyry is seen to consist of long laths of plagioclase showing banding and wavy extinction, surrounded by a crushed rim of felspar fragments. The felspar is twinned after the Carlsbad law. The ground-mass is made up of kaolinised plagioclase, the variety of which could not be determined.

(c) Extrusive Facies:—The extrusive members, excepting the tuffs and other fragmental rocks, are the more predominant members of the formations. They occur as a series of successive lava flows in irregular association with the other members. The line of demarcation between successive flows is not distinct; in general, narrow beds of tuffaceous material occurring in the porphyroid establish the parting. Flow alignment of the felspar phenocrysts can readily be detected by the eye. The felsites[b] in places are vesicular, having elongated gas cavities from ½ to 1 inch in length. Amygdules containing calcite, and geodes containing perfectly crystallised quartz, are commonly seen in these rocks. This cellular structure is typical of surface flows and deep lava beds. In the more porphyritic type, the cellular texture disappears and dense felsitic ground-masses prevail.

(2) *Diabase Dykes.*

Prior to the present examination, diabase had not been reported in this area, though pebbles of the rock had been found in the Pieman gravels, and were thought to have been derived from the diabase sills and laccolites of the Central Plateau. The occurrence of diabase here is in the form of a long narrow dyke extending from a point on the west side of the railway-line near Farrell Siding to the southern border of Boco Plain. This dyke is only about 1 chain wide where it is exposed in the cutting of the Chester Tramway, but varies considerably from point to point, though it never exceeds 3 chains in width.

(b) "Felsite" is now especially applied to those finely crystalline varieties of quartz-porphyry, porphyries, or porphyrites that have few or no phenocrysts, and that, therefore, give but slight indications of their actual mineralogical composition.—*Iddings.*

Diabase disintegrates to a yellowish-brown to chocolate-coloured soil, while the porphyroids disintegrate to a greyish-yellow soil. This difference is so sharply marked that it led to the discovery of the dyke, and was of considerable aid in defining the boundaries, as the outcrop is obscured by the soil covering. The diabase commonly developed in Tasmania disintegrates fairly rapidly, and therefore the narrow dykes are rarely, if ever, seen protruding above the enclosing rocks.

This is the only other phase of igneous activity represented in the area, and is contemporaneous with the widespread occurrence of diabase intruded in the form of dykes, sills, and laccolites at the close of the Mesozoic era.

The rock is in a remarkably fresh state of preservation, and macroscopically, appears to be made up of augite and plagioclase felspar. When examined under the microscope, these rocks are seen to consist chiefly of augite and plagioclase in equal proportions. The plagioclase shows broad lamellar twin structure and is frequently idiomorphic. The augite is commonly found in allotriomorphic particles, though idiomorphic crystals are not infrequent and are finely developed. It is packed between interlacing rods of plagioclase, but in some cases rectangular rods of plagioclase are included in the coarsely crystalline augite, exhibiting the ophitic texture characteristic of this rock.

Another diabase dyke has been discovered in the operation of diamond-drilling the ore-body at the Rosebery Mines. This occurrence is on the east side of, and courses parallel to the ore-body, and is 430 feet distant therefrom. On the surface no trace of the dyke has been found, though a difference in the colour of the soil has been observed at the probable position of the outcrop.

Macroscopically they are fine to medium textured rocks that have the characteristic diabase-like appearance, and are firm, compact, and well preserved.

Microscopically these rocks seem to be composed chiefly of plagioclase felspar, olivine, and augite. Plagioclase in the form of minute rod-like crystals is the predominant mineral constituent. The olivine and augite are packed in between these interlacing rods of plagioclase. The presence of so much olivine is more typical of the Tertiary basalts; but the general appearance of the rock and its apparent close association with the Mesozoic diabase dykes led to its inclusion among the latter under the name of olivine-diabase.

Photo. 2.—DIABASE TUFF BOULDER. [*A. McIntosh Reid Photo.*

Breccia-flow structure is well illustrated in a loose specimen broken from a large boulder found on the side of the Farrell Tramway near Boco Creek Bridge. Many smaller specimens were found in Boco Creek Valley. The rock is remarkably fresh and hard and shows flow structure in the arrangement of the inclusions of diabase rock, the longer axes of which are parallel to the direction of flow. The original vesicular nature of the rock is exhibited in the structure of the ground-mass, which contains numerous elongated amygdules filled with calcite. These vapour cavities are drawn out in the direction of flow.

Macroscopically the ground-mass presents a greyish-green appearance; the inclusions are fine to medium grained dark-green fragments, 2 to 6 inches long, and have fairly sharp edges.

Microscopic examination shows the inclusions to consist of diabase fragments; the ground-mass—probably the remelted porphyroid wall-rock of the dyke—is a devitrified glass composed mainly of kaolinised felspar.

This rock is either a diabase tuff or the filling of the upper part of the diabase neck.

(E)—Sedimentary Rocks.

The structural relationship of these formations to contiguous stratified rocks cannot be determined exactly until the adjoining districts have been exhaustively studied. Geologically, the greater part of the neighbouring districts to the north and west is a *terra incognita*.

Owing to the lack of continuous outcrops, the very dense vegetable cover, the large surface occupied by glacial and fluvial deposits, and the few artificial exposures, it has not been found possible to follow in detail the successive stages of sedimentation represented by the rocks of this district: however, they are doubtless the northward continuation of the Dundas group. The resemblance in their lithological character, and their stratigraphical relationship, at once establish their position in this group. They consist of a conformable group of schists, slates, quartzites, conglomerates, breccias, dipping at a high angle (from 40 degrees to 75 degrees) north-easterly, and striking from 40 degrees west of north to 20 degrees east of north. These sedimentary rocks preserve their strike and dip, with little variation, over the whole area, showing that they were not subjected to the intense minor folding and crushing movements as at Farrell and Read-Rosebery. They have not been greatly metamorphosed, and present a marked contrast with the slates of Sterling Valley, which are contorted in a most extraordinary manner.

At Sterling Valley the schists, slates, quartzites, &c., are much folded and crumpled, and have a marked laminated structure. The pyroclastic rocks appear to have suffered the greatest alteration at or near the contact with the massive igneous rocks, having developed a decided schistose structure, but everywhere they show the effect of intense metamorphism.

The quartzites, conglomerates, and breccias are not so easily compressed as shales, and show only a little compacting or a slightly developed cleavage normal to the direction of pressure, while the shaly strata between them are converted into slates.

(1) *Pre-Silurian.*

(a) Conglomerates.—At Higgins Creek, hard fissile slates encase a bed of conglomerate 350 feet thick, which is exposed in the face of a waterfall 80 feet high, thus testifying to its erosion-resisting qualities. The coarser old conglomerate consists essentially of rounded to sub-angular fragments very closely packed together, and arranged with their major axes parallel. The predominant pebbles, ranging from 1 to 3 inches long, are composed of quartz, while some smaller pebbles and the cementing material consist of brown clayey matter. Some of the pebbles are composed of other material which is more easily decomposed and disintegrated. These conglomerates belong to that formation near Confidence Saddle in the North Dundas district recognised by L. K. Ward([13]).

The parallel arrangement of the pebbles of the conglomerate is typical of those aqueous formations which are known to occur as deltaic deposits in existing deltas. The characteristic feature of such deposits is their persistence over very large areas; another remarkable feature recognised repeatedly, and in this occurrence also, is the way they abruptly succeed fine-grained sediments. These features indicate that the pebble beds were laid down under conditions similar to those obtaining in an extensive deltaic area. Such deltaic beds are now in process of formation

([13]) Geol. Surv. Tas.: Bulletin No. 6, pp. 34-36.

at the mouth of the Ganges or Hoogli River in India and in several other localities.

(b) Breccia-Conglomerates.—The breccia-conglomerates are different in character from those just described. They consist of anguiar to sub-angular pebbles, which are set in a matrix of a complex character. These pebbles are remarkably even and seldom exceed marbles in size. The predominant unaltered pebbles are composed of silica usually in the form of red or green chert or chalcedony; the cement has a prevalent greensh tint, due to the presence of chlorite, and is composed mainly of quartz and felspar. These breccia-conglomerates occur as massive boulders in Marionoak Valley; and in Lynch Creek Valley they occur *in situ*. Some loose boulders found in Lynch Creek have undegrone almost complete replacement by silica. The pebbles of this specimen apparently were composed of some mineral or minerals other than silica, for where the cement only has been silicified the pebble cavities are partly filled with limonite and kaolin. Partial replacement of the pebbles by silica has lent a peculiar spherulitic appearance to the rock.

These changes were effected through the influence of circulating waters, thus showing that the extent of alteration was due to the porosity of the conglomerate. This metasomatism was promoted by the granitic intrusion westward, and was characterised by the increased activity of the circulating solutions due to the influence of the heat given off during the cooling.

The breccia was examined microscopically by Mr. L. K. Ward[14], who states:—

The rock proves to be an aggregate of fragments of chert, chalcedony, and an igneous rock which seems to belong to the porphyroid group. The interstitial cement is also of complex composition, and contains fragments of quartz, felspar, and muscovite, together with calcite, kaolin, and chlorite.

"The presence of the fragments of porphyroid and of felspar seems to suggest that there has been some contribution to the rock-mass by volcanic action."

Lithologically, the rock is very similar to a rock from the Dial Range.

Overlying these breccia-conglomerates deep beds of pyroclastic breccia, very much finer in grain than those described, are found. These are true tuffs, having a com-

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(14) Geol. Surv. Tas.: Bulletin No. 6, pp. 35-36.

position similar to that of the cementing material of the breccia-conglomerate. The rock is of a brownish colour, specked with yellowish-white kaolinised felspar, and disintegrates to a very rich dun to chocolate coloured soil, which supports most luxuriant vegetation.

At the upper reaches of Higgins Creek still finer-grained members are exposed. These consist of dark greyish-brown, purple, and green coloured rocks, commonly in consecutive bands, though the prevailing colour is purple. Sericite is highly developed and much iron oxide is present.

(c) Slates.—In the most westerly portion of this area, hard, fissile bluish-black slates occur in thin beds separated by quartzites.

These slates possess a well-developed cleavage, and can be split with ease into thin slabs and flags. In the upper portion of this formation the slate appears as quite a distinct member; here it lacks highly developed cleavage, is much softer, very much crumpled and contorted, and heavily mineralised with pyrite. The slate has also undergone silicification and has been partly transformed into a rock resembling quartzite, but which retains its characteristic slaty cleavage. On the western fall of Kershaw Range, an outcrop of hard, fissile, argillaceous slate, of a brownish-blue colour, and possessing a highly developed cleavage, occurs overlain by a thin bed of quartzite. This slate can be split into very thin unwarped sheets, but it appears to lack the qualities of durability and resistance to weathering required of roofing slates. The thickness of this bed could not be ascertained on account of the deep covering of talus, but it does not exceed 60 feet. Overlying the quartzite, a dark, soft, mineralised slate appears exposed on Berry's track. These rocks contain much pyrite and show a considerable development of sericite. They cleave at an angle slightly inclined to the bedding planes, which are very distinct.

At Lynch Creek, hard fissile to non-fissile grey to black slates occur interbedded with narrow bands of quartzites and conglomerates. The average trend here is 15 degrees east of north; the dip is 75 degrees east. Some of the slates have a pronounced schistose appearance; others are very much contorted and crumpled. Cross infiltrations of silica in parallel bands are a common feature of the rock here.

At the contact with the schistose rock at Pinnacles, soft, grey, compact slates have been exposed in the underground workings and again by the removal of the wash at Strong's

Creek alluvial workings. The dip is easterly at 60 degrees, and the strike 15 degrees west of north.

At the 68-mile peg of the Emu Bay Railway, a small creek cutting across the strike exposes a number of different members ranging from purple slates to black schists. The order of succession is blue-black fissile slates overlain by porphyroid rock, which is succeeded by purple and grey slates, and these in turn by yellowish-grey and black argillaceous schists, followed by fissile slates. They are again exposed at 66 miles 75 chains, in the railway cutting, as hard fissile argillites, dark blue to dark green in colour, having the cleavage planes almost parallel to the bedding planes. They continue almost as far as the 66-mile peg, where they are succeeded by an argillaceous mudstone composed of chert pebbles the size of marbles set in an argillaceous matrix. Numerous narrow bands of quartzite separate the several slate members.

A bed of slate, 15 feet wide, occurs interbedded with the pyroclastic schists near the igneous contact. This narrow band appears to be remarkably uniform and persistent over a considerable distance. Small narrow bands 1 to 3 feet wide, interbedded with pyroclastic rock, are seen in the railway cutting at $64\frac{1}{2}$ miles peg.

At the north-eastern corner of this area, near the crossing of the tramway over Main Creek, the slates have been almost completely transformed into hornstone by the heat engendered during the intrusion of quartz-felspar porphyry. The cleavage planes of the slate are distinctly retained in the hornstone, which is of a dark grey to black colour, and presents a hard flint-like appearance.

(d) Read-Rosebery Schists.—These schists are, from an economic point of view, the most important rocks in the district, for in them are contained the most extensive and the richest ore-bodies. The name "Read-Rosebery" has been applied to them for convenience of reference by Mr. Loftus Hills(15) in his report on that district, and it will be retained here. These rocks extend along the western border of the igneous belt right through this area, and although they vary slightly in texture and composition from point to point, are identical in other respects with those already described.

The schistose rocks consist of pyroclastic and clastic accumulations, the mineral constituents of which have been

(15) Geol. Surv. Tas. Bulletin No. 19, 1915.

replaced to a large extent by secondary products. The schistose character has been induced by regional folding, the pyroclastic rock apparently suffering more severe deformation than the softer, more pliable, clastic sediments. Probably the degree of schistosity is determined, firstly, by the fragmental nature of the pyroclastic rock, which would lend itself to greater deformation; and secondly, by its position, abutting on hard, resistant, volcanic rocks.

The schists present four main lithologic facies, namely, the argillaceous, chloritic, quartzitic, and calcareous varieties of the Read-Rosebery group, and also variants of these types in the serpentinised graphitic schists developed farther northward.

Argillaceous schists are by far the most extensive and are derived principally from the pyroclastic deposits. The igneous nature of the rock is obscure. This is due to the destruction of the original structure of the rock by the development of schistosity, and also to the partial replacement of the original components by dolomite, calcite, &c. The rock is usually of a white to yellowish-green colour, and shows slightly developed folia. Small fully developed replacement crystals of pyrite are commonly found in this rock at considerable distances from the ore-bodies. Free silica in the form of opaque quartz is always present.

An argillaceous rock, showing well-preserved banded structure, occurs in the railway cuttings at and near Farrell Siding. This is a light to dark grey rock—the variation in colour being due to the distinct bedding planes—showing an entire absence of schistosity, but possessing a crystalline homogeneous appearance due to the effects of contact metamorphism. This rock is undoubtedly of sedimentary origin, but the original nature is somewhat obscure. Veinlets of pure calcite from ½ to 1 inch thick traverse the rock in all directions. Chlorite schists occur usually at or near the contact with massive porphyroid rock. They are very well developed at the Cutty Sark sections near the Pieman River Bridge, and in a lesser degree are found accompanying the ore-deposits. The Cutty Sark copper and iron pyrites lodes are wholly contained in dark green chlorite schist.

A few chains south of the Pieman River Bridge, in the railway cutting, a splendid section is obtained of the massive rock made up of quartzose, aluminous, and dolomitic material. Quartz and dolomite veins appear traversing the rock in a very irregular manner, lending an appearance similar to that of marble. A closer examination reveals the presence of felspar, and also of calcite in rhombohedral form. In the Pieman River escarpment, just below the railway, small caverns are found containing a few small stalactites and stalagmites deposited from lime solutions. Microscopic examination of these rocks reveals their igneous origin. They are made up of plagioclase and quartz phenocrysts set in a quartzo-felspathic groundmass, and contain much secondary calcite and a little dolomite. The quartz shows a much-corroded outline; the plagioclase is crushed and distorted.

Underlying this rock, and separating it from one similar in character, is a narrow bed 15 feet thick of bluish, fissile, slates. The finely banded structure exhibited in the exposures in the railway cutting at Farrell Siding is illustrative of the original bedding planes and affords undoubted proof of the sedimentary origin of this rock; but, nevertheless, it is probable that the rock is largely made up of pyroclastic material. At the northern extremity of this area (Silver Falls) the rock contains a considerable amount of graphite, and is largely composed of serpentinous and talcose materials, with also a little pyrophyllite.

Microscopic examination shows the rock to consist of quartz and plagioclase phenocrysts set in a felspathic groundmass. Secondary calcite and dolomite are also present in considerable quantity, and serpentine, pyrophyllite, and metallic sulphides in lesser amount.

This association of talcose and serpentinous minerals with pyrophyllite at Silver Falls suggests their derivation from the one source[16]. Serpentine may be produced by the action of percolating magnesian waters upon non-magnesian minerals, such as felspars, and possibly even quartz. Pyrophyllite is generally precipitated from carbonic acid solutions, which are very active in decomposing felspathic rocks. In addition to the talc, pyrophyllite, and serpentine components of the rock, quartz, calcite, and dolomite are present in considerable amounts. Part at least of the calcite and dolomite constituents were deposited simultaneously with the metallic sulphides from solutions highly charged with carbonic acid, but these minerals may have been contained in the rock, and by alteration due to the

(16) *Vide* F. W. Clarke: Data of Geochemistry, Bulletin 616, U.S. Geol. Surv., p. 603.

action of carbonated waters have been transformed into talc and serpentine.

Pirsson, in his text-book " Rocks and Rock-Minerals," states:—

" The talc schists undoubtedly represent material which was sometimes of igneous origin, peridotite, pyroxenite, or dunite, and sometimes of sedimentary origin, dolomitic ferruginous marls, &c. It may not be possible from field work and an inspection of the specimens alone unless aided by chemical analyses and microscopical study, to decide in any given case which origin the material had, and sometimes not even then. The presence of chromium, either in the form of chromite or of secondary minerals derived from it, such as kammererite, or fuchsite (a variety of muscovite, green from chromium), is indicative of igneous origin, while that of much talc would, on the other hand, be indicative of sedimentary origin."

The occurrence of chromite in the form of minute octahedra in the auriferous detrital material at Pinnacles casts some doubt on the conclusion arrived at as to the origin of the serpentine. With the exception of alluvial deposits, chromite has been found only in the peridotites and allied igneous basic magnesian rocks, or in the serpentines which have resulted from their alteration. Chromite has not been found near the Silver Falls serpentine, nor is it known to occur at any other point on this horizon. It has probably been conveyed from the Coldstream River serpentine dykes northward of this area. There can be no doubt at all that the serpentine, dolomitic rock of Silver Falls is identical with the clastic and pyroclastic formation bordering the porphyroid.

The rock here is only about 200 feet wide, and directly overlies a narrow bed of quartzite, which is resting on hard fissile slates dipping easterly at 52 degrees.

At Pinnacles and Chester, the schists possess a slightly developed talcose appearance, but the rock contains very little magnesia, and is almost wholly composed of aluminium silicate, though quartz is usually present.

These so-called talcose rocks are, therefore, either agalmatolite, pinite, or pyrophyllite schists. Agalmatolite is a variety of pinite (one of the micas), and is often mistaken for compact pyrophyllite. In composition it is similar to that of pyrophyllite (hydrous silicate of alumina), but it contains potassium. These minerals are formed in a similar manner, and are generally precipitated from carbonic acid solutions, which are very active in decomposing felspathic rocks whence they are generally derived. Pyrophyllite is an abundant constituent of the mineralised zone between Chester and Silver Falls; outside the ore channels the mineral takes the form of pinite by inclusion of potassium, and forms the base of the schistose rocks.

Evidently they are mainly pyroclastic sediments altered so much that the former character of the rock has in most cases been obliterated, but elsewhere their texture and mineral content reveal their igneous origin.

Some doubt exists as to whether the larger portion of the calcite and dolomite components of these rocks are primary, or whether they have been introduced as secondary products during the later stages of the porphyroid invasion or by the transformation of the mineral constitution. The preponderant evidence goes to show that they originated from percolating lime and magnesian waters and were precipitated contemporaneously with the metal-bearing components.

At the southern end of Bobadil Plain yellowish-grey and black calcitic schists occur overlying green and purple slates. These schists are true sedimentary rocks, and contain a considerable amount of calcite and dolomite. The junction between them is sharply drawn. They contain zinc-lead replacement deposits and are the continuation of the calcitic schists—the repositories of the Read-Rosebery ores—discussed by Mr. Loftus Hills in his report on the Read-Rosebery district.

(2)—*Pleistocene Deposits.*

The Pleistocene deposits consist of accumulations of glacial morainal material composed mainly of massive conglomerate, felsite boulders, and boulder clay of considerable thickness, occupying the old Pleistocene river and glacier valleys. The main deposit is that occupying the broad valley (2 to 3 miles wide) on the east side of the railway-line, extending from Tullah many miles northward. The even surface of this button-grass covered plain is broken here and there by large conglomerate erratics standing out prominently above the level of the plain.

The depth of the boulder-clay deposit has not been determined; a hole, 20 feet deep,sunk near the side of the valley, did not reach bedrock. Shallower deposits of lesser extent occur in several other localities in this district, but are not worthy of description. The large conglomerate erratics have been derived from the West Coast Range series. This rock is composed of hard, opaque, red-tinted quartz pebbles, varying from 1 to 8 inches in diameter, cemented by silica.

Some of these boulders contain a considerable amount of hæmatite, which not only occupies the position of the original cementing material, but is found also to have partly replaced the pebbles. Fractures along lines of weakness, produced at an earlier period under enormous compressive stresses, have caused great slabs, cleaved through pebbles and cement alike, to break away from the parent rock. In other cases, fissures, induced by compressive stresses, are filled with quartz, and occur in roughly parallel lines frequently with a second series at right angles to the first. The quartz veinlets, which are from ⅛-inch to 4 inches thick, pass indifferently through quartz pebbles and the cementing material of the conglomerate. These cracks in the conglomerate are filled with silica deposited from solution. The phenomenon is explained by assuming that they were formed during the later period of ore deposition. This argument is used also to explain the replacement of the pebbles by hæmatite.

Considerable disturbance has given the conglomerate a slightly developed foliated structure. The pebbles are flatly compressed, with the longer axes parallel to the planes of schistosity.

(3)—*Recent Deposits.*

Recent deposits consist essentially of fluviatile and glacio-fluviatile material, composed mainly of river gravels, which cover the Pieman River flood-plain, the terraces of fluviatile *debris* still clinging to the hillsides of the Pieman Valley, and the glacial *debris* derived from morainal deposits. The most extensive deposits of this kind occupy the broad Pieman River flood-plain; remnants only of the higher terraces now exist. A very good section is exposed in the Emu Bay Railway Company's ballast-pit, one half-mile north of Pieman Bridge. The base of the deposit at this point is at an elevation of 670 feet above sea-level, and about 140 feet above the present bed of the Pieman River. The deposit is made up of a succession of coarse and fine-grained deposits from 40 to 60 feet in thickness. The lowest member is a bed of soft mud and fine sand of undetermined thickness, separated from an overlying bed of similar material by a hard band of grey shaly rock, 3 inches thick. Another thin band of hard shale of equal thickness forms the parting between this and the succeeding bed. The latter member, 10 feet thick, is composed of pebbles varying in size from that of pease to marbles, and contains much carbonaceous material. Overlying this bed, a thin band of clean carbonaceous matter separates it from the coarse river wash, 20 to 30 feet thick, exposed at the surface. This wash consists almost entirely of pebbles and shingle from 2 to 4 inches in diameter, with finer particles filling the interstices, and is used as ballast for the railway-line. The higher terraces occur on the flanks of the hills at an elevation of 775 feet above sea-level, and are essentially similar to the upper bed of the flood-plain deposit just described. These deposits are laid down on the upturned edges of Pre-Silurian strata. The pebbles consist essentially of quartz derived mainly from glacial *debris*.

(F)—Geological History.

The geological history of the field is presented here in the order of succession of the several rock-groups represented in the district. The precise age of these rock-groups has not yet been definitely determined, but their age relationship to one another can be drawn within fairly close limits.

The igneous rocks were produced in at least two different stages, the order of which is the extrusion of the felsites and keratophyres and the intrusion of variants of this type, and the unconnected posterior intrusion of diabase.

(1) *Pre-Silurian Sedimentation.*

The earliest period of sedimentation is represented by the Dundas slates, breccias, and conglomerates. They form a broad group of formations of variable lithological character, and represent different phases of sedimentation. Littoral to shallow water deposits constitute the sedimentary beds, which are here about 7000 feet in thickness. The great variation in the character of the several formations indicates various phases of deposition, brought about by alternate changes of elevation and depression. These rocks are identified with the Dundas group by their lithological similarity and their stratigraphic relationship and position.

No fossils were found in this area, though a very careful search was made. The only fossils that have been found in the Dundas slates are a few obscure casts of graptolites discovered by T. S. Hall(17) at Ringville. On this evidence Mr. Hall considered the Dundas slates to be of Ordovician age. Mr. L. K. Ward(18), during his examination of the North Dundas district, carefully searched the slates at Ringville, but failed to discover further specimens containing graptolite impressions.

The determination of their age is based on their structural relationship to the porphyroids, and of the porphyroid to the West Coast Range conglomerate, the precise age of which has not been settled. In view of the comparatively weak palæontological and stratigraphical evidence bearing upon the exact age of these slates and clastoporphyroids, they have been ascribed indefinitely to the Pre-Silurian.

(2) *The First Period of Igneous Invasion.*

The first manifestation of igneous activity in this area was the eruption of the tuffs, volcanic breccias, keratophyres, and felsites. The mode of origin of this group of rocks, known as the porphyroids, has not been satisfactorily explained, but the preponderance of evidence goes to show that they are made up of both extrusive and intrusive forms. Igneous activity commenced probably during the later stages of sedimentation, but was certainly continued under subærial conditions. The fragmental nature of the lowest deposits is clearly indicated at Pinnacles Hills, where angular felsite particles are embedded in sedimentary material. The succession of the slates above the fragmental igneous rocks has been suggested as proof that the clastoporphyroids represent, in part at least, submarine tuffs consolidated by subsequent pressure, and that the conditions of sedimentation were similar both before and after the eruption(19). These extrusive rocks, therefore, appear to have been laid down conformably on the Pre-Silurian sediments. The form of the great igneous complex suggests that the location of the vents from which the eruptions took place is along a line of weakness induced by regional folding. The coarse texture and the viscous

(17) "Evidence of Graptolites in Tasmania," by T. S. Hall, Royal Society Paper, 1901.

(18) *Vide* L. K. Ward: Geol. Surv. Tas. Bulletin No. 6.

(19) *Vide* L. K. Ward: Geol. Surv. Tas. Bulletin No. 6, p. 38.

nature of the rock point to the likelihood of this line of folding being the source of the lavas, and that they did not extend far from their vents

It has already been remarked that sufficient is not known of these geological formations to enable their age to be stated definitely; but their age-relationship to the West Coast Range conglomerates has now been established, and their position is thus defined within fairly close limits. The difficulty in assigning the porphyroids to their correct position is increased because the precise age of the conglomerates is not known. The most reliable evidence available is contained in the following paragraph:—

Thus at Penguin the conglomerates overlie, and are younger than the Pre-Cambrian schists([20]); succeeding the conglomerates at Middlesex are the strata of tubicolar sandstone, which in turn are overlain by Silurian limestone ([21]). In the Leven gorge the porphyroids are older than the limestones, which are undoubtedly of Silurian age. At Middlesex the conglomerates rest unconformably upon the porphyroids, and at Darwin waterworn pebbles of porphyroid have been discovered in the basal beds of the conglomerate([22]).

Upon this evidence the porphyroids are shown to be older than the conglomerates, and the latter occur within the time-interval between the Pre-Cambrian and Silurian, and therefore may be assigned provisionally to the Pre-Silurian until further evidence permits a more precise determination of their horizon in that division.

(3) *The Period of Metamorphism.*

During the last phase of the first igneous invasion the sediments and igneous rocks were subjected to local orogenic movement, which uplifted them and gave them a regional dip in a north-easterly direction.

This diastrophic action resulted in the development of the schistose structure characteristic of the Read-Rosebery sediments; and in the transformation of the shales intc hard fissile slates.

(4) *The West Coast Range Conglomerate Beds.*

The next geological event was the subsidence of the land surface and the formation of the West Coast Range conglomerates and sandstones as a littoral deposit. The pre-

([20]) See Geol. Survey Tas. Bulletin No. 5, p 10.
([21]) See Geol. Survey Tas. Bulletin No. 14, pp. 29-30.
([22]) See Geol Survey Tas. Bulletin No. 16, pp. 59-62.

cise age of the conglomerate has not been established. Its age relationship to the porphyroids has already been discussed; and it is known to be older than and conformable with the Silurian limestones and sandstones([23]). Beyond this no definite information is available.

(5) *The Period of Ore-Deposition.*

The age of the ore-deposits occurring on the porphyroid igneous belt has been referred to in earlier publications as coincident with the Devonian granite irruption. The conclusions arrived at and expressed in this bulletin confirm those of earlier writers.

This is also the second period of diastrophism resulting in the uplifting of the whole region. The folding of the conglomerates and the more intensified metamorphism of the older rocks are due directly to the diastrophic movements engendered by the granite irruption. The conglomerates under the influence of heavy compressive stresses were fractured, but were subsequently recemented by infiltrations of silica.

The nearest granite outcrops are at Granite Tor on the east, and Mt. Ramsay on the west. Granite of similar character occurs also at Meredith Range, Mt. Heemskirk, and Hampshire Hills, and quartz-porphyry dykes (the apophyses of the main granite mass) outcrop at Renison Bell and Mt. Bischoff. It appears, then, that the outcrops of granite at Mt. Ramsay and Granite Tor (about 12 miles apart) are the erosion residuals of the main subjacent body.

The form in which the granite mass occurs is uncertain. It is held by some geolgists that the surficial outlines occur as three distinct intrusions in the form of chonoliths ([c]). Whether they are strictly chonoliths or whether the larger domes are laccoliths or batholiths has not yet been proved conclusively by the evidence put forward by any writer.

(6) *The Third Period of Diastrophism.*

There followed a long period of denudation during which large portions of the West Coast Range conglomerate and the Silurian strata were completely removed.

Subsequently the land surface subsided, and the deposition of the Permo-Carboniferous conglomerate followed.

([23]) See Geol. Survey, Tas. Bulletin No. 14, pp. 29-30.

([c]) Chonolith: A name applied to an irregularly-shaped mass of intrusive rock of dimensions very much greater than those of a dyke or a neck, and different in shape from a laccolith or batholith.

Further subsidence below the sea-level led to the finer-grained sediments being deposited on the conglomerate beds. Only very small areas remain occupied by Permo-Carboniferous strata in neighbouring districts (near Zeehan). In this area there is no record at all of sediments of this age.

(7) *The Intrusion of the Diabase.*

The close of the Mesozoic era witnessed the third period of igneous activity during which intrusions of diabase as sills and laccolites took place. Diabase occurs in this area as a long narrow dyke lying in proximity and parallel to the railway-line, between a point opposite Farrell Siding and Boco Plains. During the recent operations of diamond-drilling the ore-body at the Rosebery Mine, in the adjacent area, a narrow olivine-diabase dyke was passed through on the hanging-wall side of the lode about 450 feet distant therefrom. In addition to these discoveries there is evidence of other occurrences in the neighbourhood, and apparently they are more extensive than was at first suspected. Mr. L. K. Ward, in his report on "The Tinfields of North Dundas,"[24] records the occurrence of a narrow dyke of diabase outcropping at several points, and traversing the Renison Bell field from the north-eastern slope of Pine Hill to the buttongrass plain north of the township. Diabase occurs also capping Mts. Dundas and Sedgwick, and is a familiar feature of Central and Eastern Tasmania.

The geological sequence of events during the time interval between the intrusion of the diabase and the glacier epoch of Pleistocene time is incomplete; but the principal events, of which records are available in neighbouring areas, are described in other bulletins of the Geological Survey.

The events which have been instrumental in determining the present configuration of the country have already been outlined in Chapter IV., under the heading "Physiography."

(G)—Faults.

Faulting within the area is common, but of only minor magnitude. Three well-defined minor faults were recognised near the railway-line One runs parallel to Boco Creek for over 5 miles, extending from Boco Plains along the railway route as far south as Farrell Siding. This

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([24]) *Vide* Geol. Survey, Tas. Bulletin No. 6, 1909.

fault has evidently been developed as the result of the diabase dyke intrusion, for it is parallel, and close to the dyke, and has the same lineal extent. The fault-line is heavily mineralised, and contains much pyrite, siderite, and limonite, and dips at 65° to 75° westerly, contrary to that of any other fracture observed in the district. The course of the fault-line is 20° east of north to Chester Siding, when it changes to 12° east of north to Farrell Siding. Another is observed in the railway cutting near the 64½-miles peg, showing a considerable, but indeterminable, lateral displacement.

Secondary structure within the porphyroid is present in the form of joint-planes or cross-fractures, the most persistent and largest in an east-west direction, with dips either south or north. This fracture system occurs between the Home Rule and Langdon P.A. mines. The striking feature of this system of fracturing is not only the abrupt change of strike from a general meridional to an east-west trend, but also the change in dip. The Home Rule fracture dips southerly, while the Langdon P.A., which is situated about ¼-mile south-east, dips northerly. This effect is evidently brought about by a system of reverse faulting, which would result in both lateral and vertical displacement. Numerous minor fractures inclined obliquely to these major fault-lines traverse the system. The Home Rule cross-fracture, like that of the Langdon P.A., has been recemented through infiltration of mineralising solutions. There is still another east-west fracture, situated between those already mentioned, which appears to be connected with them by a north-south fracture.

The forces operative in the earth's crust that are known to produce fracturing are those of compression, torsion, and tension. Van Hise has shown that compressive forces operative in an approximately homogeneous substance, such as this igneous rock, result normally in two sets of fissures being formed. These occur at about 45° to the direction of the applied force, and therefore at about 90° to each other. It has also been demonstrated experimentally that whenever torsional forces are effective, two systems of fracturing tend to be produced, nearly at right angles to each other.

Whether this fracture-system is due to compressive or to torsional forces has not been determined; certainly, compressive forces have been largely operative in the region It is possible also that the fracturing is due to tensional stresses following the irruption of the Devonian granite.

VII.—ECONOMIC GEOLOGY.

(A)—Mineralogy of the Ore-deposits.

The North Pieman and Huskisson country is the geographic continuation of the Rosebery area to the south; and the Sterling Valley area lies adjacent to and south of Mt. Farrell district.

On the great mineral belt of which this district forms the northern extremity are found the most extensive and and highly productive ore-deposits of the State. On the east is the Mt. Farrell zinc-lead and copper field; on the south are a succession of mineral fields, which include such famous mines as the Rosebery and Mt. Read zinc-lead sulphide, and the Mt. Lyell copper groups.

This area may be considered also the geological continuation of the southern district, for representatives of all the different formations of sedimentary and igneous rocks, which are described as occurring in the neighbouring area (Rosebery), are to be found in the North Pieman and Huskisson district. Furthermore, the ore-deposits of greatest extent and economic value occur here on the same horizon, and under almost exactly similar conditions as there. The ore-bodies are similar also in mineralogical composition, and have a close genetic relationship to those deposits.

A general description of the mineralogy of the ores is essential to the understanding of the genesis of the ore-deposits. The lodes of this area exhibit a close mineralogical similarity in their primary constituents. The chief primary ore minerals contained in the lodes are pyrite, galena, sphalerite, chalcopyrite, barytes, and gold, and the secondary products derived from the oxidation and alteration of some of these minerals are malachite, azurite, limonite, hæmatite, and iron and zinc sulphates. The relative abundance of the primary minerals varies locally; for instance, at Chester the ore-bodies are composed almost wholly of pyrite in the main open-cut workings, and in the southern workings chalcopyrite is present in appreciable amount; at Pinnacles, galena, sphalerite, chalcopyrite, and pyrite occur in one portion of the ore-body in fairly equal proportion; in another, the ore is composed predominantly of chalcopyrite; while in other parts, barytes is most abundant. Similar variations are noticeable in the lodes at Sterling Valley, and in those contained wholly in massive porphyroid.

The occurrence of gold at Pinnacles at certain points in appreciable quantity is striking. The amount varies greatly, from a few grains per ton in the brecciated silica near the ore-shoots to over 6 oz. per ton in the selvage on the footwall. At parts of the northern workings the massive zinc-lead sulphide ore contains up to 2 oz. of gold and 10 oz. of silver per ton. It is noteworthy that neither the silver nor the gold content varies in proportion to the galena and sphalerite present; but the high values seem to be contained in the sulphide ore.

Pyrite (FeS_2).—This is the most abundant sulphide in the district, and occurs as a constituent of all the lodes. At the Chester Mine an enormous lenticular mass of ore composed almost wholly of pyrite occurs as a metasomatic replacement deposit. The pyrites is usually well crystallised, but fine-grained, and is also found massive and compact. It is found in the form of small grains disseminated through the altered tuffs and eruptives near the contact with the schists. Some of it is copper-bearing, and on weathered surfaces appears brass-yellow. It occurs in a lesser degree at Pinnacles associated with zinc, lead, and copper sulphides; at Cutty Sark, associated with chalcopyrite, in the form of perfectly-developed cubes, and in the form of pentagonal dodecahedra at Lynch Creek. At the Sterling Valley, pyrite is found lining cavities or vughs, and as narrow veinlets in the lode-channel.

Chalcopyrite ($CuFeS_2$).—Generally accompanies the pyrite, but is sparingly distributed through the large Chester ore-body. At Pinnacles it is more abundant, and was precipitated simultaneously with zinc and lead sulphides. It occurs also as the chief constituent of the lode at Midson's Mine, in lesser amount at Sterling Valley, and also in the Cutty Sark ore-bodies. It is commonly associated with chlorite schist, and is more prevalent in the altered igneous rocks than in the sedimentary. It is always in the massive form, and never in distinct crystals.

Galena (PbS).—Galena is always present in association and contemporaneous with sphalerite in almost all the lodes examined. The host of this ore is usually slate, as at the Sterling Valley Mine, where it is the dominant mineral of economic value; but it also occurs in minor quantity with the copper ores in porphyroid, and as one of the chief constituents of the mixed sulphide orebodies of the Pinnacles area. It occurs usually in a very fine state of division, and intimately mixed with sphalerite at Pinnacles, though in places larger crystalline structure is developed. At Sterling Valley the galena varies from fine granular to coarsely crystalline, the crystal faces being as much as ½-inch across.

Sphalerite (ZnS), *Zinc Blende.*—Sphalerite or zinc blende is abundantly developed, especially in those lodes which are contained in slates and clastic schists. In the latter, as at Salmon's claim, south of Bobadil Plain, it is a replacement product after calcite in association with galena. Sphalerite is a common though variable constituent of almost all of the lodes of the district. It is always found in the crystalline condition, though rarely in developed crystals. It has been observed at Sterling Valley in bands quite distinct and unassociated with galena. At Midson's claim it occurs with galena intergrown at the point of junction, but thereafter in distinct bands. The colour varies from a light-yellow, resinous brown to black. At Salmon's claim it occurs in a particularly pure form, and has a reddish tone. Distinct tetrahedral crystals are commonly noted in the cellular ore.

Barytes ($BaSO_4$).—Barytes is widely distributed throughout the mineralised zone of this area, and is the dominant mineral in certain parts of the Pinnacles lodes. It forms one of the chief mineral components of Lynch Creek lode, and is found in the Chester ore-body, and sparingly in several other lodes of lesser import. It is nearly always associated with galena, either as a more or less intimate mixture or as separate bands in juxtaposition thereto.

Barytes occurs usually in massive form, though in certain localities it is found as translucent, platy crystals. The colour is, in the purest varieties, white, but grades to grey and yellowish-brown.

Gold (Au).—Gold occurs in the detrital material and wash at Strong's Creek and the vicinity in flakes and irregularly-shaped grains with rounded surfaces. It is a constituent of the siliceous ore at the Pinnacles Mine, but is not visible in the stone until the crushed ore has been panned in a dish. Gold is found farther up the Marion-oak Valley in coarse wash, usually in the form of small rounded grains, though fairly coarse particles are frequently recovered in the process of sluicing.

Chromite (FeO, Cr_2O_3).—Chromite occurs as small iron-black particles in the wash and detrital material of Strong's gold diggings. It is invariably found in the form of octahedra; the crystal edges in most cases have been slightly rounded by attrition.

Chromite always accompanies the ultra-basic rocks, peridotite, gabbro; and the alteration product, serpentine. The occurrence here in the wash is peculiar and difficult to explain, but probably it has been derived from the serpentine reported as occurring at Coldstream River, north of this area.

Limonite ($2Fe_2O_3\ 3H_2O$).—Limonite is commonly found in the shallow oxidation zone of the ore-shoots where they outcrop at the surface, especially in the Chester pyrite lodes. The oxidation of the pyrite to limonite has taken place mainly along the original fissures or circulation channels. Limonite is found at Lynch Creek pseudomorphous after pyrite in the form of pentagonal dodecahedra, and in the form of cubes or hexahedra at Chester.

Covellite (CuS).—Occurs at Midson's claim as indigo-blue films on chalcopyrite, of which it is an alteration product. Covellite is almost always of secondary origin.

Hæmatite (Fe_2O_3).—Hæmatite is sparingly found in the Chester ore-body as an altered limonite, and as a replacement product after quartz in the conglomerate boulders on the slopes of Mt. Kershaw. The gossan resulting from the oxidation of the pyrite ore at Chester is limonite, but the limonite in places has been altered by metamorphic action to hæmatite.

Azurite ($2CuCO_3(OH)_2$) *and Malachite* ($CuCO_3Cu(OH)2$). These blue and green carbonates of copper are most commonly found occurring in chlorite in the oxidised portions of the Cutty Sark ore-bodies. They are also found as secondary products in the Sterling Valley lodes. They are formed in the upper parts of ore-deposits by the action of carbonated waters on copper compounds. The first process in the alteration of the chalcopyrite is the oxidation of the copper to sulphate. This compound is reacted upon by carbonic acid solutions to form the carbonate compounds.

Arsenopyrite ($FeS_2\ FeAs_2$).—Arsenopyrite is contained in the Sterling Valley Mine ore-body in association with galena, sphalerite, chalcopyrite, and pyrite. It appears more abundant in the siliceous portions of the lodes. It is always in the massive form.

Pyrophyllite, hydrous silicate of alumina ($HAlSi_3O_6$).—Pyrophyllite is a soft mineral with a greasy feel and pearly lustre, and has a foliated structure. The colours vary from white, yellowish-white, pink to green, and rarely purple; but when air-dried they all become nearly white. Pyrophyllite is abundantly developed at Chester and Pinnacles, where it constitutes the greater portion of the gangue of the lodes, and in a lesser degree is a constituent of the Silver Falls lode.

The occurrence at these localities is in the form of silvery-white foliated scales intimately mixed with the metallic sulphides with which it has been simultaneously precipitated. Under the magnifier it appears to be crystallised.

A sample of this mineral taken from the Chester Mine shows the following composition:—

	Per cent.
Water (combined), H_2O	6·50
Silica, SiO_2	59·80
Alumina, Al_2O_3	33·80
Total	100·10

The specific gravity is 2·78.

This mineral occurs at North Lyell in massive form, with a micaceous scaly structure. An analysis of the mineral from this locality is given for purpose of comparison:—

	Per cent.
Water (loss on ignition), H_2O	6·02
Silica, SiO_2	62·30
Alumina, Al_2O_3	31·40
Soda, Na_2O	trace
Potash, K_2O	trace
Lime, CaO	Nil
Magnesia MgO	Nil
Total	99·72

The greatest development of pyrophyllite is in the vicinity of felspathic rocks, from which it has been derived by the action of carbonated solutions.

Pinite (hydrous silicate of aluminium and potassium).—An alteration product of felspar, is a soft green waxy mineral, very abundantly developed in this district. It forms the base of the pyroclastic schists.

Sericite (hydrous silicate of alumina and potassium).—A variety of muscovite characterised by its silky lustre, is widely distributed throughout the district. It is most commonly found as an alteration product in the argillaceous schists west of Chester, and in the sandstones south of the Pieman River and Bobadil Plain.

Quartz (SiO_2).—Quartz generally occurs in massive form, though crystal faces are developed in quartz cavity fillings, and in white opaque quartz outcrops near Pinnacles. Quartz is abundantly developed at Pinnacles as a lode constituent. It has the appearance of a replacement product, and has been subjected to such heavy stresses that it has been greatly crushed. The brecciated quartz has been recemented by metallic sulphides.

The lode quartz is frequently in the form of dense, hard chert. Another variety is that of hornstone, which is a contact metamorphic product derived from clay slate. At Lynch Creek silica has completely replaced a hard volcanic breccia, and occurs also as a replacement product after limestone.

Quartz is commonly a component of the lodes; in some cases it is the dominant mineral.

Chlorite (Silicate of aluminium, iron, and magnesium).—This light to dark green alteration product is of common occurrence throughout the mineralised zone, and is found in greatest abundance near the contact of the eruptives with the sedimentary rocks, where it is in the form of schist, and contains pyrite and chalcopyrite lodes. It is also widely distributed, though in lesser amount, throughout the whole area.

It is of secondary origin, and appears as the result of hydrothermal alteration, usually of some aluminous ferromagnesian mineral. The origin of the mineral here has not been determined. Probably the aluminous constituent has been derived from felspar and the magnesia from ascending hydrothermal solutions.

Siderite ($FeCO_3$).—Iron protocarbonate occurs as a vein filling in the lode at Chester Siding, and abundantly in narrow veinlets in the Sterling Valley Mine. The siderite is usually massive to coarse granular.

Calcite ($CaCO_3$) is one of the most abundant minerals found in the district. It is usually found in rhombohedral form, though sometimes massive. In the deep railway cutting immediately south of Pieman Bridge it commonly accompanies dolomite in narrow veins through the pyroclastic rocks, and a transparent variety resembling Iceland spar was noticed crystallising in its common rhombohedral habit. It is also found filling amygdules in volcanic rocks, especially in the diabase dyke, and abundantly in the calcite schists.

Dolomite (CaMg) CO_3, is an abundantly developed mineral and is widely distributed. It occurs most commonly at Silver Falls Mine in the ore-bearing rock, having been deposited from hydrothermal solutions. It is also a common constituent of the volcanic-breccia of the diabase dyke. At Salmon's claim it is abundant, and occurs in its rhombohedral habit, showing curved faces.

Epidote.—Epidote is widely though not abundantly distributed. It is found near the lode exposed in the railway cutting near Farrell Siding in the form of thin columnar aggregates of crystals possessing the characteristic yellowish-green colour.

Actinolite ($Ca(Mg,Fe)_3$, $(SiO_4)_3$).—Actinolite is commonly found in felsite rocks, especially near Farrell Siding. It is a dark green mineral found occupying cracks and as facings in the felsite in the form of radiating, acicular crystals.

Talc (H_2Mg_3 $(SiO_3)_4$).—This mineral has been formed at Silver Falls under almost identical conditions as serpentine. It is not abundantly developed.

Serpentine ($H_4Mg_3Si_2O_9$).—Occurs at Silver Falls as a green secondary mineral, either derived from magnesian silicates, which were first formed within the calcareous rock by metamorphic processes, or by the action of percolating magnesian waters upon felspars—the latter origin seems the more probable.

The mineral is found at Silver Falls and is of only mineralogical interest.

(B)—Source of Mineralising Solutions.

The theories held to account for the filling of mineral veins from solutions containing metallic compounds have of late years been reduced to two main and opposing principles. The principle of the first theory is that meteoric circulating waters, having dissolved out the metallic contents of the country-rock in their descent to regions of high temperature, and having become heated, have risen through fissures and deposited their mineral content as vein material. The second principle is that the solutions are derived directly from the irruptive magma of which they are actually component parts, and having been released during the processes of rock-consolidation and cooling, have found their way upward and have deposited their mineral content as fissure fillings.

Variation in the constitution of the minerals formed by deposition from gaseous or liquid solutions depends upon the temperature and pressure under which the deposition took place. The temperature and pressure of the solutions are an expression of the vertical range of the minerals and of the distance the solutions have migrated from the magma. The absence of minerals characteristic of pneumatolytic deposits shows that the solutions had travelled considerable distances, and that the temperature and pressure were greatly lowered before the deposition of their contents from solution.

The solutions which produced the veins and the rock decomposition in the earlier period of deposition were rich in silica, and seem to have directly followed the earlier porphyroid eruption; those that produced the metallic ores were rich in magnesia, lime, iron, and also in silica, and seem to have followed the granite irruption of Devonian time.

There are two possible explanations of the genesis of these ores: one is that they are due to the after phenomena of the porphyroid volcanic activity; the other is that they owe their origin to the later granite irruption. Proof of the first hypothesis presupposes the existence of those minerals which are the expression of the effects of contact metamorphism, for the porphyroid group includes intrusive as well as extrusive members. Minerals formed under high temperature and pressure are in some cases quite distinct from those formed under low temperature and pressure, and the nature of the mineral development may be regarded as an expression of the vertical range of their occurrence. In this connection it may be mentioned that persistent minerals are of no diagnostic value in themselves, and are useful in this regard only in their association with other minerals.

In general, all minerals characteristic of the deeper vein zones are entirely absent, but in certain parts high temperature minerals—not necessarily vein constituents—occur that appear to indicate an earlier period of ore deposition. These deposits are characterised by chalcopyrite and pyrite ores contained wholly in chlorite and associated with actinolite, or else occurring in the prophyroid in a chlorite and quartz gangue. Deposits of this type have doubtless originated under conditions of high temperature and pressure, and possibly represent a period of ore deposition widely separated from the economically more important metasomatic deposits and fissure fillings occurring along the borders of and contained in the porphyroid. A metamorphic origin is suggested by the irregular occurrence of the metallic ores, chalcopyrite and pyrite—which as bunches and disseminations in the chlorite lack definite continuity—and the absence of other metallic sulphides.

It is not to be inferred from the foregoing statement that there is absolute proof of an earlier period of mineralisation, as there is not enough reliable evidence available to arrive at a definite conclusion. This statement is to be considered, therefore, in the nature of a suggestion only, based on the result of very careful observation, and is made here with the object of promoting further investigation.

As none of the characteristic minerals of contact metamorphic deposits are present, and only persistent minerals are seen in association with and contained in the important lodes, it will appear that the ore deposits were formed at a period later than the extrusion of the felsites and the intrusion of the porphyries.

The origin of these magmatic waters, then, is from the great granitic reservoir, the nearest outcrops of which are at Mounts Ramsay and Granite Tor, in neighbouring districts. In other words, these hot ascending waters were originally contained in the granitic magma, and released from it by decreasing pressure, due to its irruption into the upper part of the lithosphere. The mineralisation began during the final processes of rock-solidification subsequent to intrusion, the residual solutions resulting from consolidation having been the agents which produced the mineralisation. The metals in all cases are considered to have been derived, together with the mineralising solutions, from the granite magma.

Some of the minerals found associated with other ores show characters which help to connect them genetically with the tin ores derived from the Devonian granite. Such minerals are those which contain boron and fluorine. Mr. L. K. Ward([25]) reports the discovery of fluorspar at Thomas' Blocks, and its occurrence in considerable abundance in the rock adjacent to the lode at Rosebery has long been known. Fluorspar is a mineral characteristic of lodes contained in or associated with granite. For instance, it is a common constituent of the tin-wolfram deposits of the Shepherd and Murphy Mine, Moina; and of the Story's Creek Mine, Avoca; and in greater or less amount in all deposits of this type. Bismuth ores, which have also a close genetic relationship to those of fluorine, occur in abundance at Kitson's workings in the south-eastern portion of the Mt. Farrell field; chalcopyrite in association with axinite and actinolite formations occurs at the Colebrook Mine near Rosebery; other minerals, such as pyrrhotite and arsenopyrite, characteristic of tin ore deposits, are commonly found with zinc-lead sulphide ores in these districts.

The evidence set forth here is sufficient to show that the ore-bearing solutions and those responsible for the tin ore deposits have a close genetic relationship, and that they must have originated in the granitic magma. It has been shown also that the mineralisation is due to ascending solutions.

(C)—Nature of Ore Deposits.

The first possible factor to be considered is the nature of the rocks—the repositories of the ores—both as to physical character and chemical composition. It is generally held that coarse-grained massive beds of rock, being more easily fractured than fine-grained beds, offer a more favourable locus for the deposition of ore, and in general the amount of replacement varies directly as the intensity of the fracturing. The most extensive ore deposits of this area, and in fact of the whole West Coast region, are contained in schistose pyroclastic rocks. The schistose character has been induced by regional folding, the tuffaceous rock apparently suffering more severe deformation than the softer, finer-grained slates and sandstones; and for this reason also rock-fracturing has been far more extensively

([25]) *Vide* L. K. Ward: Geol. Survey, Tas. Bulletin No. 3, p. 65.

developed in the tuffs than in the fine-grained sediments. It is not to be inferred from this statement that all the ore mined in the district is derived from lodes contained in the tuffaceous beds, as there are numerous cases where the fracturing of the slates near the porphyroid has led to the deposition of extensive ore-bodies, and again fracturing in the hard, massive porphyroid has resulted in the formation of rich small lodes. The purpose is merely to point out at what stratigraphic horizon the mineralisation has been most intense. All of the more important lodes of this district are located along the junction of the porphyroid and sedimentary rocks. The weight of the evidence appears then to indicate that the main determining factor in the matter of localising the mineralisation has been the amount and intensity of the pre-mineral fracturing in the sediments, the extent of the development of schistosity, and the chemical composition of the rock.

Posepny, in "Genesis of Ore Deposits," states:—

> "With relation to the xenogenites, epigenetic or mineral deposits, the first question concerns the space which every secondary mineral or mineral aggregate requires to establish its existence. It must either have found this space waiting for it or it must have made room by driving out an original mineral."

In this area, both as regards fissure fillings and metasomatic deposits, channels of access for the ore-bearing solutions had been provided by pre-mineral fractures in the rocks. The deposits occur either in the solid porphyroid as narrow fissure fillings, in the clastoporphyroid near the point of junction with hard porphyroid as hydrothermal metasomatic deposits, or in the slates and sedimentary schists partly as replacements and partly as precipitations.

The enclosing rocks, and especially the felspar porphyries, have been greatly decomposed. Careful investigation into the nature of this alteration shows that the solutions which caused it were very highly charged with carbonic acid and magnesian solutions. These solutions and magnesia in considerable quantities. Clearly, they were hydrothermal solutions derived from the igneous magma during the waning stages of cooling and rock-solidification, as shown by the excessive development of carbonates and sulphides, and in addition, the formation in such quantity of the secondary minerals, pyrophyllite, pinite, chlorite, talc, serpentine, and sericite, all of which are alteration products of felspar due to the action of carbonic acid and sulphur, and that they contained lime had the effect also of concentrating the silica constituent of the rock along certain favourable courses.

The information contained in the following pages on the nature of the ore-bodies is amplified by the more detailed remarks given under the description of the mines.

The ore-bodies may be considered as belonging to five classes, viz.—

(1) Pyrite and galena replacement deposits.
(2) Galena-sphalerite-chalcopyrite deposits.
(3) Chalcopyrite veins.
(4) Silver-lead veins.
(5) Alluvial gold deposits.

(1) The pyrite ore-bodies are the most extensive, and occur as hydrothermal metasomatic replacement deposits at Chester and the vicinity. These deposits are composed almost wholly of pyrite, with, in addition, small amounts of chalcopyrite, galena, and sphalerite, and occur in large, irregularly-shaped, lenticular masses. All the deposits of ore occur in direct association with faulting-fissures traversing the rock in a direction parallel to the planes of schistosity, and with zones of crushed brecciated rock produced by movements of disturbance. The undisturbed rocks are everywhere barren of ore. The very rich bands of ore, from 6 inches to 4 feet thick, occurring in the ore-bodies, occupy the original fissures along which the ascending mineral solutions circulated and attacked the more soluble constituents of the schists. The shearing and compressive stresses induced during and following intrusion leaves the country-rock much cracked and jointed, providing channels of access or conduits for the ore-bearing solutions. The brecciated structure of the siliceous rock (probably deposited contemporaneously with the porphyroid intrusives) and the joint-cracks provide lesser channels of access along which the solutions have penetrated laterally and attacked the susceptible rock-mass. The main fissure already mentioned is only one of several parallel fissures which are connected by smaller intersecting fissures, the whole fracture system presenting a very large surface available for chemical action, and thus the deposition of metallic sulphides from the ore-bearing solutions was greatly facilitated and accelerated. The cores from the diamond-drill holes show that between the fissures certain bands of schist have been almost wholly replaced by pyrite, whereas in

other parts there are bands of argillaceous and siliceous schists (much less susceptible to the action of mineral-bearing solutions), which remain almost unattacked. The richer bands are thus separated from the poorer bands of ore by narrow walls of almost barren rock. This irregular replacement of the rock, which appears to indicate a selective tendency on the part of the mineral in solution, for the more soluble bands is well illustrated in the accompanying sketch (Plate II.). The schistose structure represented by the enclosing rocks shows in the ore the most minute detail of the structure of the replaced rock, and is strongly indicative of the process of molecular replacement. There is not a sharp line of demaraction between the ore-body and the enclosing rock, the ore usually merging gradually into the rock.

The ore-body shows pyrite sparsely disseminated as perfectly crystallised grains to massive, clean, and coarsely crystalline. The perfectly-crystallised condition of the pyrite in the partly-replaced rock is indicative of the porosity of the schists. The cubic crystals vary in size from minute to $\frac{1}{4}$-inch faces.

The ore-bearing solutions had their solvent power greatly increased by the large amount of carbonic acid contained in them. Carbonic acid acts as a reducing agent in removing surplus oxygen, and in reducing sulphates in the solutions to sulphides. In addition, it is mainly instrumental in the dissolution of the aluminium silicate contained in the felspar. The occurrence of so much pyrophyllite as the chief mineral constituent of the gangue is indicative of the nature and composition of the ore-bearing solutions. The pyrophyllite and pyrite were deposited simultaneously, the abundance of the former mineral preventing the formation of large crystals of pyrite. The presence of so much barium sulphate in the ore suggests that the alkaline sulphide solutions were largely made up of barium sulphide, which acts as a solvent of metallic sulphides. The pyrite was formed long in advance of any other sulphide (perhaps with the possible exception of chalcopyrite), as it is more easily and quickly deposited from solution. Galena and zinc-blende, which occur in insignificant amounts, were the last formed of the metallic sulphides, and occur intergrown in narrow bands in the fissures.

The gossan resulting from the oxidation of the pyrite is limonite, but the limonite in places has been altered by metamorphic action to hæmatite. The oxidation of the pyrite to limonite has taken place mainly along the original fissures or circulation channels through which the solutions carrying the ores ascended. It is probable that these fissures contained the little copper ore present, and that the chalcopyrite, being more easily oxidised and forming more active solutions, was instrumental in accelerating the oxidation. Meteoric waters have played only a small part in the oxidation of the ore; their quick circulation through the porous rock has led rather to a leaching of the copper contents. The oxidising effect of the meteoric waters is confined mainly to the fissures, and is limited in depth to the level of "D" bench of the open-cut. Complete oxidation of the ore extends only 5 feet below the surface.

The galena and sphalerite replacement deposits occur at Salmon's claim, Bobadil Plain, and at the Lynch Creek discovery, west of Pinnacles Hills. Salmon's lode is composed of galena and sphalerite, with very little chalcopyrite and pyrite, and is contained in sedimentary schists near the junction with slates. These schists, although largely argillaceous, contain an appreciable amount of calcite finely disseminated throughout the rock, and as narrow irregular veinlets occupying small fractures. The galena and zinc blende occur as is usual in close association, the blende predominating.

The Lynch Creek lode is composed of gossanous cellular silica, with abundant barytes and a little galena. The galena occurs very sparingly as blebs distributed throughout the mass. These lodes appear to be replacement products after limestone or dolomite, which must be in a very narrow band, as specimens were unobtainable owing to the heavy soil covering.

(2) *Galena-Sphalerite-Chalcopyrite Deposits*.—The most important of these is that of the Pinnacles mines, which occurs in association with much barytes in a gangue composed almost wholly of pyrophyllite. The barytes occurs usually fairly free of metallic sulphides, save galena, which is scattered through this mineral in very small blebs. All the other components were precipitated from solution simultaneously, and present a densely crystalline, variegated appearance. The presence of so much pyrophyllite has prevented the growth of crystals of the metallic sulphides, which, with the exception of part of the chalcopyrite, are in a very fine state of division. The ores are mainly precipitations from solutions which were highly charged with carbonic acid, but replacement of the enclosing rock has taken place to some extent. The lodes are

fissure-fiillings in altered pyroclastic sediments near their junction with slates. The richer shoots of ore are contained in an earlier siliceous formation, which had suffered brecciation and further fracture, and was subsequently recemented by metallic sulphides, mainly chalcopyrite. At certain parts of the lodes, which are arranged *en echelon*, the main constituent is chalcopyrite, and this mineral is invariably found predominating in the siliceous portion.

At the Silver Falls Mine there is no defined lode, in the strictest sense of the word. It appears that the metallic minerals were derived from infiltration of ore-bearing solutions through the porous rock. The ore is composed of galena and zinc blende and a very little chalcopyrite scattered as blebs through a highly dolomitised rock. This dolomite has suffered further alteration to serpentine and talcose material, and is associated with pyrophyllite. The metallic sulphides occur in a very fine state of division, and never in large aggregates, and were evidently deposited in a similar manner to those of the Pinnacles lodes. The pyrophyllite as a gangue mineral is quite subordinate to the dolomite and limestone.

(3) Chalcopyrite veins are confined almost exclusively to the porphyroids, either massive or schistose. A typical lode of this kind is that of Midson's claim, Sterling Valley. This is a fissure vein in quartz felspar porphyry schist of the dark-green colour, characteristic of the rock in this locality. These fissures are usually narrow, varying from an inch or two to 3 feet in width, and they do not persist unbroken over great distances. The wall-rock for several feet on either side of the fissure has been completely replaced by silica. The silicified wall-rock contains a little chalcopyrite, usually as small blebs. The lode content is fairly clean chalcopyrite contained in a siliceous gangue. In addition, galena and sphalerite occur in subordinate amounts as a narrow band in the fissure, and a little chlorite is also present. The galena and sphalerite were the last to be precipitated from solution. Lodes of this type are commonly found in massive porphyroid, but so far as developments have been carried forward they have not proved persistent in depth or length.

(4) Silver-lead veins are typical of those occurring at the Sterling Valley Mine. These veins are fissure-fillings in sheared graphitic slate, near its junction with porphyroid. The vein, or the mineralised part of the shattered shear zone, averages 4 feet in width, but it pinches and swells, and in places is only a foot or two wide. The vein has

little regularity in this shattered country. The ore-bodies are typical examples of breccia veins, and usually strike parallel to the general structural planes of the country-rock. Along these planes the mineral solutions have circulated, depositing quartz and metallic sulphides. The metallic sulphides contained in the lode are galena, sphalerite, pyrite, and a little arsenopyrite and chalcopyrite. The vein varies in character; in some places sulphides with subordinate quartz constitute the fissure-filling; in other places coarsely granular quartz is an abundant constituent, in association with metallic sulphides, particularly in the central part of the vein; and in the southern end quartz is the dominant mineral.

(5) Alluvial gold deposits are confined to the eastern side of Marionoak Valley, in the vicinity of Pinnacles Hills. The gold is found in detrital material, containing a considerable proportion of metallic sulphides derived from the ore-bodies in proximity thereto. A more complete description is contained in the notes on Strong's Creek gold diggings.

(D)—The Structure of the Lodes.

In general the lodes of the North Pieman and Huskisson district are fissure veins. Those that are not simple fissure-fillings have been formed by hydrothermal metasomatic replacement of the enclosing rock, the mineralising solutions having found access by pre-existing fractures.

In some instances the fissures are filled with high-grade sulphide minerals, while the wall-rock has been completely replaced by silica.

Although there is considerable variation in the type of fissure the veins generally have a tabular form. At Chester the pre-mineral fractures, which served as circulation channels for the ore-bearing solutions, are arranged in roughly parallel lines, and are connected by smaller intersecting fissures. At Pinnacles there are several major parallel fissures, arranged *en echelon*, and striking obliquely to the general trend of the schists, which make up the fracture system. The fissure-filling presents a very brecciated appearance. The fissures have been reopened in some places, and later depositions from ore-bearing solutions have recemented the brecciated rock and filled the later opening. Slipping planes or slickensides are commonly noted on the walls of the main fractures, and indicate vertical displacement.

At Silver Falls there is evidence of considerable disturbance; slickensided surfaces are commonly noted in the orebody. There are no indications of intense fracturing; rather it appears that the metallic minerals were derived from infiltrations of ore-bearing solutions in the porous rock.

(E)—Effect of Country-rock.

The effect of the country-rock on the deposition of the minerals is at once apparent on consideration of the various types of deposits encountered under different conditions. The great change in the constitution of the ore-bodies occurring on the one horizon may be attributable to the relative effect of the alteration in the enclosing rock, due to variable metamorphism, and to local variations in the composition of the ore-bearing solutions. Thus the character of the rock-formation and the extent of the pre-mineral fissuring at Chester have provided favourable conditions for the deposition of ores from hydrothermal solutions by metasomatic replacement. The original schistose rock, though dominantly argillaceous, is believed to have contained a considerable proportion of calcite, which would greatly facilitate the substitution of mineral matter in solution for mineral matter in the solid condition. Further north, at the Pinnacles Mine, the geological conditions for replacement were not so favourable, and the lodes are largely formed by precipitation from solution.

There seems to be some distinction between the selective power of different solutions. For instance, the argillaceous pyroclastic and clastic sediments seem to favour the deposition of ores dominantly pyritic. An increase in the calcite content of these porous rocks leads to the deposition of ores in which galena and sphalerite predominate. Lodes contained in slates are composed of galena, sphalerite, and chalcopyrite, with galena as the predominant constituent; and chalcopyrite ores are almost invariably contained in massive and schistose porphyroid. The occurrence of the chalcopyrite ores in the massive porphyroid is explainable by the fact that chalcopyrite is generally deposited as precipitations, lining. and filling-fissures, their deposition being in no way controlled by the nature or composition of the country-rock. The fractures in the porphyroid are usually narrow and sharply defined, and although there may be no opening, the fractures are persistent for considerable distances. In the slates the fissures are not as distinct as in the porphyroid, but present a shattered, irregular fracture-system, the boundaries of which are generally not sharply defined. The general effect is that of a fracture zone. The fissures in the schists are very irregular, and the ores they contain occur as lenticular masses conformable to the structural planes of the enclosing rock. The foliation planes of the schists are approximately parallel to the boundary of the adjacent igneous rock. When this conformity exists between the schist planes and the fissures the ore-bodies are found to be more regular than those occurring in cross-fractures. The galena occurs here as a hydatogenetic deposit, and probably was partly precipitated by the agency of the carbonaceous material contained in the slate.

Zinc-lead sulphide deposits are derived from solutions at the intermediate level zone, and at a temperature ranging from 150° C. to 300° C., and relatively high pressure. These solutions are acid in character, and coming into contact with calcium carbonate are neutralised by this compound. The zinc and lead sulphides cannot remain in solution under neutral or alkaline conditions, and are deposited by molecular replacement of the calcium carbonate.

As the calcite schists are poorly represented in this area the deposition of zinc-lead sulphides usually took place, not as metasomatic replacement, but as precipitations from solutions by other means. Zinc blende is frequently found to have crystallised out before the galena, although at Pinnacles, Silver Falls, and in other localities the precipitation took place simultaneously.

In the western portion of this area, near Lynch Creek, a quite distinct mineralised zone exists. The geological conditions for the deposition of ores by hydrothermal metasomatism have been favourable. The lodes are composed of gossanous, cellular silica, carrying abundant barytes and a little galena as replacements after limestone and dolomite.

The apparent selective tendency of the solutions for these particular rock-formations have been observed, not only in this area, but also in all those mining fields, as far south as Darwin that are genetically related.

(F)—The Effect of Oxidation.

The zone of oxidation of the lodes is very shallow. The rate of oxidation does not greatly exceed that of erosion, and the alteration has only appreciably effected the ores near the surface. In almost all cases unaltered sulphides are encountered within 10 feet of the surface.

The causes of the limitation of the effects of oxidation are the impervious nature of the schists near the lodes, due to the development of pinite and the consequent destruction of the porosity of the rock, and the rapidity with which the surface waters are carried off. In the description of the topography it has been mentioned that the surface is prevailingly mountainous, and that the slopes are generally so steep that the waters are rapidly carried away to the main drainage channels. The rain-waters, therefore, have little opportunity to act upon the ore-bodies.

In almost all cases the lodes are capped by limonite, due to the oxidation of pyrite and chalcopyrite. The latter mineral also shows alteration to malachite, azurite, and covellite. In the shallow workings iron and zinc sulphides have been converted to sulphates, which are easily soluble in water, and find only a temporary habitat on the walls of the workings.

(G)—Secondary Enrichment.

The metallic minerals of these deposits have been but slightly leached near the surface. In some lodes, as at Sterling Valley and Pinnacles, the selvage is remarkably rich in silver, and in the latter locality contains also a considerable amount of gold. This concentration of the precious metals is an indication of the secondary alteration by leaching of the soluble constituents. The brecciated chert so strongly developed in the Pinnacles and Chester ore-bodies appears to be cemented by pinite and by pyrite. The cementing material has been completely removed in scme parts, leaving the chert in a loosely brecciated condition. The perviousness of the rock is exemplified by the large volume of water flowing from this formation in the underground workings of the Pinnacles Mine. If this chert formation contained metallic sulphides, they have long since disappeared under the solvent action of percolating waters, and any secondary enrichment of metallic sulphides must be below the level of these workings.

At the Lynch Creek lode the iron pyrite constituent has been almost completely removed from the siliceous matrix, leaving only a little limonite in the cellular lode material. The extent of oxidation and subsequent leaching cannot be ascertained, as no developments of any kind have been undertaken.

(H)—Alteration of the Wall-Rock

In almost all of the lodes considerable alteration of the wall-rock, as the result of vein-formation, has taken place. The extent and nature of such alteration depend upon the constitution of the rock and the chemical and physical condition of the ore-bearing solutions. In the Sterling Valley area the change has been brought about by solutions containing much silica, and has resulted in the complete silicification of the porphyroid wall-rock from 2 to 4 feet. The slates do not seem to have been greatly altered, save perhaps the partial replacement along certain planes by siderite and the dissolution of soluble components, resulting in the destruction of the fissility of the rock. The siderite is probably the result of carbonic acid solutions reacting on the iron pyrite. Graphite, which is commonly noted in the slate, may have been an original constituent, but may have a secondary origin.

Felspar porphyry at Pinnacles has been completely transformed into kaolin for considerable distances beyond the vein, and on the other side of the vein the slaty material has been reduced to a soft, puggy mass. These alterations have been brought about by the action of solutions highly charged with carbonic acid and magnesia, resulting in the transformation of portion of the argillaceous constituent to pyrophyllite and pinite. The pyroclastic schists have undergone alteration to pinite. In another part of this report mention is made of the alteration of dolomite rock to talc and serpentine.

(I)—Selvage and Breccia.

In nearly all the lodes selvage is developed on the walls to a greater or lesser extent, and is indicative of considerable movement along the fissure planes. It consists of finely ground wall-rock produced by differential movement of the walls on one another. This finely ground material has suffered chemical change by the action of mineral-bearing waters circulating along the channel thus formed. The selvage carries in some places high values in silver and gold. The selvage on the footwall of the Sterling Valley lode contains 190 oz. of silver per ton; and at the north open-cut, Pinnacles Mine, it carries upwards of 6 oz. of gold per ton.

Fissures in some instances show movement both prior and subsequent to the introduction of the vein material. The large quantity of breccia fragments included in the fissures is indicative of considerable movement between the walls. This brecciated vein material and wall-rock has been cemented by metallic sulphides. The faulted condition of the veins is common to all the ore-bodies, but is more highly developed at Pinnacles. Here, the pre-mineral chert has suffered severe deformation and thorough brecciation.

Further indications of the faulting movements within the fissures are provided by the presence of slipping planes or slickensided surfaces. Such planes have been observed in all the lodes examined, and vary in degree from point to point.

(J)—Erosion of the Ore-Bodies.

There is no basis of comparison by which the full effects of erosion can be measured. The relative rates of erosion of the porphyroid and the schists convey only the most meagre information, and any estimates based on this are purely hypothetical. Notwithstanding this fact, it has been established that the amount of erosion has been considerable. For instance, the outcrops of Sterling Valley ore-bodies, which occur in slates and schists, are in a depression fully 1000 feet below the porphyroid on either side; at Pinnacles the ore-bodies occurring in pyroclastic schists at the base of the hills are 500 feet below the summit. A similar comparison can be made in connection with the Cutty Sark group and others occurring in the porphyroid. At Chester, on the other hand, the ore-bodies are found near the summit of Mt. Kershaw and are wholly pyritic.

It is noteworthy that neither at Pinnacles nor at Sterling Valley, where the erosive effects have been greatest, are the lodes capped with pyrites or its alteration product, limonite. In each case the primary minerals, galena, sphalerite, and chalcopyrite, are found outcropping at the surface.

(K)—Strikes and Dips.

The greater number of the fissures strike in a general direction parallel to the trend of the igneous belt nearby; but some contained in the igneous rock do not conform to this rule. The latter series are discussed in another chapter They strike due east and west, and dip either to the north or to the south.

The general strike of the fissures is from 10 degrees to 30 degrees east of north, and the dip is south-easterly, the angle of inclination being from 60 degrees to 75 degrees. At the southern end of the mining field the strike is from 10 degrees to 30 degrees west of north, and the dip is north-easterly at an angle varying from 60 degrees to 75 degrees.

Another irregular occurrence is that of Samuel Smith's lode, between Farrell Siding and Boco Plains. Here the fissure strikes 10 degrees to 30 degrees east of north, but, in contrast with all other lodes in the district, the dip is north-westerly at an angle between 60 degrees and 75 degrees. This occurrence is referred to in another chapter.

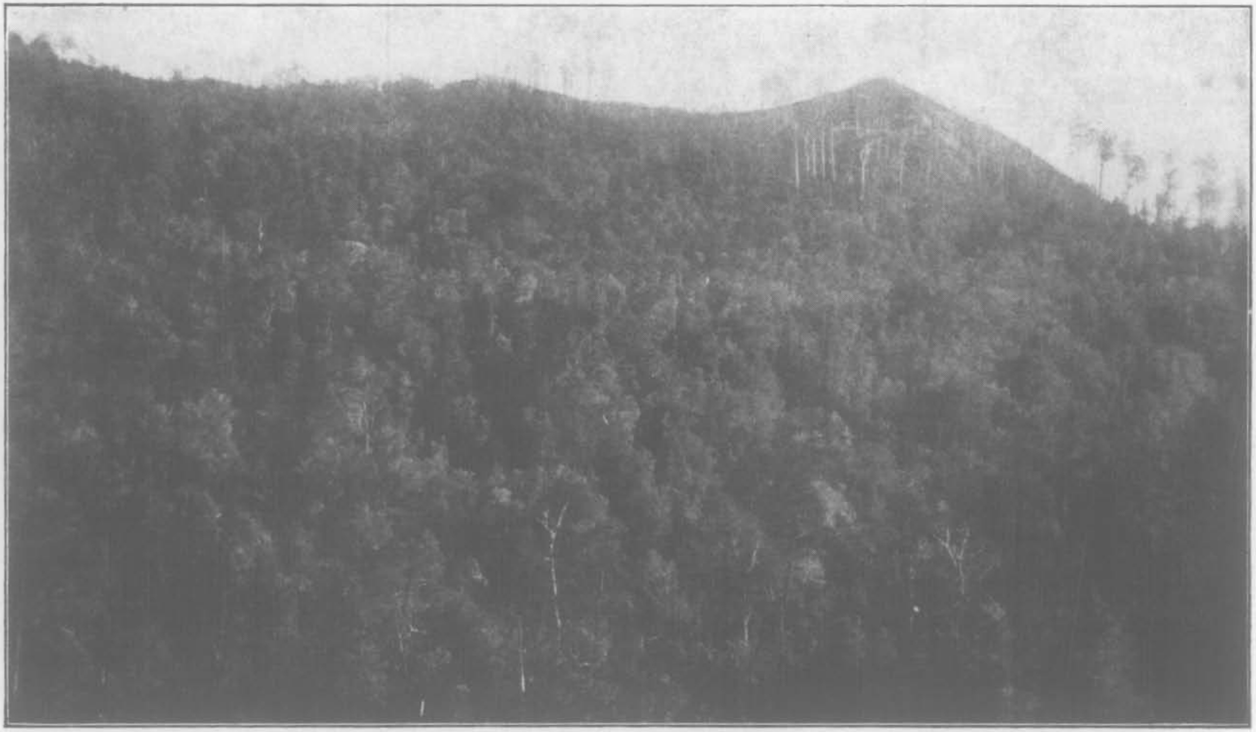


Photo. No. 3.—Mt. Kershaw from the South-east. [H. W. Judd Photo.

VIII.—THE MINING PROPERTIES.

(1)—Chester Mine.

(a) Area, Situation, &c.

The Chester property now consists of: Two mineral leases, 7220-M, 80 acres, and 7221-M, 30 acres; dam site, 1148-W, 37 acres; water-right, 1010-W; tramway lease, 996-T; and lease, 1021-M, 15 acres, at Chester Siding. The mine, owned by the Mount Lyell Mining and Railway Company Limited, and now operated by Messrs. Cuming Smith and Company, is situated near the summit but on the eastern fall of Mount Kershaw, 1400 feet above sea-level, and 800 feet above the Piedmont. The nearest settlements are Tullah, 7½ miles distant eastward, and Rosebery, 7½ miles to the south. The seaport of Burnie is 63 miles distant by rail in a north-easterly direction.

The mine, originally known as Kershaw's Iron Blow, was discovered in the year 1896 by F. Kershaw and H. Sandison, well-known prospectors who figure prominently in the early history of discovery of the western mining division. The earliest developmental work of which there is definite record was performed by these prospectors under the direction of John Godkin, who in 1896 held an option for the purchase of the property. The mine was considered at this time to have a very promising future as a source of copper ore, but subsequent developments failed to realise the expectations of those interested, and in consequence the mine was abandoned. It was found that this immense pyritic ore-body, although containing a little chalcopyrite, zinc blende, and galena, was of value only as a source of sulphur. For this purpose the Mount Lyell Company secured the leases in 1908, and, after thorough examination, mining development on a large scale was undertaken. During the period 1909 to 1913 inclusive development and exploration work was carried on systematically, and a large tonnage of ore, containing 37·2 per cent. sulphur, was excavated, sorted, and shipped.

(b) Ore-bodies.

The predominant mineral constituent of the ore-body is pyrite; accessory minerals are chalcopyrite, galena, sphalerite, hæmatite, and limonite. Associated gangue minerals are pyrophyllite, barytes, calcite, dolomite, chlorite, and talc. Chalcopyrite was detected in only one specimen from the main open-cut workings, though it occurs in appreciable quantity in the southern ore-body. The copper content arising from the admixed chalcopyrite is usually about 0·1 per cent. to 0·5 per cent. higher than which it is seldom found. In but few places is the pyrite entirely free from copper. The iron of an old shovel, which had been lying in a ditch cut to carry off the drainage water from the open-cut, was found to be completely coated with copper. Galena is poorly represented, though it occurs here and there associated always with sphalerite as narrow bands in the fine-grained, massive pyrite filling the small fissures. It is evident that the zinc and lead sulphides were the last of the metallic ores to have been precipitated from solution. Arsenic is either completely absent or its amount hardly reaches 0·1 per cent. A small silver content, 1 to 2 dwt. per ton, is fairly constant, while the amount of gold present is generally insignificant.

The ore-bodies consist essentially of pyrite in an argillaceous and siliceous gangue—mostly pyrophyllite and quartz. Barytes and calcite are fairly abundant gangue minerals, but very irregularly distributed.

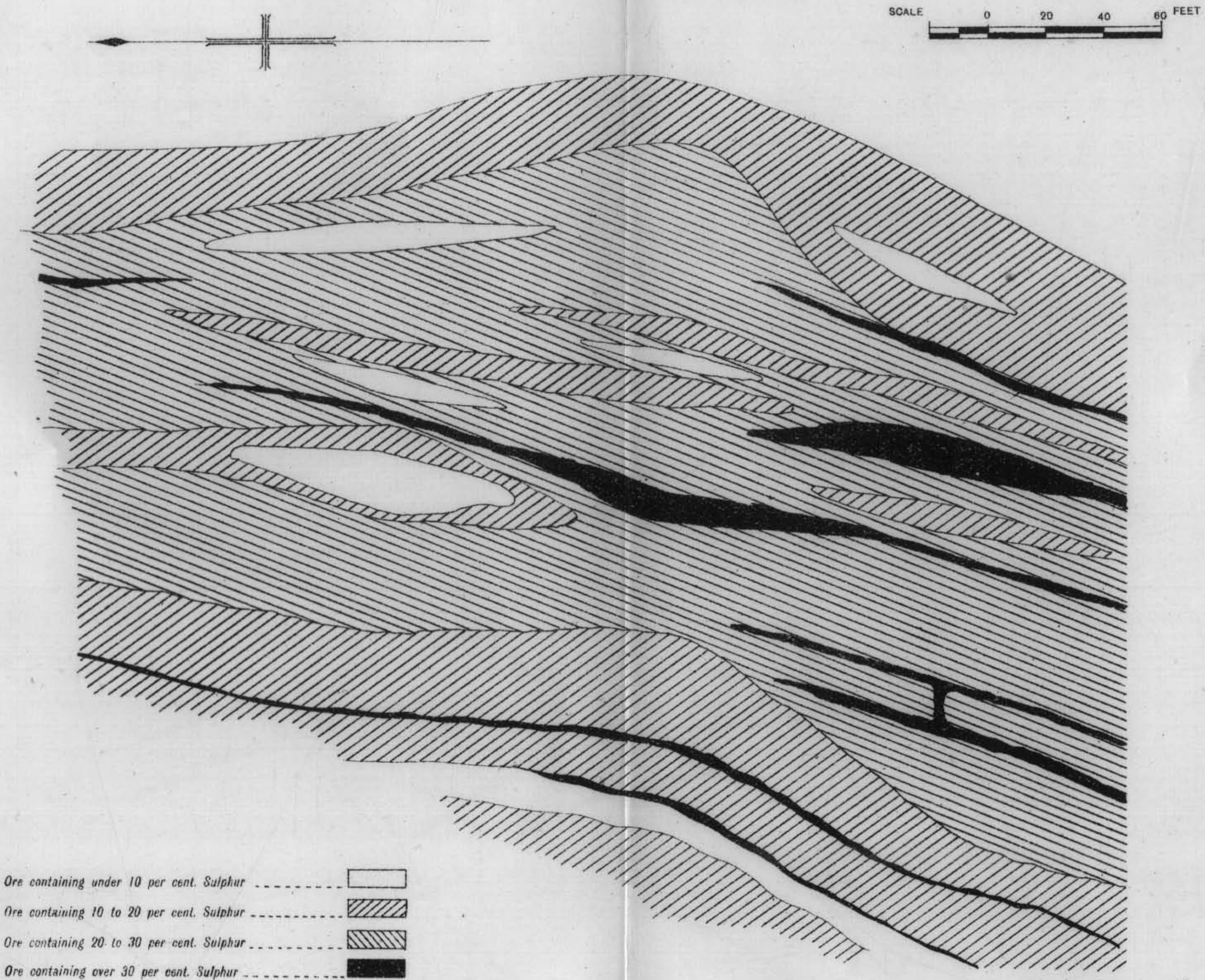
The country-rock in which the ores occur is a schist of variable character made up of both igneous and sedimentary material, the predominant varieties being argillaceous, siliceous, and chloritic. The pyrite occurs also in purely pyroclastic rock and even in the massive igneous rock.

The pyrite deposits are typically lenticular in form, coinciding in strike and dip with the planes of schistosity of the enclosing rock. The strike varies from 10 degrees to 20 degrees east of north; the dip is 60 degrees to 65 degrees in a south-easterly direction. The thickness of the lenses varies from 20 to 280 feet; their horizontal length on the surface at the main workings has been proved to exceed 600 feet, and may be continuous with the south-west workings 1500 feet distant. The extent and value of the ore-body has been determined by diamond-drilling. The lowest and longest bore-holes passed through pyrites of high grade and nearly 300 feet in width. No. 7 bore, 240 feet in length, sent in horizontally from the 1180-feet contour level, passed through 60 feet of 26·23 per cent. sulphur ore, 30 feet of 9·0 per cent., 90 feet of 24·3 per cent., 40 feet of 15·3 per cent., and 8 feet containing 40·0 per cent. sulphur. No. 10 bore, 316 feet in length, sent in horizontally from the

PLATE II.

CHESTER MINE

PLAN OF ORE-BODY



A. McIntosh Reid
Act Assistant Government Geologist

Open Cut. Mt. Kershaw.

Mill Site. Haulage Line.

[A. McIntosh Reid Photo.

Photo. 4.—CHESTER MINE WORKINGS.

1120-feet contour, proved ore of 20 per cent. grade over 250 feet in width, and passed through several small bands containing from 34 per cent. to 46 per cent. sulphur. No. 11 bore-hole, dipping at an angle of 10 degrees, is 95 feet in length, and commences at a point on the 1390-feet contour between the main and south-west workings. The ore-body is much narrower and the grade lower than that of the main workings, but it may prove payable. Nos. 12 and 13 bore-holes were sent through the ore-body exposed in the south-west workings. The lode here is similar in appearance and quality to that in the main workings, but is of lesser extent.

(c) Development.

The ore-bodies have been exposed on the surface by a number of long parallel trenches, placed 100 feet apart, and by deep open-cuts. In addition to these works several shallow pits were sunk, and a crosscut was sent in at the 1150-feet contour from the eastern face of the hill, a distance of 100 feet in a north-westerly direction. The ore-body has been further tested by diamond-drilling to the 1100-feet contour or over 300 feet below the outcrop near the crest of the mountain. The drill-holes were sent in across the lode from the eastern side and extend from the northern end of the main workings to the south-west open-cut, or a distance of 1600 feet.

The ore-body, occurring on the eastern fall of the mountain and dipping with the slope of the surface, is ideally situated for economic mining. Advantage was taken of the natural facilities in adopting the open-cut system. The open-cut, divided into six benches placed 20 to 30 feet apart, is 170 feet deep, 250 feet wide near the hill summit, narrowing to 15 feet at the level of the lowest bench. The cut extends into the hill 150 feet, with inclination sufficient to drain it at the bench levels and to provide for the easy trucking of the ore from mine to bins. The open-cut is towards the north-west across the strike of the lode. Heretofore, the obstacle of greatest importance in the operation of this mine has been the necessity to remove such immense quantities of second-grade material to get at the marketable lump ore. When the narrow rich bands of pyrites were reached on the several benches it was encasing it as is compatible with good mining practice. extracted with as little of the lower grade material The rich ore (containing over 37 per cent. sulphur) was sorted and conveyed in trucks to bins set over the haulage line; the poorer material, containing up to 25 per cent. sulphur, was dumped. A considerable quantity of overburden, consisting mainly of oxidised lode material, has been removed in preparation for an extension of the cut when work is resumed.

From these workings a self-acting inclined tramway, 30 chains in length, carries the ore to storage bins at the foot of the mountain, whence it is transported over a steel-rail ground tramway, 1 mile long, to the main storage bins at Chester Siding.

The south-west ore-body, 1500 feet from the main workings, has been stripped of overburden sufficiently to gain an idea of its extent, and a little work has been done to prove its value.

Still further south a small shaft sunk on the ore-body has exposed pyritic ore containing a much greater proportion of copper pyrites than is usually present in this ore.

(d) Suggested Modification of Mining Method.

The ore-body dipping easterly with the surface slope is almost free of overburden for 300 feet below the outcrop near the summit of the hill. The more resistant lode material is far less eroded than the softer tuffs and felsites which directly overlie the schists containing the ore. Advantage was taken of these conditions in adopting the present system of mining and the transportation of the ore to the storage bins at the foot of the hill. No exception could be taken to the system adopted under the conditions obtaining at the time, when only the highest grade ore, containing over 35 per cent. sulphur, was sought. Now it is intended to extract ore of all grades and concentrate the pyrite content in the milling plant at present in course of erection. The site of the milling plant is directly below the main open-cut, about halfway down the haulage line, and is so placed that a much more economical method of mining may be introduced. The suggested modification is, in effect, an adaptation of what is generally known as the "milling" system of open-cut mining. In the application of this system to the Chester ore-body the procedure is as follows:

A main tunnel or crosscut—large enough to admit of horse traction if necessary—commencing at the level of the top of mill bins, is driven at right angles to the open-cut workings. The grade of the tunnel would be such that the loaded trucks may gravitate from the working face towards the mill bins. When this tunnel has reached a point at right angles to the ore dumps, drives are sent in underneath these dumps and rises carried to the surface; at the same time the main tunnel is continued towards the ore-body. The second-class ore (60,500 tons) dumped is rilled to these rises and supplies sufficient cheap material to keep the mill in operation until development has been advanced to such a stage that the main ore-body is ready to be attacked. When the tunnel has reached a point directly below the lower benches of the open-cut, drives are sent in on either side in a direction parallel to the strike of the ore-body; from these drives rises—about 50 feet apart—are carried through to the open-cut workings. The ore is broken directly into the rises, which serve as storage bins. In applying this method it will be found convenient to break the ore in benches not less than 30 feet high, and to arrange long working faces, in order that a large number of men may be employed at one time.

It must be kept in mind that once the ore-body is entered the development by tunnelling and rising produces almost enough ore to pay for this work. The cost of tunnelling through the soft decomposed felsitic rock would not be much greater than the cost of the construction works required to connect the mill bins with the haulage line. It obviates the necessity of so much handling of the ore from the mine to the mill bins, and eliminates altogether the employment of the now unsatisfactory haulage line. The suggested alteration would permit of the bench system of open-cut mining being continued, and would not necessitate any outlay on special works other than that required for driving and rising.

(e) Ore Reserves and Production.

At present development is well ahead of mining, and very large tonnages have been proved to exist by diamond-drilling the ore-body. The irregularity of the ore-body precludes an exact estimate of volume being arrived at, but an attempt has been made to form some idea of its size by calculation from data gained by diamond-drilling. The quantity of probable ore has been estimated on this basis at 2,800,000 tons. The ore contains in bulk over 20 per cent. sulphur, this also being the proportion contained in the second-grade material dumped. The greater part of this immense ore-body is as yet untouched. Below the 1100-feet contour no drilling has been done, but at this level ore of exceptional quality and in large quantity has been intersected.

The critical worth, below which mining at a profit cannot be counted on under prevailing conditions, has been put at the value of 15 per cent. sulphur ore. In arriving at this figure allowance has been made for the inevitable post-war reduction in the market value of pyrite. All rock containing a less percentage could not, on this basis, be estimated as ore. The narrow lean or low-grade bands of ore occurring in the ore-body will undoubtedly be mined with the richer ore, and will act as a diluent, reducing somewhat the average grade. In handling large quantities it will be found unprofitable to attempt to separate these poor bands from the richer material; and it may be found even that the very rich ore, which occurs in narrow bands from 1 to 5 feet thick, will be more cheaply separated by milling than by hand-sorting at the mine. In any case the very rich ore, not requiring concentration, must be crushed dry before export. The objections to sorting at the mine are that special arrangements must be made for storage and handling, and the delay in the removal of the broken ore militates against economical operation.

The following particulars relating to the production of pyrites ore from the Chester Mine have been supplied by the Mount Lyell Mining and Railway Company:—

Period.	Surface Stripping Removed.	Oxidised Overburden Removed.	Seconds Dumped at Mine.	Percentage of Sulphur in Seconds Dumped.	Units of Sulphur in Seconds Dumped.	Seconds Stacked on Mine.	Percentage of Sulphur in Seconds Stacked.	Units of Sulphur in Seconds Stacked.
	Tons.	Tons.	Tons.	Per Cent.		Tons.	Per Cent.	
Up to March, 1913.	11,474	12,407	53,446	21·21	1,133,928·1	...	...	...
For half-year ending 30th September, 1913	115	1152	7099	20·09	142,645·6	276	29·97	8271·9
Totals	11,589	13,357	60,545	Average 21·08 per cent.	1,276,573·7	276	29.97	8271·9

Iron Pyrites sent to Yarraville Sulphuric Acid Works.

Period ending 1913.	Pyrites exported *viâ* Burnie.				Percentage of Sulphur contained in Pyrites Exported.	Units of Sulphur contained in Pyrites Exported.
	Tons	cwt.	qrs.	lbs.	Per Cent.	
Total at March, 1913..	31,821	9	2	17	37·54	1,194,628·29
Total half-year ending 30th September, 1913	4402	2	3	0	35·16	154,784·19
Totals 30th September, 1919.	36,223	12	1	17	Average 37·25 per cent.	1,349,412·48

(f) Estimate of Cost of Production.

	s.	d.
Mining, per ton	2	4
Handling at mine	0	4·5
Delivery of ore from mine to mill	0	4·5
Milling and mill repairs	1	8
Development	0	6
Depreciation and repairs	0	5
Supervision and official expenses	0	5
Total cost of crude ore mined and milled, per ton	6	1

The discarded broken ore is estimated to contain 20 per cent. sulphur, and the ore remaining *in situ* contains over 20 per cent. sulphur. As the grade of the ore must be increased from 20 to 40 per cent. to be marketable, it appears that 1 ton of 40 per cent. concentrated ore is recoverable from 2 tons of crude ore. Assuming a loss in milling of 30 per cent. of the pyrite contained in the ore owing to the lack of slime-saving appliances, the recovery would then be in the proportion of 1 to 3.

On this basis the concentrated ore at the mill bins would cost 18s. 3d. per ton—adding to this sum 4d. to defray the cost per ton of the delivery of the concentrates from the mine to the railway siding; and 1d. per ton cost of loading—the total cost amounts to 18s. 8d. per ton on Emu Bay Railway trucks at Chester Siding. These estimates are based on the production of comparatively small quantities of ore, and may be considerably reduced by operating on a larger and more comprehensive scale.

The determining factors in pyrite production are:—The cost of transport; the nature of the gangue material, and the presence of deleterious impurities; the suitability of the ore for effective and complete roasting; and the cost of mining and concentration.

(g) Water-supply.

The Chester Mine is favoured with a splendid site for water conservation. About 10 chains north of the main open-cut workings a dam site of 37 acres has been leased. This dam site is a button-grass covered, almost land-locked basin, the only outlet of which, from 2½ to 3 chains wide.

is at the south-east corner. This natural basin is at an elevation of 1200 feet above sea-level, or 400 feet above the foot of the hill. The catchment area of the basin is very small, but the supply of water will be drawn from Hollway Rivulet, to which a water-race has already been surveyed from the dam. The dam will not be utilised for water conservation at this stage, as all the water required is for milling purposes and will be drawn directly from Hollway Rivulet, which, even in the summer months, carries enough for this purpose. The water wil be conveyed by water-race to the northern end of the basin, thence from the southern end to the intake of the pipe-line directly above the mill.

(h) Equipment.

Provision is made for the transportation of the ore from the mine to the foot of the hill by means of a self-acting inclined tramway from the open-cut to the foot of the hill, thence to the siding by a well-formed ground tramway. The self-acting inclined tramway is a double road, steel-rail, 2 feet 6 inch gauge line, designed on the gravity plane principle. The trucks are controlled by brake-blocks operating upon two grooved wheels, 7 feet 6 inches and 8 feet diameter, set horizontally, which carry the rope. The rope passes round the back wheel, thence round the front wheel, returning to the back and again to the front until three turns are taken. The friction induced by the large surface of the rope applied to the wheels overcomes the tendency of the rope to slip round the wheels when the brake is sharply applied. The brake blocks are set directly above the rope grooves, and are attached to double-acting levers which in turn are connected by a rod to the brake wheels. The trucks, 15 feet x 4 feet x 3 feet, are of the double-bogie type with central discharge, and hold 8 tons of pyrite. The haulage, about 30 chains in length, is capable of handling 200 tons of ore per working day of eight hours. The working of the haulage line is rather cumbersome, owing to the constant varying strain on the brake gear, and requires careful handling to stop the trucks exactly at the desired position. By adopting the tail-rope system, and thereby equalising the strain or load, much of the difficulty encountered heretofore in working the haulage may be obviated. The grade of the haulage increases from 1 in 40 at the foot of the hill to 1 in 2 at the send-off.

Accommodation for upwards of 80 men is provided in well-appointed commodious huts. A well-furnished hall, about 60 x 30 feet, used for church services, meetings, and as a club-room, was built by subscription augmented by the Mount Lyell Company. Other buildings include manager's residence, mine offices, workshops and boarding-houses, provision store, and a post and telephone office (temporarily closed).

A concentrating plant, capable of treating 100 tons of ore per working day of eight hours, is at present in course of erection. Additional equipment includes an air-compressor plant designed to supply power to twelve rock-drilling machines.

(i) Pyrite Concentration.

Pyrite ore, as it is broken at the mine, is not in a condition suitable for roasting in the furnace. A considerable quantity of the first-grade ore will be in lumps too large to be economically utilised in this condition, and will require reduction by crushing to about 3-inch size; the second-grade ore, containing much waste rock, must be subjected to further treatment to remove the greater part of the useless material and thereby increase the sulphur content of the ore.

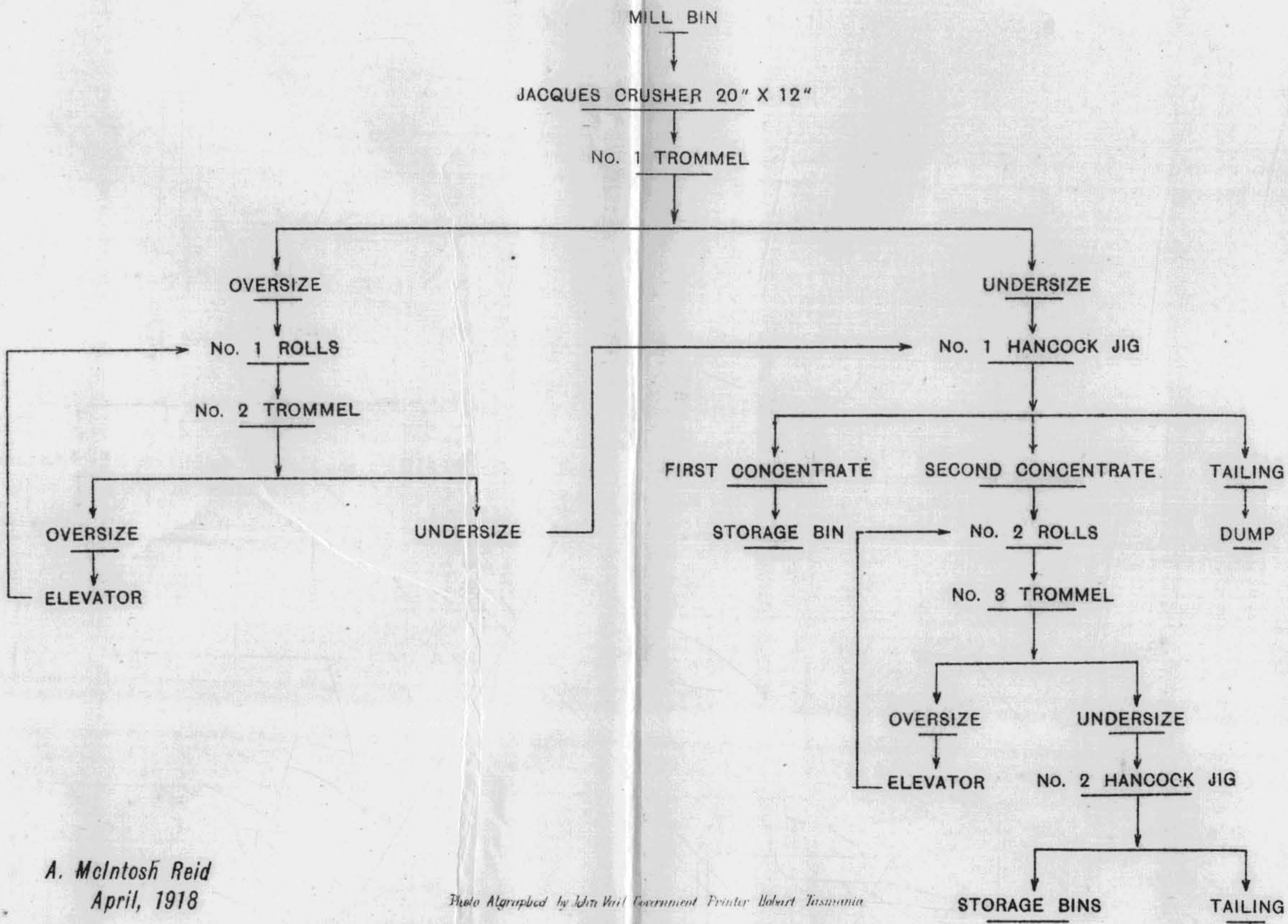
The separation of pyrite from gangue material such as pyrophyllite, quartz, and calcite, is very easily accomplished owing to the difference between the specific gravity of the ore and the minerals composing the gangue. The specific gravity of pyrite is 4·95 to 5·10; pyrophyllite, 2·8 to 2·9; calcite, 2·71; and quartz is 2·66. Barytes occurs as a constituent of the lode matter of the Chester Mine, but, although it cannot be separated from pyrites by water concentration, the relative quantity present is so small that it will not materially affect the value of the concentrate. The specific gravity of barytes is 4·3 to 4·6, only a little less than that of pyrite.

The object to be aimed at is to produce a concentrate as high in sulphur content and as free of all deleterious substances as is possible. Zinc, lead, antimony, copper, calcium, and magnesium are undesirable impurities; arsenic, if only in small quantities, does not greatly affect the value of the resultant sulphuric acid if the latter is to be employed in the manufacture of fertilisers. Pyrite containing copper is more valuable, but it is necessary to only roast it to such a point that the copper still remains in the form of

FLOW SHEET

PLATE III.

PYRITE MILLING PLANT



A. McIntosh Reid
April, 1918

Photo Algraphed by John Vail Government Printer Hobart Tasmania sulphide, because it is thus more easily extracted. Lead, zinc, and calcium carbonate are disadvantageous in iron pyrite because they form soluble sulphates on roasting. Pyrite which is poor in sulphur gives a smaller relative yield, and the cost of working is proportionately greater for the same quantity of sulphur than in rich pyrite.

Very fine-grained dense ore is sometimes objectionable because it decrepitates violently in the furnaces. This can be obviated by reducing the pyrite to "fines" and roasting in shelf burners.

The size of the ore for exportation depends upon the nature of the roasting plant—some plants treat only "fines," others "fines" and lump ore.

(j) Milling Tests.

The following particulars relating to milling tests of the Chester pyrite ore have been supplied by Mr. L. Williams, late Manager of the Chester Mine.

In July, 1911, a parcel of low-grade pyrite ore, weighing 211 tons (dry weight), was treated in the North Mount Farrell Company's concentrating plant at Tullah. This parcel was truly representative of the ore-body, and even included portions of the wall-rock which were broken during the operation of mining. Although the mill was not designed for the concentration of pyrite ore, the test may be regarded as satisfactory, as it proved conclusively that a complete separation of the pyrite from the gangue can be made. The test, extending over three days, was not continued long enough to effect the necessary adjustments to the plant to produce the best results; but, at the end of the third day, the alterations then made resulted not only in a more complete separation, but also in a higher grade concentrate. Information concerning the weight of concentrated ore recovered by each unit of the plant is not available. The 211 tons of crude ore treated, containing 20·46 per cent. sulphur, produced 61¼ tons of concentrated pyrite, containing 35·17 per cent. sulphur.

The highest grade jig concentrate contained 38 per cent. sulphur; the highest-grade sample from card table contained 50·40 per cent. sulphur; the highest-grade sample from Wilfley table contained 44·60 per cent. sulphur; the highest-grade sample from Sperry slime table contained 46·60 per cent. sulphur. Loss in tailing from jig, 12 per cent. sulphur; from Wilfley table and card table, 8 per cent. sulphur; from Sperry slime table, 6·4 per cent. sulphur.

No attempt was made to effect the separation of the gangue material from the adhering finely-crystallised pyrite which passed out in the jig tailings. To bring about this result the coarse jig tailing must be subjected to such comminution that the pyrite particles become detached from the gangue. The crushed product is then treated on concentrating tables to complete the separation.

In March, 1913, further tests were made on a smaller parcel by Mr. Lonsdale Smith, of the Mt. Bischoff Extended Mine, Waratah. The ore, after having been crushed, was passed through a 40-mesh screen, mixed with water, and, without previous classification, fed to a Wilfley table. The crude ore contained 13·43 per cent. sulphur, from which a 35 per cent. recovery of concentrate was made, containing 41·5 per cent. sulphur.

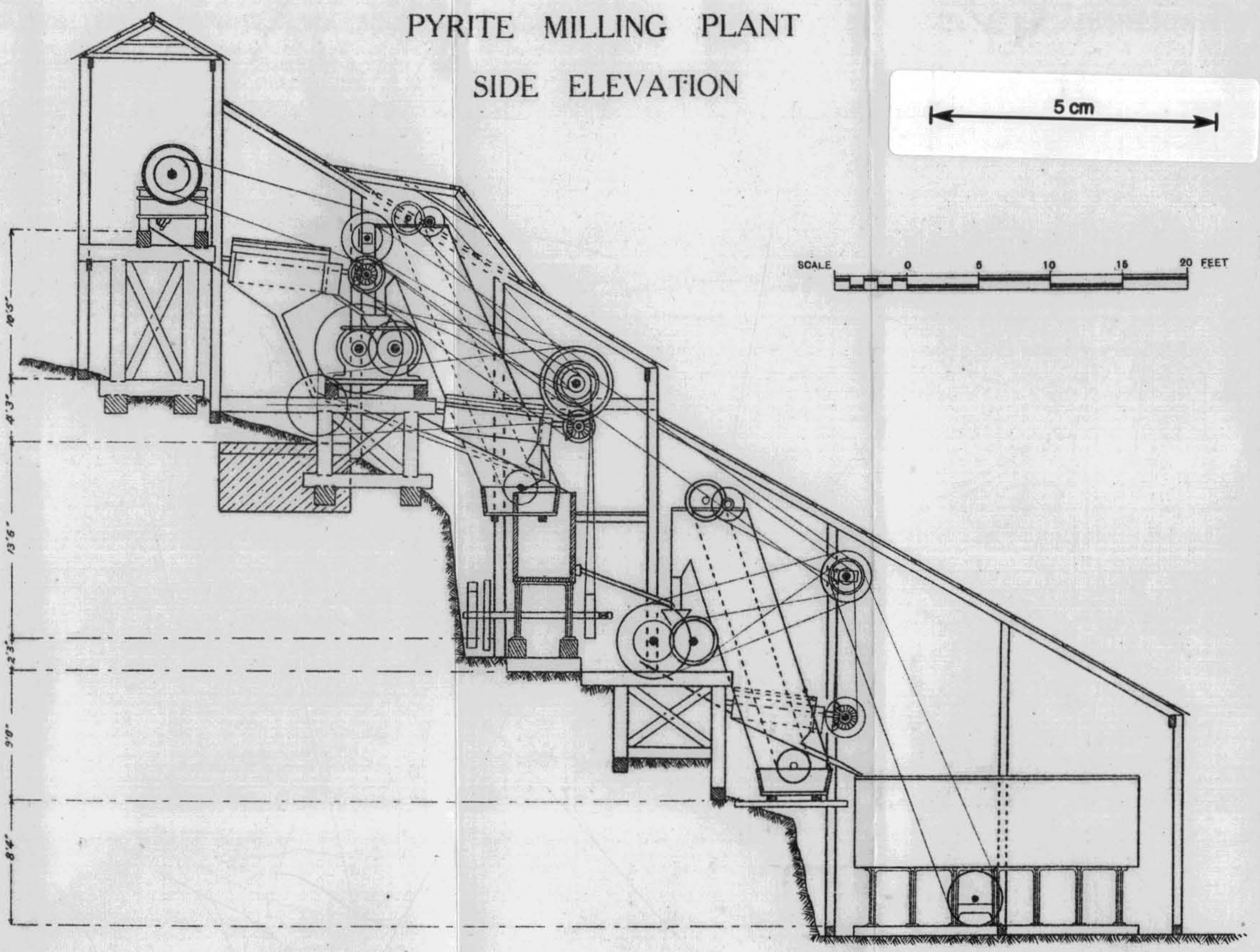
These tests show that the bulk of the ore is in a very fine state of division, but may be easily separated from the soft, argillaceous gangue material, and concentrated to a highly marketable product, by grinding to a fineness equal to the size of the particles of crystallised pyrite, and treating on concentrating tables of card or Wilfley type.

(k)—Process of Milling.

The ore from the mill bin is run on to a grizzly or a perforated shaker; the finer particles pass to trommel No. 1, the coarser are conveyed to the crusher. The crusher is a 20-inch by 12-inch Jacques (Richmond, Victoria) roll-jaw, stone-breaker, and is run at 280 revolutions per minute, and crushes to 25 mm. size. The product from the crusher falls to No. 1 trommel (perforations 5 mm. in diameter), which is run at 25 revolutions per minute. The finer particles (undersize) are delivered to No. 1 Hancock jig, the coarser (oversize) to No. 1 rolls (30-inch by 16-inch), which is run at 105 revolutions per minute, and crushes to 5 mm. size. The crushed ore is conveyed to No. 2 trommel (of the same mesh as No. 1); the oversize is returned by elevator to No. 1 rolls to be recrushed; the undersize is led to No. 1 Hancock jig. The first-grade product of No. 1 Hancock jig is taken to the storage bin; the second-grade passes to No. 2 rolls, thence to No. 2 trommel, which has perforations 2 mm. in diameter. From No. 2 trommel the oversize is returned by elevator to No. 2 rolls and recrushed; the undersized particles are conveyed to No. 2 Hancock jig.

PLATE IV.

PYRITE MILLING PLANT
SIDE ELEVATION



A. McIntosh Reid
actg Assist. Government Geologist

Photo Algraphed by John Vail Government Printer Hobart Tasmania.

The first-grade product of the No. 2 Hancock jig is delivered to the storage bins, the tailing and the second-grade product is dumped.

The concentrating plant is driven by a suction producer gas engine of 80 brake horsepower. This engine against full load consumes 10 bags of charcoal in eight hours. The charcoal used is a residual by-product from the volatile products of wood in the manufacture of acetic acid, wood alcohol, &c., and costs, delivered at Chester Siding, 2s. 6d. per bag. A small suction producer gas-engine will be installed to provide motive-power to a dynamo, which will be used to provide light for mill-house illumination.

The capacity of the mill is put at 12 tons of crude ore per hour, or (working 16 hours per day, and allowing for stoppages and repairs to plant) at the rate of 1000 tons per week. This quantity (assuming a loss of 30 per cent. owing to insufficient comminution to separate the fine particles of ore and gangue and the non-inclusion of slime-saving machinery in the milling plant) would produce over 300 tons of high-grade concentrated pyrite per week.

The Hancock type jig is peculiarly adapted for the concentration of low-grade ore such as pyrite, on account of its ability to treat a crushed product of varying size, and also because of its large capacity. The addition of sand and slime concentrating tables to the present milling plant will greatly increase its efficiency, as much of the pyrites, though well crystallised, is in a very fine state of division, and will require further reduction to separate it from the adhering particles of gangue. Some companies employ in addition a drying plant to remove a portion of the large quantity of moisture contained in the fine concentrate, and thereby reducing the cost of freight. There are so many disadvantages in this practice to offset the saving in freight, when much handling is entailed in the conveyance of the concentrated ore from the mine to market, that it may be neglected.

In the design of machinery employed in the concentration of pyrite ore it has been found necessary to use woodwork as much as possible in those parts exposed to the action of the sulphuric acid, which is naturally generated by the oxidation of sulphur contained in the pyrite; and, for the same reason, the milling plant should be run clear of ore. and wash-water run through before closing down. The action of weak sulphuric acid solutions upon the ironwork of the plant is such that depreciation and cost of repairs are very heavy.

The estimated cost of the machinery, timber, and the erection of plant and buildings, for a concentrating plant such as that illustrated in Plate IV., is from £3000 to £3500.

(l) General Remarks.

The existence in Australia of a large and rapidly-increasing market for pyrite justifies the extensive exploitation of known pyrite deposits of economic importance, and the development of any ore-bodies of promise. The present market and the high-prices prevailing are due mainly to the failure of Spanish supplies and the increased demand for fertilisers.

With railway communication so close at hand, the installation of modern milling appliances, and the adoption of economic mining methods, it should be possible to profitably exploit such low-grade formations as that exposed at Chester, where a very large tonnage of ore has been proved to exist by developmental work. There should be no difficulty whatever in supplying the future mill with sufficient ore in order to maintain an output of 350 tons of concentrated pyrite per week.

The mining and treatment of purely pyrite ores will be profitable only where large tonnages are produced. The profit per ton is so very small that producers often find it difficult to carry out developmental work far enough in advance of extraction to ensure a large regular output. At the Cheser Mine very large reserves of ore have been opened up, so that no difficulty need be anticipated in this connection.

(2)—Sections 3711m and 3712m.

One of the original lessees (Mr. A. C. Gordon) reports having discovered galena in a heavily-pyritised formation on these sections. The occurrence is near the junction of pyroclastic schist and slate. So little permanent developmental work has been done that no idea of its value can be formed.

(3)—Section 1893-93m, 33 Acres.

About 100 yards from the north-west corner of this section, at a point near the Pinnacles track, an outcrop of pyrites has been discovered during the present examination. So much of the surface is covered with peat that it is difficult to ascertain the extent of the deposit. It is contained in a siliceous gangue, and occurs in pyroclastic schist.

(4)—Section 1894-93m, 38 Acres.

Another discovery of pyrite has been made near the intake of the water-race at Hollway Rivulet. The pyirtes occurs coarsely crysallised in a quartz gangue as a strongly-defined deposit contained in tuffaceous material. This deposit is worthy of further attention.

(5)—Pinnacles Mine.

Sections 7146-m, 80 acres; and 7147-m, 40 acres.—The Pinnacles Mine is situated 2½ miles north of Chester, on the western fall of Pinnacles Hills.

All the important workings are included in the two sections leased by Mr. W. J. Hodge, of Zeehan.

The lodes were discovered by McGuinness Bros. in 1896, and developmental work at shallow levels has been carried on in a desultory manner ever since. Recently a considerable amount of developmental work was done by mining companies and syndicates, with the object of determining the prospective value of the deposits.

(a) *Ore-bodies.*

The most striking feature of the Pinnacles ore-bodies is the very great development of silica, usually in the form of chert. The chert occurs in two or more bands from 20 to 50 feet wide, separated by argillaceous sediments (altered slate) and pyroclastic material. It occurs along or in proximity to massive porphyroid, and is derived from siliceous solutions which emanated from these highly acidic igneous rocks during the later stages of solidification.

Under the action of compressive stresses this cherty rock has developed a decided banded structure resembling cleavage. During the period of ore-deposition the rock suffered severe deformation and brecciation, thus providing an easy channel of access for mineralising solutions. The brecciated particles are found to be cemented by chalcopyrite and pyrite derived from ascending solutions introduced along the cracks of the brecciated rock. Subsequent to this mineralisation, further movement led to the reopening of the fissure, and there ensued a second stage of ore-deposition in which galena, sphalerite, chalcopyrite, barytes, pyrite, and pyrophyllite were precipitated more or less simultaneously. These ore-bodies are typical examples of breccia veins, and usually strike parallel to the general structural planes of the country-rock.

Slipping-planes or slickensides, along which selvage is present, were observed striking parallel to the veins. The selvage in the north open-cut workings was found to contain upwards of 6 oz. of gold per ton. The amount of selvage is indicative of considerable movement along the fissure-planes.

The full extent of the mineralisation cannot be determined until further development has been effected.

At considerable distances beyond the fissure the brecciated rock is found to contain pyrite, and, in very much lesser amounts, those other metallic sulphides contained in the lode proper. The points to be determined are—firstly, whether mineralisation was intense; and secondly, whether it extended far from the fissure. If the brecciated chert originally contained much mineral matter the greater proportion has been leached out by meteoric waters. The rock is so easily pervious to water that oxidation down to water-level would be thorough and complete.

(*b*) *Development*.

The nature and extent of the Pinnacles ore-deposits have been investigated at a number of points on the surface by open-cuts and trenches, and at shallow depths by shafts and tunnels. At all of these places ore of fair grade is exposed, and at two points rich zinc-lead sulphide ore-bodies have been opened up. Developments extend from the northern part of Section 7146-M to the southern boundary of Section 7147-M, or over a distance of 40 chains. The ore-body exposed in the south open-cut on the southern boundary of Section 7147-M is probably the most important development from an economic point of view, and offers the greatest encouragement to further exploration.

The natural conditions are not favourable for economic development by means of tunnels, as the ore-bodies outcrop along the western flank of Pinnacles Hills only 40 to 60 feet above their base. The southern ore-body offers greater opportunities in this connection, and could be

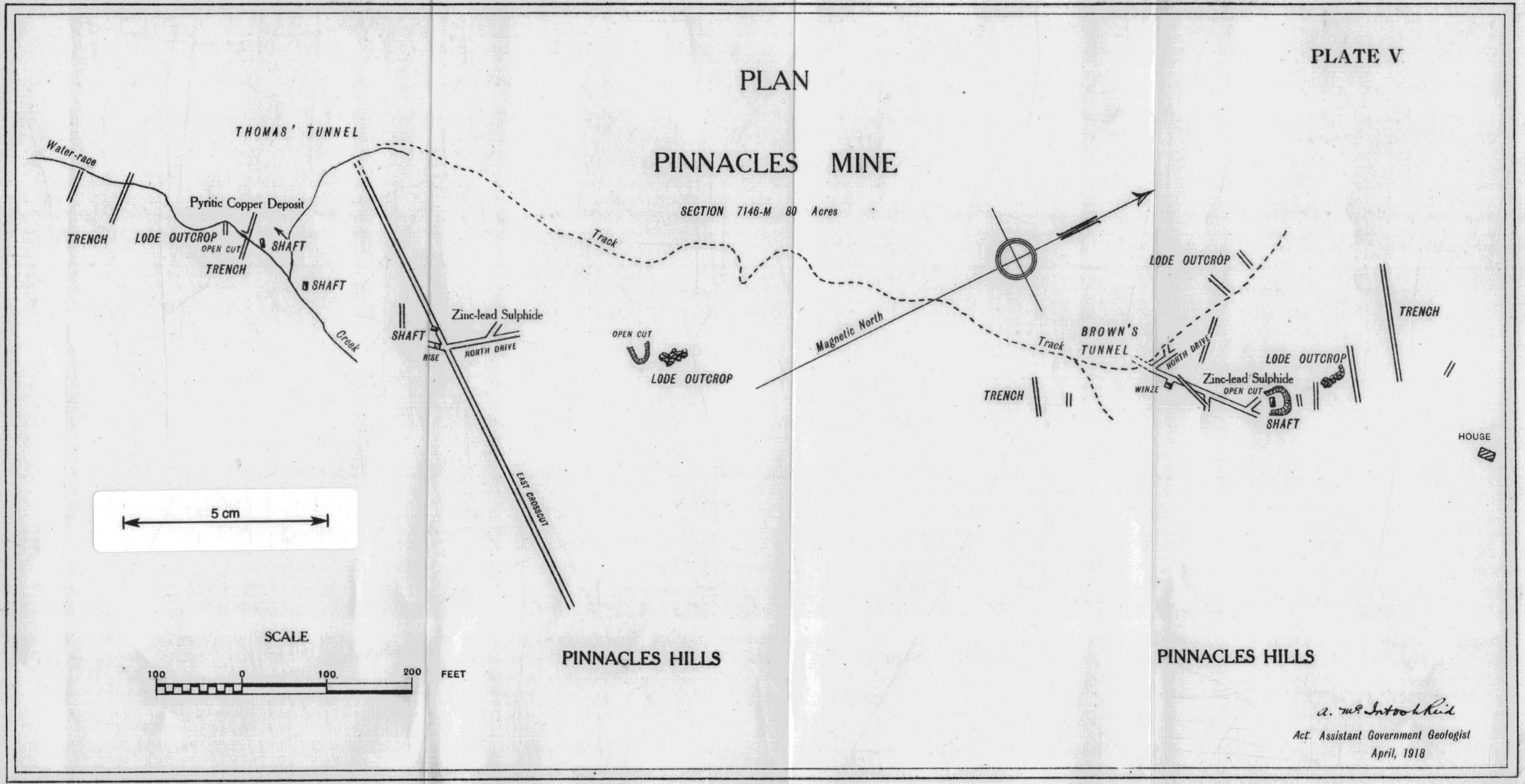


Photo Algraph John Vail Government Printer Hobart Tasmania

attacked at a depth of 200 feet by a tunnel driven from the Marionoak valley.

The present tunnels at the points where the lodes are cut are not more than 60 feet below the surface, and the shafts also are only 30 to 40 feet deep. Development by means of shafts was found to be very costly owing to the large volume of water encountered.

(c) North Open-cut and North Shaft.

The north open-cut is situated on the eastern face of a small knob, 140 feet north of the entrance to Brown's tunnel. The lode outcrops strongly from McGuinness' trench past Brown's tunnel up to this point; thereafter it is not exposed on the surface, but is cut in several trenches further north. Between Brown's tunnel and the open-cut a band of high-grade zinc-lead sulphide ore 1 foot wide shows on the surface. This band of rich ore is encased in brecciated chert, which, with the zinc, lead, and copper sulphides cementing it, was formed at an earlier stage of ore-deposition. The open-cut is only of small extent, being 20 feet wide 30 feet long, and 20 feet deep. In the floor of the open-cut a shaft has been sunk 30 feet on the band of zinc-lead sulphide ore. The whole lode-formation, consisting dominantly of siliceous material, at this point has a massive appearance, and is fully 20 feet in width. Selvage in the form of black pug occurs on the footwall carrying strikingly high gold and silver values.

The lode is contained in argillaceous and siliceous schist near the junction with felspar porphyry.

The following table contains the results of a number of analyses made of the ore from these workings:—

	Tonnage.	Iron.	Zinc.	Lead.	Copper.	Gold.	Silver.
	Tons.	%	%	%	%	Ozs.	Ozs.
			North Open-cut.				
Oxidised capping..	8·00	3·48	0·65	Nil.	0·20	0·30	0·75
Siliceous lode matter	25·00	5·04	1·60	Nil.	0·86	0·30	0·75
Black pug	0·075	7·13	29·46	Trace	1·82	6·20	5·30
Copper-lead-zinc sulphide ore......	0·050	5·22	17·04	10·17	1·18	1·45	4·59
Clayey material ...	4·00	4·78	1·40	Trace	0·27	0·16	1·04
Zinc-lead sulphide Ore	—	4·80	34·5	29·4	1·50	1·20	10·60
			North Shaft.				
Siliceous lode matter	23·0	6·70	3·20	Trace	0·54	0·25	0·85
Ditto	20·0	8·96	3·10	0·69	0·34	0·25	0·85
Ditto	14·4	7·05	2·00	0·30	0·12	0·05	0·45
—	2·0	7·73	2·10	0·54	0·19	0·05	0·35
Zinc-lead sulphide ore from 11 feet depth...............	—	9·22	17·80	19·74	4·31	2·30	7·70

(d) Brown's Tunnel.

This tunnel, sent in across the ore-body in a general north-easterly direction, is part of the work carried out in the year 1899 by A. T. Brown on behalf of the Tasmanian Pinnacles Proprietary Limited.

These workings expose a very wide mineralised zone, the most striking characteristic of which is the great development of cherty quartz. The chert crumbles on the application of a little pressure. This is due to the presence of innumerable, indistinguishable, uncemented fractures. The metallic minerals are usually exceedingly fine-grained, but, although found disseminated in small amount over a very wide area, occur in large particles concentrated near the footwall.

One of the richer ore shoots is passed through in the approach trench at the entrance to the tunnel. This shoot has been driven on northerly for 31 feet. On the left side of the drive and in the cuddy sent in westward the material is brecciated chert; on the right side galena and zinc-blende, associated with cellular quartz, pyrite, and selvage material, occupies an infiltration channel 6 inches wide. This ore is erratic and short.

At a point on the southern side of the crosscut, 25 feet from the entrance, a winze has been sunk 20 feet on a small vein of zinc-blende ore. The shoot at this depth has not shown any improvement.

From the crosscut 35 feet farther on a short drive has been sent in south-eastward on a band showing heavy pyrite mineralisation. Fifty feet farther eastward along the main crosscut a cuddy has been driven northward through pyritic material contained in chert. The crosscut was continued 23 feet farther in similar mineralised siliceous rock.

The rich band of zinc-lead-copper sulphide ore exposed in the northern workings nearby occurs on a smaller and poorer scale here. Very little barytes is present, and pyrophyllite is much less abundant than in the southern workings.

Analyses of bulk samples of considerable quantities of mineralised chert, broken from different parts of the workings, were made and gave the following results:—

	Tonnage.	Iron.	Zinc.	Lead.	Copper.	Gold.	Silver.
	Tons.	%	%	%	%	Ozs.	Ozs.
Main End.							
Siliceous lode material	125·5	3·91	0·62	Trace	0·045	0·037	0·396
North Drive.							
Siliceous lode material	76·25	3·57	0·83	0·06	0·05	0·027	0·235
Lode at Entrance.							
Siliceous lode material	91·0	11·75	1·99	0·47	0·343	Trace.	1·098

(e) *Main or Thomas' Tunnel.*

These workings, situated 12 chains south-west of Brown's tunnel, consist of a long crosscut sent in 581 feet on a bearing 96 degrees, from which a north drive on the lode 85 feet long is sent in at 263 feet on a bearing 20 degrees 40 minutes, and a south drive commencing at the same point is sent in 18 feet on a bearing 218 degrees. From a point 14 feet along the south drive a rise connects with the surface.

The crosscut passes through 250 feet of kaolin, which is derived from the decomposition of the felspar constituent of the porphyry. This felspar porphyry forms the footwall of the lode, and near the north drive is fairly solid. At 263 feet the lode is passed through, thence the crosscut penetrates black argillaceous schist and altered slate in alternate bands, white argillaceous (pinitic) schist, and lastly hard siliceous rock similar to that occurring in Brown's tunnel. A very large volume of water is flowing from the face.

The lode is 3 feet wide, and dips south-easterly at 82 degrees. It consists dominantly of barytes, with galena, sphalerite, chalcopyrite, and pyrite as accessory components. The galena usually occurs as small particles scattered through the barytes, but is found also in massive form associated with chalcopyrite and sphalerite. Copper pyrites occurs also as blebs and as capillary filaments in the zinc-lead sulphide ore. The metallic sulphides are contained in a gangue of pyrophyllite and chlorite. In some specimens there is a decided banded arrangement of the metallic constituents. The ore shoot is encased in cherty quartz which appears banded and possesses a sharp cleavage.

In the crosscut several minor veins were cut, but were not followed. In every instance they are poor, being generally composed of pyrite.

The following is the result of an analysis of the ore stacked at the entrance to the tunnel :-

	Tonnage. Tons.	Iron. %	Zinc. %	Lead. %	Copper. %	Gold. Ozs.	Silver. Ozs.
Siliceous lode matter carrying galena...	52	1·62	4·51	7·25	0·12	0·025	7·65

(f) McGuinness' Shaft and Trenches.

These workings are situated 120 feet south of the entrance to Thomas' tunnel, and consist of a shaft 30 feet deep and two open trenches sent in across the ore-body. Here the ore consists of brecciated chert cemented by chalcopyrite, pyrite, and sphalerite. The ore-body is contained between grey argillaceous schist on the footwall side and black argillaceous slaty material on the hanging-wall.

A bulk sample of 5 tons of siliceous lode-matter stacked at these workings showed by analysis that the ore contains :—

Iron.	Zinc.	Lead.	Copper.	Gold.	Silver.
5·39%	1·75%	Trace	1·43%	0·03 ozs.	0·97 ozs.

(g) West Trenches.

These workings consist of four parallel trenches, the first of which is situated 90 feet westward of North Open-cut. They expose mixed sulphide ore similar to that occurring in Brown's tunnel.

Analyses of the ore show it to contain:—

Iron.	Zinc.	Lead.	Copper.	Gold.	Silver.
%	%	%	%	Ozs.	Ozs.
5·56	3·15	Nil.	2·19	Trace	0·61
0·95	4·26	13·56	0·25	0·06	8·34

(h) South Open-cut Workings.

These workings consist of an open-cut or open trench, 100 feet long, sent in across the lode in an easterly direction, and are situated on the southern boundary of 7147-M. The open-cut is only 15 feet deep, and 5 to 8 feet wide.

The lode, striking 10 degrees east of north and dipping 70 degrees easterly, is at this point between 20 and 30 feet wide.

Cherty silica, carrying chalcopyrite and pyrite, constitutes the larger portion of the ore-body, and encloses a band of ore, 2 feet wide, which is composed of an intimate mixture of galena, sphalerite, chalcopyrite, and pyrophyllite. Originally the vein consisted almost wholly of siliceous material, probably derived from the solutions emanating from the intrusive porphyroid; subsequently, during the period of ore deposition, the vein and the country rock in the vicinity were deformed and brecciated. The brecciated quartz and country rock were cemented by pyrite, chalcopyrite, and in a much lesser degree by galena and sphalerite which were deposited from ascending solutions introduced along the slipping planes and brecciated rock. Pyrite is found in the shattered wall-rock on either side up to 30 feet from the lode.

During the later stages of ore deposition the vein suffered still further fracturing. In the fissures thus produced, ore-bearing solutions circulated and deposited their burden of zinc, lead, and copper sulphides and pyrophyllite. These minerals were deposited simultaneously, though a slightly developed banded structure, indicating progressive precipitation, is noticeable in some specimens. The several minerals are usually in a very fine state of division, though blebs and stringers of chalcopyrite and blebs of galena and zinc-blende occur in the finer-grained mass. Pyrophyllite appears in its common habit as silvery-white folia, apparently separating very thin bands of ore, but also intimately admixed therewith. Barytes, so abundant in the ore of the northern workings, is not contained in this lode.

A complete analysis of a typical piece of this sulphide ore gave the following results:—

Sulphur.	Iron.	Zinc.	Lead.	Copper.	Insoluble.	Total.
32·21%	13·74%	29·80 %	15·19 %	0·93 %	8·20 %	100·07

Fifty-five tons of mixed sulphide and siliceous ore stacked at the entrance to the open trench contains: —

Gold.........	0 ozs.	5 dwts.	8·7 grains	—
Silver	1 „	4 „	18·7 „	—
Copper......	...	...	...	0·65 %

A complete analysis of the country-rock shows it to contain:—

Iron.	Silica.	Alumina.	Loss on Ignition.	Gold.	Silver.
0·52 %	75·60 %	20·80 %	2·60 %	Trace	Trace

About 4 chains from the South Open-cut, in a northwesterly direction, a trench 10 feet deep and 50 feet long has been cut in a north-easterly direction across an ore-body about 10 feet wide. The ore is composed of brecciated quartz cemented by pyrite, sphalerite, and chalcopyrite. Pyrite is the most abundant of the metallic sulphides present; sphalerite occurs in considerable amount, but chalcopyrite is only in small quantity. Galena and barytes are either entirely absent or are present only in very small amounts.

(i) General Remarks.

The indications of the potentialities of the Pinnacles area are decidedly encouraging. Perhaps the most striking features of the lodes are their width and continuity. The persistence of these lodes along the strike is indicative of their continuation in depth, as the surface length is generally a measure of the depth they attain.

The great difficulty encountered in the development of the lodes has been their unfavourable position relative to the topographic relief, so that exploitation by means of adits has been practically impossible. Development by means of shafts has been prohibitive by reason of the heavy drainage cost. Exploration by the use of diamond-drills, which are especially adapted to the search and development of such large and continuous ore-bodies, is strongly recommended.

Mining interests in this area may be said to have lain dormant for several years, though spasmodic and ineffective attempts have been made from time to time by lessees and others to discover richer lodes or richer shoots in the known ore-bodies. The remoteness of the area from transportation facilities, the comparatively low grade of the ore, and the difficulty experienced heretofore in treating economically complex ores of this type, have combined to bring about the condition of stagnation prevailing at present.

At the present time the lodes are on the borderland between payable and unpayable ore-bodies, but the erection of the proposed large works by the Read-Rosebery Mines Limited, capable of treating complex ores of this type, will probably provide conditions under which the lodes may be profitably exploited.

The ores contained in the lodes of the Read-Rosebery mines are similar to those of Pinnacles, and have been successfully experimented upon. The following extract from the first annual report of the Mt. Read and Rosebery Mines, relative to the successful treatment of those ores, is of interest:

> "The ore is commonly regarded as extremely refractory, being a dense intimate mixture of zinc-blende, galena, and pyrite. The amount of gangue is slight, and mechanical separation by means of ordinary wet concentration is not feasible, although good results were obtained by flotation. The owners were, therefore, practically restricted to the sale of their argentiferous galena ores, and the penalties imposed upon the zinc contents were detrimental to the securing of a satisfactory profit. The recent successful introduction of the electrolytic method for the recovery of zinc in ores of the average type of these mines has so materially improved the position that the present time is opportune for the application of this method, with every certainty of commercial success."

Under existing conditions mining the lower-grade copper ore at Pinnacles cannot be considered a profitable undertaking. It is possible, however, that with the introduction of a method of treatment by water-concentrating plants, such an ore may also be mined to advantage.

The values in the lodes are very unevenly distributed, and the average content is probably not very high, although shoots of rich ore have been found. Such shoots of ore are represented in the South Open-cut workings, where a lode of considerable promise is exposed. The facilities for exploiting this lode by means of adits are much better than in the northern workings, and in general the lode presents more encouraging features.

(6)—Strong's Creek Gold Diggings.

Strong's Creek is a small tributary of the Marionoak River, and has its source on the west side of Pinnacles Hills. The creek was named after Tom Strong, a well-known prospector, who discovered alluvial gold there in the year 1896. The camp located here can be reached by foot-track from the Chester Mine in about 2½ miles, and by pack-track from Boco Siding in 4 miles. The alluvial ground is found chiefly along the Marionoak River and its tributaries on the eastern side. The streams on the western side of Marionoak River, having their sources beyond the mineralised contact-zone and the flood-plain of the river, contain very little gold. The gold-bearing wash is confined within narrow limits to the Marionoak Valley, and extends 1 mile northward of the main workings. The wash and detrital material, varying in depth from 1 to 15 feet, is made up of angular to subangular particles of very diverse character, the predominant rocks being chert, talcose schist, dolomite, quartz, and felspar porphyry. The lowest stratum, containing the major portion of the gold, is composed mainly of subangular to rounded quartz pebbles, ranging from 1 to 3 inches in diameter. Some of the wash had certainly been conveyed to this position by the Marionoak River when it occupied a higher level, the remaining portion was derived from the lode material and its enclosing rocks near-by. Occurring in such shallow deposits, the gold is naturally confined to the wash near the bed-rock, the concentration being accounted for mainly by the agency of gravitation. The gold is, without doubt, very near its source, and is probably a disintegration product of the Pinnacles ore-bodies, which are known to contain appreciable quantities of gold. The alluvial gold is associated with galena, pyrite, chalcopyrite, and chromite. The former minerals are derived from the lodes in proximity; the origin of the latter mineral is discussed in another chapter.

The character of the gold is variable; it occurs in flat scales and flakes, in rounded particles, and in irregularly-shaped grains bearing evidence of attrition. The gold is of high quality, and occurs usually in very fine grains, but particles weighing upwards of 5 gr. are frequently found. The variation in the fineness of the gold depends on the original differences in the gold contained in the lode from which it was derived.

Strong's workings, confined to the headwaters of the creek, are the most extensive. A considerable amount (about 1000 cubic yards) of ground was sluiced, and a tunnel over 100 feet long was driven northerly under the wash and detrital material. The wash comes in about 40 feet from the end, where the floor of the tunnel is 18 inches below the bottom of the wash. Wing drives were sent in westerly from the end, and at 30 feet back, through wash that carried a little gold.

A number of prospect holes in the adjacent ground northward show goldbearing wash from 3 to 6 feet deep. The bed-rock, blue mica slate or phyllite, is intersected by many quartz stringers, and a quartz vein 3 feet wide. This vein-quartz has a cherty appearance, and a most unusual and peculiar texture. The appearance is that of a hard chert, but under the slightest pressure it fractures along planes arranged in rudely parallel lines. The evidence suggests that the chert is a replacement product, and has suffered brecciation.

On the western bank of the Marionoak River, near the crossing of Atkinson's track, shallow alluvial ground, from 2 to 4 feet deep, has been "cradled." The workings, which are not extensive, show shallow quartz wash, carrying a little gold resting on decomposed felspar porphyry.

It is doubtful whether this alluvial ground is sufficiently rich and extensive to warrant the construction of the long water-race required to convey water for sluicing operations.

(7)—Silver Falls Claim.

Section 5586-M, 80 acres, is one of a group of five isolated sections situated 2 miles north-west of Pinnacles Mine. These sections, originally pegged in 1891 by the discoverers (John Lynch and others), are located on the lineal extension of the mineral-bearing zone developed southward. Very little exploratory work has been carried out.

In the year 1911 a local syndicate known as the Granville Mining and Prospecting Association, was formed for the purpose of developing mineral discoveries, and among others, the Silver Falls was selected as worthy of attention. Leases 5586-M and 5587-M, each of 80 acres, charted in the name of R. F. Irvine, were secured by the syndicate. Exploratory work on a small scale, carried out under the supervision of Thos. McDonald, failed to expose ore of marketable value, and operations were discontinued.

Access is had from Pinnacles by means of a lightly-blazed trail, though, it is stated, a more direct and easier route from the Emu Bay Railway is available from a point 2 miles north of Boco Siding.

(*a*) *Ore-body.*

The lode was exposed first in the cliff 110 feet high, over which the the waters of Ross Creek fall. From this point the creek turns sharply southward, following the course of the lode for fully 15 chains, showing the massive ore-body standing out prominently on the eastern side of the deep valley. The highly resistant nature of the magnesian rock forming the gangue in which the metallic minerals are contained is strikingly evidenced by the complete removal of the softer overlying slates to the present base level of erosion, leaving the lode exposed as a high wall of rock flanking the hill. This comparatively narrow bed of rock occurring in contact with quartz felspar porphyry and felsite is the repository of all the more important ore-deposits in this and the adjacent areas southward.

The ore-body strikes about 10° east of north, and dips to the east at 65° to 75°. The exact width (at least 50 feet) could not be determined. The lode is composed of galena, sphalerite (zinc blende), and a little chalcopyrite sporadically distributed through silicified and serpentinised dolomite. In addition to these minerals, scattered particles of pyrite also occur. A close examination of the rock forming the gangue reveals the presence of carbonaceous material, in the form of graphite, together with a considerable amount of calcite, barytes, talc, and a little pyrophyllite.

On the face of the rock near the waterfall calcareous tufa, 2 feet thick, has been deposited. At this mine the rock appears to be more calcareous than in any other part of the same horizon. Slickensides or slipping-planes, bearing evidence of considerable movement, are commonly seen, the striæ striking easterly. Movement took place prior to the deposition of the ore, and subsequent to the partial serpentinisation of the rock, as the slipping-planes show that the ore has remained unaffected, while the serpentine shows slickensided surfaces. The metallic minerals were deposited following thorough brecciation of the rock, and are found filling fractures and joint-planes, and as a replacement product after calcite. Brecciation is more apparent in the partly silicified rock, the fractures having become almost indistinguishable in the softer serpentinous material.

Ore-deposition from hydrothermal solutions, highly charged with carbonic acid, was accompanied by the precipitation of magnesium and calcium carbonates in considerable amount. The ore occurs in a very fine state of division, the preciptation of other minerals evidently interfering with the crystal growth of the metallic sulphides.

(b) *Development.*

Although this lode was one of the first discovered in the district, very little development has been accomplished. The removal of scrub from the lode material near the waterfall and the opencutting of the orebody at several points constitute the entire improvements. At the base of the cliff below the waterfall, the footwall of the lode has been broken across, exposing galena-bearing dolomite rock similar to that already described. A sample of this ore was submitted for treatment to the Government Assayer (Mr. W. D. Reid), who reported the metal contents to be—lead, 9·4 per cent.; zinc, 1·7 per cent.; silver, 14 dwt. 9 gr. per ton. Another small open-cut was made across the footwall of the ore-body 10 chains southward, where ore of similar character is exposed. Still another open cut or trench was made into the lode 5 chains further southward, with no alteration. Other works consist of surface stripping and trenching of minor importance.

The massive ore-body rising abruptly from the bed of the creek affords exceptional facilities for development by means of tunnels and open-cuts. Rarely are such natural facilities provided that work on a considerable scale may be undertaken with a minimum outlay.

Further exploratory work is required to definitely determine whether the ore-body is rich enough to be operated economically. That already carried out is on a scale too small to prove the value and extent of the ore-body; even the open-cut work penetrates a few feet only beyond the foot-wall. Crosscutting the ore-body at intervals of 200 feet by tunnels sent in from the western side would supply sufficient data from which an approximate estimate of value may be computed, and provide information upon which more extensive exploratory work may be outlined. The chief obstacles in the operation of this mine are— the necessity to concentrate the minerals of economic value; the difficulty of access; and the lack of means of transportation to the railway.

Further developments are not expected to reveal much richer material than that exposed at the waterfall, but if the grade improve slightly, the mine, operated on a sufficiently large scale, may become a profitable producer.

It is to be regretted that this large orebody has not been thoroughly tested.

(8)—Lynch Creek Prospect.

This is a strong lode, outcropping in the valley of Lynch Creek, a tributary of the Huskisson River, at a point near the crossing by Atkinson's track. Its position relative to the Pinnacles Mines is 2½ miles due west, and it may be reached from that locality by foot-track.

The discovery of this lode was made by the writer during the present geological examination of the district.

This belt of mineralisation is quite distinct from that of the porphyroid to the eastward, and is probably the continuation of that reported on by Mr. A. Montgomery in 1892([26]). This was a barytes-galena formation discovered near the point of confluence of the Que and Huskisson Rivers. It is referred to in the following terms:—

> "On the eastern side of the Huskisson, and close to the river, a discovery of galena has been made which goes by the name of the Just-in-Time claim. It is about a mile south of the crossing of the Que River by the pack-track from Waratah to the Pieman River. The outcrop shows a mixture of quartz, barytes, galena, and a little calcite. The lode is evidently a strong one, over 2 feet wide at the least, and

([26]) *Vide* A. Montgomery: "Report on the Country Traversed by the Route of the proposed Waratah to Zeehan Railway." Secretary for Mines Report, 1892.

probably quite 5 or 6 feet wide. Its course is not altogether clear, but appears to be nearly north and south. No first-class ore is yet exposed, though a good deal of the material would probably be worth concentrating. The country-rock is limestone and sandstone. This is a discovery of some importance, and is well worth following up to see if richer ore may be obtained."

The many points of similarity of the Lynch Creek prospect to that just described, in that it is contained in limestone and consists essentially of barytes and galena, and the situation relative thereto, are strongly suggestive of their belonging to the one belt of mineralisation.

The lode material at Lynch Creek is a siliceous gossan carrying abundant barytes and occasional blebs of galena. The limonite of the gossan is derived from the oxidation of pyrites, but a considerable portion of the original pyrite constituent has been leached out, leaving the silica in cellular form. Evidently it was originally a very pyritic ore. Pseudomorphs of limonite, in the form of pentagonal dodecahedra, after pyrite, are commonly observed in the ore. Barytes is found in the form of white plates several inches long, and occurs usually in narrow bands in the cellular silica; galena is always found accompanying the barytes.

A sample of siliceous gossan from the outcrop in the bed of Lynch Creek was submitted to Mr. W. D. Reid, Government Assayer, who reported the metallic contents to be—lead, 1·7 per cent.; silver, 3 dwt. per ton. The greater portion of the metallic content has beeen removed by the solvent action of the running water, and the assay is, therefore, no criterion of the value of the ore; but the presence of silver still remaining in the ore is an indicaton of greater values in the unattacked lode material.

Very large loose blocks of ore were first discovered in the bed of Lynch Creek just above the point of crossing by Atkinson's track. These boulders of ore were observed in the creek for 10 chains northward, and ore was noticed, apparently *in situ*, in the bed of the creek. An attempt to follow the course of the lode on to the steep hills on either side of the creek failed because of the heavy mantle of talus and surface soil concealing the outcrop. The short stay in this locality did not allow of a thorough examination being made, but enough information was gained to indicate the probable value of the ore-deposit.

The ore-body is doubtless a metasomatic replacement of limestone by ore-bearing solutions derived from a granitic magma during the later stages of rock solidification. These solutions contained a very large amount of silica, and were strongly acidic. It is probable that the original limestone bed was very narrow, as no limestone was noticed, and its presence is inferred only from the structure of the silicified rock. In the non-mineralised portion the rock appears in the form of very delicate cells, the sides of which are made up of very thin partitions of silica. Some of these cellular shapes appear like casts of fossils, but if so, they are too obscure to be recognised. Silicification has not been confined to this horizon. The conformable beds of breccia-conglomerate, largely made up of pyroclastic material, in places have also undergone replacement by silica.

The facilities for economic mining are decidedly good. On either side of the creek hills rise very steeply over 800 feet above the bottom of the valley. Timber for all purposes is here in abundance, and a plentiful supply of water is available even in the dry season.

The indications of the potentialities of this orebearing horizon as a source of galena are decidedly encouraging, and certainly justify far greater attention being paid to this district than obtained heretofore. Want of accessibility has been the great obstacle to the advancement of this portion of the district, but as developments warrant it communication with the main thoroughfares will be provided.

(9)—Salmon's Claim.

Section 7646-M, 78 *acres*.—This property is situated at the southern end of Bobadil Plain, on the western side of the Emu Bay Railway-line, between the 67½ and 68 mileage pegs.

The lodes exposed on this section were discovered last year by Alfred Lapham in the banks of a small stream flowing westward into the Pieman River.

There are two quite distinct parallel ore-bodies, the more important being that on the eastern side, which for purpose of reference will be called the "eastern lode."

Developments consist of a small cut sent in on the eastern ore-body; another small cutting on the western formation; and light surface prospecting here and there over the intervening area. So little developmental work has been done that it is quite impossible to form an idea of the extent or value of either ore-body; but the examination of the structural and mineralogical features of the ore-body has furnished much data from which certain generalisations may be made.

The eastern ore-body, exposed on the northern bank of a small creek, consists essentially of zinc-blende and galena, and is contained in calcitic schist. There is no definite wall to this lode, nor has its lateral extent been determined; but it is certainly 5 or 6 feet wide, and probably the ore-bearing formation will prove to be much greater than this. No attempt has been made by trenching to ascertain the lineal extent of the ore-body, the outcrop of which on the northern end is covered by fluviatile deposits and on the southern, a few chains distant, by the Pieman River.

Sphalerite or zinc-blende is the predominant mineral constituent, and occurs as crystalline bands parallel to the foliation of the schist, and also as thin irregular filaments traversing the rock. Sphalerite occurs also with calcite filling joints and cracks, under which conditions of deposition it has developed a highly crystalline structure. The crystals have usually the tetrahedral habit, and are commonly twinned. The colour varies from light yellow through resinous-brown and reddish-brown to black.

Galena is quite subordinate to sphalerite in the constitution of the ore, and although always in close association with sphalerite usually occurs as blebs and disseminations through the calcitic schist. Galena commonly occurs crystallised in cubes; also in massive and coarsely granular form.

Limonite, derived from the oxidation of pyrite and chalcopyrite, always accompanies the more valuable minerals. It is found pseudomorphous after calcite in acute rhombohedra.

Calcite is very abundantly developed in the schists containing the ores, and is probably a recrystallisation product of the original limestone. These are the calcitic schist beds described by Mr. Loftus Hills in his report on the Read-Rosebery Zinc Lead Sulphide Deposits as being the repositories of the ore-bodies(27).

Some calcite, crystallised in the form of acute rhombohedra, is younger than the zinc-blende. On the weathered surface the calcite appears brown.

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(27) *Vide* Loftus Hills: Geol. Survey, Tas. Bulletin No. 19, 1915.

Quartz is an abundant constituent of the ore, and is generally older than the zinc-blende. It is generally found in the opaque crystallised form capping the ore-body.

In addition to those minerals already described as being components of the ore-body, pyrite and chalcopyrite occur in small quantity.

The ore-body is a metasomatic replacement of calcitic and argillaceous schists. These schists are true sedimentary rocks and are unrelated to the crystalline schists further eastward. Calcite, being the more soluble mineral, has been replaced through the agency of the ore-bearing solutions in a far greater degree than the argillaceous constituent.

The greater portion of the lode is contained in greyish-yellow schist which is conformably overlain by a black argillaceous schistose rock containing a little sphalerite and calcite in very thin veinlets.

A sample of zinc-lead sulphide ore submitted to Mr. W. D. Reid, Government Assayer, for analysis was found to contain:—

Zinc	22·7 per cent.
Lead	2·2 per cent.
Silver	1 oz. 4 dwt. 12 gr.

The strike of the lode is 20 degrees west of north; the dip is north-easterly at an angle of 65 degrees.

The western lode formation is composed of pyrite and chalcopyrite contained in altered porphyroid. The porphyroid occurs here from 12 to 20 feet wide between bluish-black and purple slates. Megascopically this gangue rock has a peculiar mottled appearance, the spherules being drawn out or elongated and showing a decided schistose structure. In some specimens the dark spherules give place to those of a green colour. Secondary alteration shows incipient development of heliotrope-coloured pyrophyllite, and leucoxene derived from ilmenite. White bands or veinlets of calcite traverse the rock in rudely parallel lines, and here and there considerable bunches occur; dolomite, in the form of curved crystals and also massive, is abundant.

The metallic minerals, chalcopyrite and pyrite, are contained in the gangue as blebs and disseminations, and are never abundantly developed. This lode is fully 12 feet wide, and has been proved to extend southward for several chains. In the bank of another creek farther south another capping is exposed carrying chalcopyrite and pyrite similar to that already described.

The ore-body is contained between purple and dark-blue slates which strike in a direction 30 degrees west of north and dip easterly at an inclination of 75 degrees. Fractures in the lode formation contain quartz veins 10 to 12 inches thick.

Slickensides are commonly noted in this lode indicating movement subsequent to the vein filling. The elongation in one direction of the spherules, and the brecciated condition of the lode material supply further evidence of faulting, but in this case the movement took place prior to the deposition of the metallic minerals. The extent of this movement cannot be determined, as there are no recognisable beds outcropping to serve as a basis of measurement, but it is known to be comparatively slight.

Further development on a small scale may be undertaken by crosscutting the ore-body from the eastern bank of the Pieman River. Such a crosscut would pass through the western lode in less than 100 feet, and intersect the eastern ore-body in about 200 feet. The outcrop of the eastern lode is only about 80 feet above the summer water-level of the river, and as the river in flood rises as much as 30 feet, the maximum amount of "backs" available is only 50 feet. Work at this shallow depth can only be regarded as exploratory, but should be undertaken to provide information upon which future developments on a more comprehensive scale may be based.

Before selecting the site of the tunnel entrance, it is necessary to ascertain the highest point reached by the Pieman River flood-waters. An allowance of 10 feet above this point should provide a sufficient margin upon which work may be carried on in safety.

On reaching the ore-body by the crosscut, drives north and south should be undertaken to determine its lineal extent and value. It is possible that the amount of ore extracted in this operation will be of such value as to defray the cost of the work.

If successful developments attend these preliminary operations, those of a more permanent character may be begun. The permanent works will consist of a main shaft, the site of which will be determined to some extent by the results of the preliminary operations. As the dip is towards the east, it may be advantageous to sink the shaft on the eastern side of the railway-line. In any case, it will be so placed that the ore may be delivered direct to the loading bins.

Such facilities as are provided here are rarely met with in mining. The Emu Bay Railway passes within 3 chains of the outcrop of the eastern lode, and a ready market will soon be available at the large metallurgical works about to be erected by the Read-Rosebery Mines Limited in the vicinity of Zeehan. A splendid site for a railway siding, both as regards natural grade and length and width of straight, is available at Bobadil Plain.

It has been mentioned in an earlier paragraph that so little developmental work has been accomplished that it is quite impossible to form an idea of the extent and value of the ore-body, but the geological conditions are so favourable that an outline of a future scheme of operations has been considered advisable. It is impossible to foresee the result of developmental work on these lodes, but the eastern lode offers such encouraging features and can be explored at such a small cost that one must regard it as a good mining risk.

(10)—Cutty Sark Group.

The deposits on Sections 1726-93M, 1725-93M, 1876-93M, and 1770-93M were discovered in the year 1896 by Fred. C. Brooks—after whom the settlement at the Pieman Bridge was named—and the mine was operated by the Cutty Sark Prospecting Association.

These ore-bodies were reported on first in 1898 by Mr. Harcourt Smith, and in 1900 by Mr. W. H. Twelvetrees. Very little developmental work has been accomplished during the last 16 years, but attention has been drawn to them lately following the more active exploitation of the parent mine at Rosebery. It will, therefore, be necessary here only to supplement the descriptions already published with mention of the developments that have been carried out since.

In general the ore-bodies are decidedly pyritic, and occur chiefly as irregular bunches and disseminations in chloritic schists, or as well-defined fissure fillings in felsitic rocks. The lodes do not persist unbroken for any considerable distance along the surface, but occur as short separate lenses outcropping at several points in a more or less straight line. None of these lodes has been developed at depth, though numerous small openings have been made to determine their surface value.

The ore is composed chiefly of pyrite, with subordinate chalcopyrite, and its derivatives azurite and malachite. The gangue minerals are chlorite, calcite, quartz, and a little hæmatite.

The trend of the lodes, which coincides with that of schistosity of the country-rock, is 15 degrees to 20 degrees west of north; the dip is at an inclination of 65 degrees to 75 degrees easterly.

(a) Section 1876-93M, 36 *Acres.*

About 40 yards north of the Pieman River Bridge an ill-defined pyritic lode is exposed in the railway cutting. The occurrence is one of pyrite, and in much lesser quantity, malachite, disseminated throughout the enclosing rock and occupying the joint planes therein. The country-rock is a pyroclastic schist that has suffered considerable alteration by reason of its nearness to the intrusive igneous rock. The lode is exposed again in a trench and a shallow shaft near the southern boundary of Section 1770-93M. The lode here is about 3 feet wide and contained in dark-green chloritic schist. Well crystallised pyrite is the predominating mineral, but malachite is abundant; a little galena and blende are also present, and were the latest precipitants from solution. The metallic minerals occur intimately mixed with the chlorite along these lines of concentration.

(b) Section 1770-93M, 77 *Acres.*

The main workings of the Cutty Sark Mine are situated in the valley of Robbie Creek, which passes through this section. Developments consist of a tunnel, 300 feet long, driven on a bearing 280 degrees from the valley of Robbie Creek; and a deep open trench, 20 feet long, 15 feet deep, and 4 feet wide, sent in from the northern side of the hill on a body of quartz carrying pyrite and a little chalcopyrite. The main crosscut commences near the contact of quartz-felspar porphyry and chlorite schist, and is wholly contained in the latter rock. The felspar constituent of the porphyry near the hanging-wall has undergone almost complete kaolinisation. Another body of ore, on the same line as those already mentioned, has been cut on the west bank of Robbie Creek at a point 4 chains further southward. Here the pyrite is more massive and the chalcopyrite constituent is more abundant than in the other workings, and they both occur in a gangue composed of white, opaque quartz and chlorite. The ore-body has the appearance of a defined lode and is much richer in metallic minerals at this point than in the exposures further north. Chalcopyrite is always found here in the more siliceous part of the ore-body, and not always in association with the pyrite.

Attention is directed to the greater possibilties of improvement in the lode as developments are carried farther southward, where the facilities for prospecting and economic mining are equally good.

(c) Section 1726-93M, 80 *Acres.*

This section is situated 6 chains south of Farrell Siding, and is one of those leased by the Cutty Sark Prospecting Association. Developments consist of a tunnel over 100 feet long sent in the eastern bank of Boco Creek in a direction 35 degrees east of south.

The metallic sulphides contained in this lode are pyrite and chalcopyrite; malachite, an alteration product of chalcopyrite, is also present. The ores are contained in chlorite schist as irregular bunches and disseminations. The pyrite usually occurs well crystallised, generally in cubic form. It is evident that the pyrite and chalcopyrite were deposited contemporaneously with the formation of the chlorite.

These lodes, on the north side of the Pieman River, afford very little encouragement for further exploitation; on the southern side the facilities for development are better, and the opportunities for finding richer ore-bodies are much greater.

(11)—Hawkesbury Mine.

Sections 1700-93M, 80 *Acres; and* 1701-93M, 80 *Acres.*

These sections lie to the south of the Cutty Sark Mine and on the same belt of mineral-bearing country.

The workings were visited in 1898 by Mr. Harcourt Smith, whose report appears in the annual publication, issued by the Mines Department, of that year. Since that time very little exploration has been carried out and the mine appears now in the same stage of development as it appeared then.

Developments consist of a number of trenches sent in across the ore-body from the west side of the ridge; further improvements are the sinking of a shaft 54 feet deep, from the bottom of which a crosscut has been sent in 40 feet in an easterly direction. From an examination of the *debris* at the shaft-mouth, the ore-body is considered to be very poor. Here again, the rock consists of chlorite with disseminations of pyrite and chalcopyrite in much lesser amount.

The geological features of this mine are similar to those exhibited by the Cutty Sark group. The origin of the chlorite has not yet been definitely established. It is always of secondary origin, and appears as the result of hydrothermal alteration, probably of some aluminous ferromagnesian mineral. Synchronously with this development, pyrite and chalcopyrite ores were deposited, hence the very irregular occurrence of the metallic sulphides in the chlorite schist. The schistosity has been developed subsequently, the metallic minerals in this soft matrix remaining almost unaffected.

(12)—Samuel Smith's Lode.

This is a long line of lode (at one time included in the holdings of the King Boco Prospecting Association) extending from a point in the railway cutting near Farrell Siding along the course of the railway-line to Boco Plain.

There are two or three features of this occurrence that are of particular interest. Firstly, its unbroken continuity in an almost perfectly straight line, and its regularity as to size for nearly 5 miles are particularly striking; and, secondly, in marked contrast to that of all other lodes in the district, the dip is westerly. Whether these peculiarities have been brought about as a result of the intrusion of diabase in the form of a long narrow dyke, the outcrop of which courses so closely parallel to, and has the same lineal extent as, the fissure, has not yet been definitely settled; but all the evidence which has been gathered points to such being the case.

The strike of the fissure varies slightly from point to point, but the average shows it to be 20 degrees east of north; the dip is 70 degrees north-westerly. Near the southern end the trend of the lode alters to 12 degrees east of north, the dip remaining the same.

There are a number of exposures in the cuttings along the railway-line, all of which have been sampled and assayed for silver. In each case silver is present, but in very small quantity.

The nature of the ore varies slightly from point to point, but the predominant metallic constituent is iron in one or more of its compounds. At the 63½-miles peg, the lode is composed dominantly of limonite and quartz, with a considerable amount of siderite and a little chlorite, and occurs as a vein 2 feet wide contained in porphyroid. Further north at Chester Siding the ore shows in two bands, each over 1 foot wide, divided by a "horse" of mullock 3 feet thick. Here the ore is almost wholly limonite. Near the 62-miles peg the lode is 2 feet 6 inches wide, and is composed of limonite; near the 61-miles peg the ore is very siliceous, and the vein is 5 feet wide; at 60½ miles the lode is calcite and limonite; and at 59 miles pyrite is the main constituent. The lode is contained in quartz-felspar porphyry.

It has been reported that this ore contained tin, and that assays showed the presence of 0·25 per cent. of this metal. This is most improbable, especially in view of the fact that recent tests of the ore failed to discover a trace of this metal.

This lode could be easily explored by crosscutting from any point in Boco Creek Valley, which is parallel thereto.

The indications are not such as to warrant the expenditure of any considerable sum in development.

(13)—Home Rule Prospect.

This prospect is situated 3 to 4 chains west of Section 3560-M, and at the big bend in the Pieman River above its confluence with Boco Creek. The lode was discovered by Edward Higgins in the year 1915. It is an east-west fracture-filling parallel to the Langdon P.A. cross-fracture, but unlike the latter the dip appears to be southerly. The vein, which is only a thin opening in massive felspar porphyry from 2 to 4 inches wide, contains galena, sphalerite, hæmatite, and a little pyrite in a calcite gangue.

This vein is remarkably persistent, and runs parallel to the course of the Pieman River for several chains; thence the outcrop enters the bank and is obscured by peat and soil. During the greater part of the year the exposed portion of the outcrop is covered by the waters of the river.

This formation is of no economic value, and is of interest only in that it occupies one of a number of parallel cross-fractures in the porphyroid.

About ½-mile south-east of the Home Rule vein, and at the river bend near the western boundary of Section 3645-M, another parallel vein similar to that just described occurs. A trench has been cut on the southern side of the river along the course of the vein, and has exposed ore consisting of galena, sphalerite, and pyrite. The country-rock is a felspar-porphyry, slightly altered near the lode.

(14)—The Langdon Prospecting Association.

Section 2382-M, 40 *Acres.*

This mine is situated on the southern side of the Pieman River, about ½-mile south-east of the Home Rule, and 1¼-mile north-east of Pieman Bridge. These workings were examined in 1908 by L. K. Ward, and are described in the publication on the Mt. Farrell Mining Field (28). No further developmental work has been carried out since then, and, therefore, the report of that examination is applicable to-day. A few extracts from this report are included here:—

"The lode was first discovered at the point where Innes' track crosses it by a prospecting party, who worked northward from Rosebery along the felspar-porphyry belt. It exhibits a marked peculiarity of structure, in that the strike is due east-and-west. The dip is northward.

"A tunnel has been driven southward from a point 30 feet below the outcrop, on a bearing of 147 degrees. At 30 feet the lode was passed through.

"It is said to have been driven another 30 feet on the same bearing. The portion of the drive past the lode is blocked by waste. The tunnel was carried past the lode, for the reason that the values had so materially decreased in depth that it was thought the lode was still ahead.

"It has been reported that the upper portion of the workings produced some very good galena, of which about 40 tons were taken to the smelters. A few specimens lying on the tip showed good coarse galena with resinous-looking blende.

"There is a drive on the lode from the adit for 30 feet in an easterly direction. The back of the drive shows that the ore-body has pinched to a width of only a few inches,

(28) L. K. Ward: Geol. Survey, Tas. Bulletin No. 3, pp. 115-116.

and, in fact, can hardly be traced at the intersection of the drive and tunnel; about 10 feet from the end of the drive there are 6 inches of ore, consisting of coarse galena mingled with resin blende. But, on the whole, the galena seems to have given place to resin and ruby blende.

"The contraction of the ore-body and the impoverishment in the lead content have no doubt led to the abandonment of active work, and the mine has been idle for 12 months.

"There have been several trenches cut on the western continuation of the lode outcrop, but they show only zinc blende with traces of galena in veins through a mineralised zone. These trenches extend to the western boundary of the section, and have not indicated sufficient values to justify further prospecting at a depth.

"The country-rock is a felspar-porphyry, which is slightly altered near the lodes, probably by the development of sericite. Numerous veinlets of silica are to be seen in the country-rock near the lode, and these veinlets seem to have a tendency to run in an east-west direction. The country-rock is also indurated here and there by an intimate impregnation of silica, till it resembles a chert.

"Higher up the hillside, 250 feet along the track, there is a little work done on a gossanous capping. The lode is 6 or 7 feet in width, and carries a number of small veins up to 3 inches in width of zinc blende, and very occasional splashes of galena. The blende has by weathering acquired a coating of limonite, but the undecomposed material is dull yellow, and has been mistaken for carbonate of iron. Too little of the lode was exposed to determine the dip. The strike seemed to be a little north of east.

"There has been some trenching on the adjoining section, 2524-M, now vacant. In one of the trenches below the track on the eastern boundary a small vein, 4 to 6 inches in width is exposed. It strikes N. 55° W., and dips to the north-east at from 80 degrees to 85 degrees. The lode contents are blende and a little galena in a band of silicified felspar-porphyry. A trench running a little east of north has been put down to cut the continuation of this lode, but without success.

"There is also some trenching on the line of the Langdon lode, and in one trench a lode a foot wide, carrying some veins of tarnished blende and galena, is visible.

"The veins that have been located in this section seem to carry blende rather than galena."

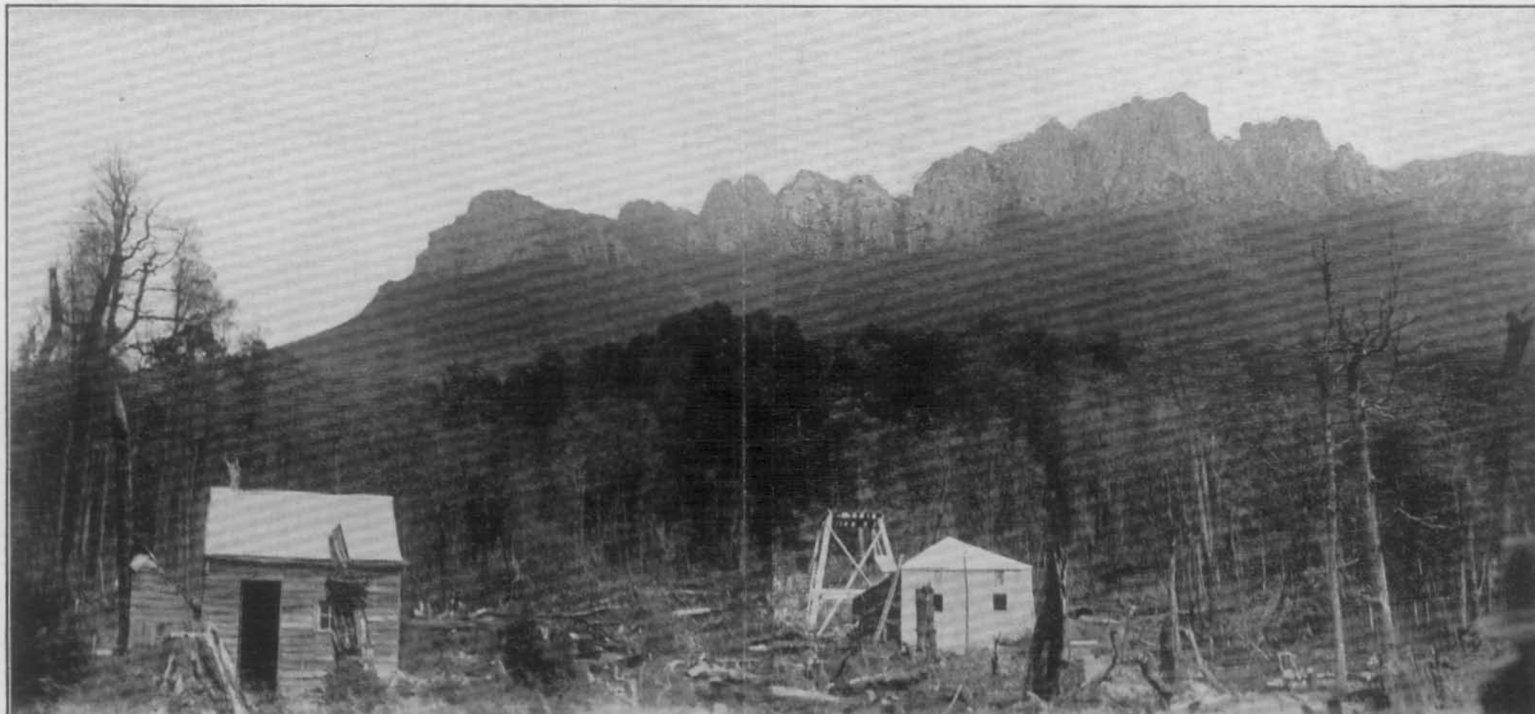


Photo. 5.—MT. MURCHISON: STERLING VALLEY MINE IN FOREGROUND. [*A. McIntosh Reid Photo.*

Sterling Valley Area.

The Sterling Valley area occupies the northern part of the Murchison district, and is situated midway between the townships of Tullah and Rosebery, which are by road 10 miles apart.

The Sterling River, from which this area takes its name, has its source in the saddle connecting Mts. Murchison and Black.

A general description of the physiographic and geologic features of the area has been embodied in the report on the North Pieman and Huskisson District. A further detailed description of the geology of this area is contained in the excellent report by Mr. L. K. Ward on the Mt. Farrell Mining Field,(29) the southern boundary of which abuts on this area.

From a developmental point of view the district cannot be considered old. The earliest, and in fact the only works of importance, have been carried out since 1912 by the Sterling Valley Mining Company.

In addition to the mines a great asset in the future development of the area is the very fine forest which clothes Mt. Black and the slopes and foothills of Mt. Murchison. The higher altitudes are the habitat of King William pine; the lower are occupied by myrtle, stringy-bark eucalyptus, and celery-top pine. These forests will be attacked from the valley of the Sterling River, and transport will be along the Sterling Valley tram route, *via* Tullah, to Farrell Siding.

(15)—Sterling Valley Mine

Section 4013m, 80 *Acres.*

The most important mine in this area is that known as the Sterling Valley.

The lode was discovered in the year 1911 by Mr. J. Lynch, a well-known prospector of the western mining fields, who sold the lease of the mining rights to a Melbourne company. The Sterling Valley Mining Company was organised in 1912, and developmental work was begun in August of that year under the supervision of Mr. J. H. Astell.

Exploratory work on a comprehensive scale was undertaken, and included the crosscutting of the ore-body at the

(29) *Vide* L. K. Ward: The Mount Farrell Mining Field, Geol. Survey, Tas. Bulletin No. 3, 1908.

lowest suitable point, from which drives were sent in north and south. Active operations continued until early in the year 1915, when work was temporarily suspended pending the removal of the abnormal conditions created by the war.

Plans have been made to operate from a main shaft, the sinking of which has been commenced, and the necessary machinery placed in position.

(a) Ore-body.—The ore-body is composed dominantly of galena and sphalerite, with abundant pyrite and arsenopyrite, chalcopyrite, and siderite in much lesser amount. The metallic minerals are usually contained in an opaque quartz gangue, which is abundantly developed in the southern end of the workings.

Galena usually occurs in rich shoots 20 to 50 feet in length, sometimes in intimate association with sphalerite in a quartz gangue. Zinc blende is more frequently found in clean veins 2 to 6 inches wide on the footwall side of the lode. Rich bunches of galena occur in the shattered hangingwall rock as much as 10 feet beyond the lode proper, but these are not persistent, and no definite idea of their actual size is obtainable.

The vein or the mineralised part of the shattered shear-zone averages 4 feet wide, though it varies greatly from point to point. The richer ore is obtained mainly from a single vein, but here and there veinlets terminating in bunches lead off into the wallrock. The vein varies in character; in some places sulphides with subordinate quartz constitute the fissure-filling, and in the southern end quartz is the dominant mineral.

The vein is a fissure-filling in sheared graphitic slate near its contact with porphyroid. The slate and porphyroid are much crumpled and contorted, the latter in cross-section presenting a peculiar corrugated aspect. Miniature reverse faulting is commonly noted in the slate.

In general the ore-body has little regularity in this shattered country. Shoots 20 to 50 feet long, separated by 10 to 20 feet of almost barren material, recur at intervals in the drive for 230 feet.

The fissure in which the lode occurs shows movement both prior and subsequent to the introduction of the vein material. The original vein was probably a small one, composed mainly of quartz with a little pyrite, galena, and sphalerite. Subsequently the vein and wall-rock suffered severe deformation and brecciation. The fragments of country-rock and vein material were cemented by pyrite, galena, sphalerite, and arsenopyrite. On the footwall side, 2 to 3 inches of selvage occur, which indicate a differential movement of the vein walls on one another.

At the southern end of the workings the chalcopyrite constituent of the lode has been transformed to malachite. Other evidences of local oxidation are the occurrences of the sulphates of zinc and iron deposits on the walls of the drives, but complete oxidation of the ore does not extend below 5 feet from the surface.

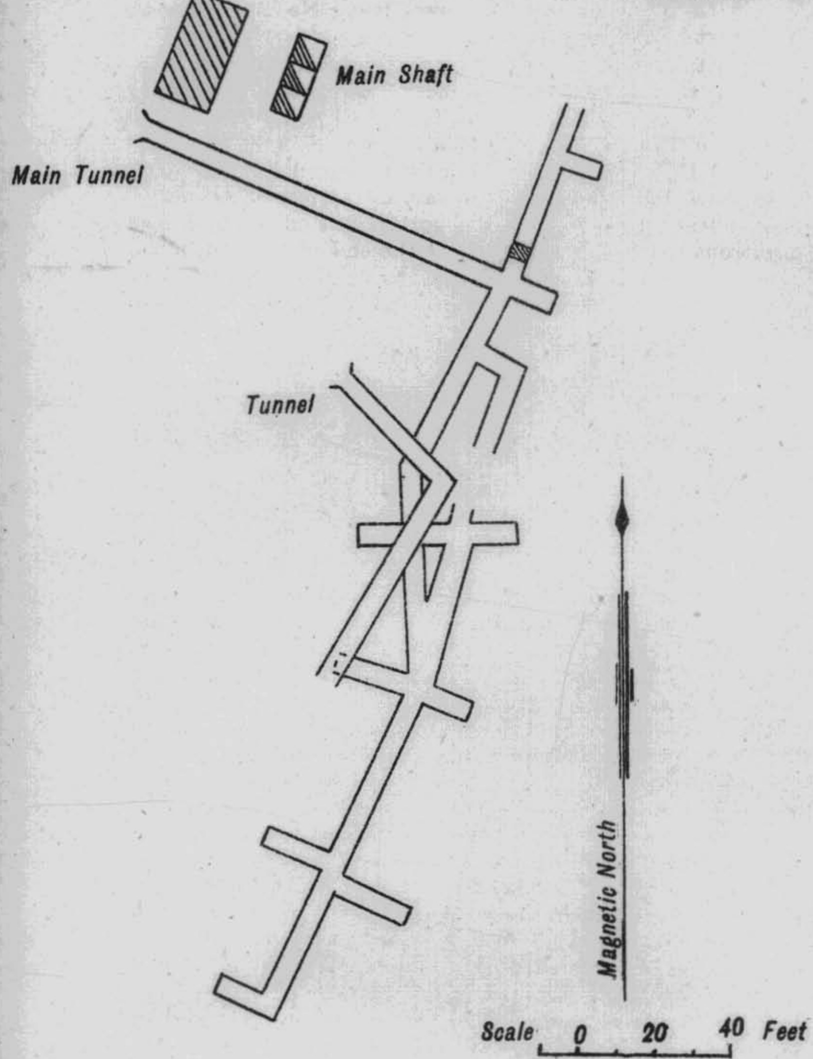
The trend of the lode is in general rather constant, though numerous marked local changes appear in the workings. The average strike is 30 degrees east of north, and the dip is at an inclination of 73 degrees in an easterly direction.

The selected ore averages 60 per cent. lead and 50 oz. silver per ton. A sample of selvage material from the footwall contained 190 oz. silver per ton. Very little ore has been stoped, most of that exported having been recovered in driving along the course of the lode. During the first quarter of 1913 parcels of ore weighing 51 tons were sold to the Tasmanian Smelting Company, whose works are at Zeehan. Details of the sale are contained in the following table, and convey an idea of the value and the nature of the ore:—

ACCOUNT SALES, STERLING VALLEY MINE.

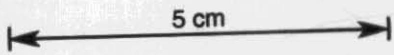
Description.	Date.	Net Weight			Net Price per Ton			Proceeds.			Assay Value.		Average Quotations.	
	1913.	Tons.	cwts.	qrs.	£	s.	d.	£	s.	d.	Pb %	Ag ozs.	Lead per ton.	Silver per oz.
Galena	January	20	10	3	10	8	8	214	5	8	52·6	44·0	£18·07	31·64d.
Galena	March	21	15	1	9	13	7	210	13	9	54·85	43·6	£16·42	30·52d.
Concentrated galena	April	6	16	1	10	15	9	73	10	11	60·5	50·2	£15·98	28·65d.
Galena	April	0	19	1	10	17	8	10	11	8	60·8	50·6	£15·98	28·65d.

PLATE VI



STIRLING VALLEY MINE WORKINGS

Photo Algraphed by John Vail Government Printer Hobart Tasmania.



(b) Development.—The property is developed by two tunnels, both at very shallow levels. No. 1 tunnel is only 15 feet below the surface; the lower level, No. 2, is from 45 to 60 feet below the surface.

No. 1 tunnel is approached by a deep trench 37 feet long, coursing 43 degrees east of south. The outcrop is exposed at the end of the trench, and from this point the lode is driven on 61 feet in a direction 31 degrees west of south. The first 10 feet of rock exposed in the trench is unmineralised, black fissile slate; the remaining 27 feet shows abundant pyrite disseminated throughout the slate, and also numerous veinlets of quartz. At the end of the trench the lode formation is 3 feet wide and is composed of galena and zinc-blende in a siliceous matrix. Six feet along the drive southward, a hole 3 feet deep shows a band of high-grade galena, 6 inches wide, on the footwall; farther south this band contracts to 2 inches, and continues thus to the working face. In addition to this band of galena, some second-grade ore and several bands of silica show in the back of the drive near the end.

The No. 2 or Main Tunnel workings are much more extensive, and include 257 feet of crosscutting and 325 feet of driving. The main crosscut, 116 feet long, bearing 66 degrees 15 minutes east of south, passes through 30 feet of quartz-felspar porphyry schist, 53 feet of black slate, then enters the lode channel, consisting of slate carrying siderite, zinc-blende, pyrite, and a little galena. At 103 feet from the entrance the workable veins of galena and zinc-blende are intersected, and from this point the main drives north and south commence. The main crosscut is extended 15 feet beyond the lode proper through mineralised slate. The north drive is sent in 50 feet on a bearing 21 degrees east of north. At 10 feet from the crosscut a rise is carried through to the surface, and at 40 feet an east crosscut is sent in 12 feet. Good grade milling ore, from which a fair amount of selected ore may be obtained, shows in the back of the drive and also in the working face. A very fine bunch of first-grade galena, 3 feet wide, is exposed in the east crosscut near the north working face. The extent of this ore has not been determined.

The main drive, coursing 28 degrees 10 minutes west of south for 53½ feet, exposed two veins of galena, that on the eastern side 12 inches and the other 8 inches wide. This rich shoot continues for 20 feet south of the main crosscut, and was stoped up 20 feet above the drive. A small crosscut sent in easterly 15 feet intersected a narrow vein of galena on which a wing drive southward is carried 30 feet. A large vugh, with well-crystallised pyrite lining the walls, is cut into at this point. The main drive is continued on a bearing 1 degree 27 minutes east of south for 18 feet, whence a crosscut 14 feet long is sent in westward, and a crosscut 30 feet long eastward. The workings on the westward side are beyond the lode channel; the eastern workings show galena and zinc-blende with much pyrites and quartz. The main drive is continued on the same course for 41 feet, where it meets the eastern wing drive on the lode. Near this junction a vein of galena and zinc-blende, 4 inches wide, increasing a little further southward to 6 inches of clean, high-grade zinc-blende and 2 inches of galena shows on the footwall. The floor of the drive at this point is raised 2 feet. Crosscuts sent in east and west reveal slightly mineralised fissile slates containing numerous veinlets of silica. The southern face of the main drive is reached in 94 feet on a bearing 25 degrees west of south. At 52 feet a western crosscut passed through a strong siliceous body of ore containing a band 8 inches wide of galena, arsenopyrite, zinc-blende, and pyrite. The eastern crosscut passed through soft black slate containing numerous parallel bands of pyrite, each upwards of 1 inch in thickness.

At the end of the main south drive a short crosscut westward exposes a very strong lode formation, fully 6 feet wide, composed of white opaque quartz with pyrite, arsenopyrite, malachite, and a little galena and blende.

Further development consists of the sinking of the main shaft—three compartments, 12 feet by 4 feet in clear—to 20 feet. Considerable excavation has been necessary to make provision for the surface appointments at the shaft opening. The configuration of the country does not admit of mining on an extensive scale by tunnelling, therefore recourse is had to the shaft method of exploitation.

(c) Equipment.—Provision for operating from the main shaft is made by the installation of a first-motion winding engine (14-inch cylinders), a pumping engine (20-inch cylinders), connectel to a sweep-rod and balance-bob. This plant is firmly set on a concrete foundation, and is comfortably housed. Further equipment at the mine consists of poppet-heads with pulley-wheels in position and the usual accessory requirements of mines.

(d) Milling Plant.—The greatest material asset of the company is the milling plant, which was purchased from the Murchison Mining Company. The mill has not yet been removed from the original site of its erection, about halfway between the Sterling Valley Mine and the township of Tullah, but when required for use will be re-erected on a suitable site at the mine.

This mill is an extensive and efficient concentrating plant.

A galloway boiler—size 240 x 60, working pressure 100 lb. per square inch—supplies motive power to a 14-inch single-cylinder steam engine of 25 horse-power, which drives the milling machinery.

The ore is delivered from the mine trucks to a bin of 100 tons capacity, from which it is fed to a 14-inch x 12-inch Blake crusher, whence it passes to No. 1 trommel (holes 25 mm. diameter). The undersize is conveyed to a set of three trommels, having holes 5, 3, and 2 mms. diameter respectively, arranged in tandem. From these trommels the oversize is elevated and reground in No. 1 rolls, whence it is conveyed to a set of trommels, sized, and delivered to a set of plunger-type jigs suitably ragged. The oversize from No. 1 trommel is conveyed to a 10-feet diameter circular revolving picking table, on which the poor material is sorted from the ore and discarded. The ore is discharged to No. 2 rolls, from which it passes to a series of four trommels, having holes 3, 2½, 2, and 1½ mms. diameter, arranged in tandem descending order. From this set of sizing trommels the product is carried to 4 plunger-type jigs suitably ragged and of the required stroke to treat the sized product of the trommels. The seconds product of the jigs is reground in rolls and returned for further treatment. The slimes and fine sands are elevated to spitzkasten and then treated on Wilfley tables.

The capacity of this mill is set down at 35 tons per working day of eight hours. It is stated that the tailing loss does not exceed 1½ per cent. lead.

At the milling plant the company operates a saw-bench capable of cutting timber of all sizes required in connection with the work of the mine.

(e) Transport and Communication.—The mine is easily accessible from Tullah by means of a fairly well graded wooden tramway. The Sterling Valley Company laid down this tramway on the Tullah-Rosebery road formation as far as the mine. A substantial wooden bridge, strongly anchored to concrete blocks, crosses the Murchison River.

Beyond the Sterling Valley Mine the road is 10 feet wide, and well formed, but very badly graded. The culverts and bridges are constructed of celery-top pine logs, and the whole work may be regarded as a well-constructed road.

Ore from the mine is conveyed to Tullah by horse-tram, thence to Farrell railway siding by steam-tram. The cost of transport of the ore from the mine to the market is excessive.

(f) General Remarks.—The decision of the management to operate the mine from a main shaft is considered perfectly sound, and is fully justified by the developments attending the exploratory work. The present workings can be regarded only as a preliminary prospecting operation upon which the more extensive permanent works will be designed.

It is impossible, on the evidence gathered, to more than indicate the probable nature and extent of the ore-body at depth. The large fracture zone and its persistency along the strike are a measure of its continuance along the dip. That the ore is at least of equal richness at moderate depth may be safely anticipated, although of course there always exists in an undeveloped ore-body of this type a certain element of risk. But the mine has a promising outlook, and the lodes are worthy of being energetically prospected with a view to exploitation upon a much larger scale.

(16)—Albert Midson's Prospect.

This property, held under prospector's licence, is situated 4 miles south of Tullah township and ¼-mile on the east side of the Sterling Valley Tramway, and was discovered in the early part of the year 1917. The lode is exposed on the surface occupying the apex of a narrow ridge which rises southward from the tramway upwards of 200 feet. The lode occupies a well-defined fissure in schistose quartz porphyry (porphyroid) of the dark-green colour characteristic of the rock in this locality. The spheroidal quartz phenocrysts have not been appreciably affected by the forces inducing schistosity, and stand out in relief above the folia. On the footwall side of the fissure the porphyritic schist has suffered partial replacement by silica and chalcopyrite, though the latter mineral is in very small amount outside the lode proper; on the hanging-wall side the replacement by silica extends 4 feet beyond the fissure.

The mineral constituents of the lode are chiefly chalcopyrite and its derivatives, covellite and malachite. Quartz, sphalerite, galena, pyrite, and chlorite occur in lesser amounts. Galena, sphalerite, and quartz show symmetrical crusted structure with the chalcopyrite, exhibiting characteristics typical of fissure fillings.

A considerable portion of the ore is remarkably rich in copper, and in addition contains silver and a little gold. The ore, as a whole, is sufficiently rich for export. A sample of chalcopyrite submitted to Mr. W. D. Reid, Government Assayer, for analysis, is reported by him to contain :—

Copper 25·15 per cent.
Silver, 8 oz. 19 dwt. 15 gr. per ton.

The strike of the lode is 20 degrees west of north; the dip is almost imperceptible, the tendency appears to be towards the west. The width of the vein varies from 10 inches at the surface to 3 inches at the bottom of the trench 15 feet lower down. No attempt has been made to determine the lineal extent of this fissure on the surface, but it can be traced for at least 2 chains along the ridge, and probably much farther if the soil cover were removed.

Developments consist only of a small open-cut 30 feet long, 15 feet deep, and 6 feet wide, sent in from the northwest fact of the hill.

Fully 100 feet of " backs " can be got by driving from the north side of the hill, and the " backs " increase rapidly going south. Probably the best means of attacking this lode is by driving on the fissure southward from a suitable point on the north fall of the hill. The fissure, even if it be closed, should be traced down the face of the hill until a suitable point at the desired level is arrived at for the proposed tunnel opening.

The vein pinches and swells along the strike and also the dip, and resembles many others of a similar character occurring in this district. Not one of the great number of these fissure veins contained in porphyroid rock has been explored below 60 feet from the surface. The occurrence of pinches and swells is indicative of faulting within the fissure, and gives rise to irregularities in the vein along both the strike and dip. The extent of the fault was not determined.

This discovery deserves more attention and could be cheaply explored by driving along the course of the fissure southward. Probably the amount of ore recovered in driving along the lode would be of value sufficient to pay for the work, especially if the tunnel commences at a swell in the fissure. Every facility is provided for the economical exploitation of the ore-body.

(17)—J. Fulford's Claim.

Section 2862-m, 40 *Acres.*

This claim is part of the original Harris' Reward property, and is situated near the tramway 1 mile north of the Sterling Valley Mine.

The lode occupies the summit of a narrow ridge elevated about 35 feet above a button-grass plain, and outcrops continuously for nearly 1000 feet. The trend of the lode is 20 degrees east of north, and the dip is westerly at an angle of 67 degrees.

The ore-body is about 4 feet wide, and is composed of quartz and chalcopyrite, with pyrite and arsenopyrite in subordinate amount sporadically distributed through the quartz. It is contained between argillaceous schist on the hanging-wall and schistose felspar porphyry on the footwall side.

Developments consits only of a deep trench, 35 feet long, 4 feet wide, and 6 feet deep, sent in from the western side of the ridge. Any further development will have to be undertaken by means of a shaft.

The prospect does not warrant the expenditure which would be required to explore the lode.

IX.—UTILISATION OF PYRITE.

(1)—Pyrite.

Pyrite is found under a great variety of associations. It is a common constituent of ore-bodies, and occurs also as a minor accessory constituent of many igneous rocks.

In most cases pyrite is a secondary mineral, but it is sometimes primary.

Composition—Iron bisulphide, FeS_2, S. 53·3 per cent., Fe 46·7 per cent.

Crystallisation—Isometric, usually in cube and derivatives, and also in pentagonal do-decahedron. It commonly occurs massive, granular, and in globular forms.

Cleavage—Indistinct, parallel to the cube faces and to the octahedron.

Hardness—6-6·5, brittle.

Fracture—Conchoidal and irregular.

Lustre—Metallic, splendent to glistening.

Colour—Pale brass-yellow.

Specific gravity—4·9 to 5·1.

Streak—Greenish-black to brownish-black.

Aspect—Opaque.

Pyrite readily changes to an iron sulphate by oxidation, some sulphur being set free. It also alters to limonite, and from limonite to the red oxide of iron, hæmatite. Limonite and hæmatite often occur pseudomorphous after pyrite.

A great deal of the sulphate of iron (copperas) of commerce is derived from its decomposition, but its chief value is as a source of sulphur.

(2)—Sulphur.

The compounds of sulphur which form the principal sources of supply are pyrite, marcasite, chalcopyrite, bornite, galena, sphalerite, and pyrrhotite.

Sulphur is an element which plays an important part in the arts and sciences. One of the simplest and one of the most easily produced compounds of sulphur is sulphur dioxide (SO_2).

This compound of sulphur and oxygen is made by burning elemental sulphur or by roasting pyrite in air. Sulphur dioxide gas has many uses in various industries. Some of the methods of utilisation are classfied as follows:—

(1) It is used in the manufacture of sulphuric acid; paper-pulp by the sulphite process; sodium sulphate by the Hargreaves process.

(2) Sulphur dioxide may be reduced to elemental sulphur by several processes. The Hall and Thiogen processes are more generally employed.

Its use in the manufacture of sulphuric acid only will be dealt with here.

(3)—Sulphuric Acid.

Sulphuric acid is such an important chemical agent that most of the greatest industries are directly dependent upon its use. It is used in America in the refining of petroleum; in some countries for the galvanising and tin-plate industry for pickling or cleaning the steel before it goes to the metal baths. In Europe large quantities are required in the Leblanc process of producing sodium carbonate and sodium hydrate from sodium chloride. But more sulphuric acid is consumed in the manufacture of fertilisers than in all other industries put together. It may be noted that the United States of America produced in 1916 over 950,000 tons of sulphuric acid as a by-product from the roasting of copper and zinc ores. This represents about 25 per cent. of the total sulphuric acid made in the United States, the remainder being obtained by roasting pyrite or elemental sulphur specially purchased for the purpose.

The relative importance of outlets for sulphuric acid in the United States is appended, and was taken from estimates compiled by an officer of the United States Geological Survey[30]:—

	Tons.
Manufacture of fertilisers...	2,400,000
Refining of petroleum products	300,000
Iron, steel, and coke industry...	200,000
Nitro-celiulose, nitro-glycerine, celluloid, &c. (pre-war conidtions)	150,000
All other industries...	200,000
Total	3,250,000

([30]) *Vide* A. W. S. Wilson: "Pyrites in Canada," Canadian Geol. Survey.

This quantity, in terms of 50 degrees Baumé acid, is consumed in the United States per annum.

Sulphuric acid is manufactured at the present time by two entirely different processes, namely, the chamber process and the contact process. In the United States two smelters use part of their furnace gases for making sulphuric acid by the chamber process. A minimum of 4·5 to 5 per cent. sulphur dioxide in the gases is necessary for satisfactory operation, and this percentage of sulphur dioxide results from the discharge of the poor gases from the high grade matte furnaces and from the converters.

Pyritic smelting is practised as at Mount Lyell, the sulphur being oxidised by the blast and serving in part as fuel. The gases from the furnaces contain about 5·5 per cent. sulphur dioxide, and are sent to the chamber plant for conversion to sulphuric acid. The Mount Lyell Company, at the Queenstown works, has been experimenting upon the furnace gases with the object of recovering the sulphur content in the elemental condition.

There is no record in the Official Year Book of the consumption of pyrites in Australia, nor is there any information concerning the manufacture and consumption of sulphuric acid.

The Commonwealth Statistician has furnished the following statement showing the quantity and value of sulphur, and also pyrite, imported into Australia during the past three years:—

	Sulphur.		Pyrites.	
	cwts.	£	cwts.	£
1913...	603,865	148,204	256,702	28,255
1914-15... ...	421,497	104,343	481,351	51,916
1916-17... ...	991,780	419,833	30,000	4208

It will be noticed that the last year's figures show a very large increase in the quantity of elemental sulphur imported, and a corresponding decrease in the importation of pyrites. The greater quantity of elemental sulphur is now imported from Japan.

(4)—Recoverable Sulphur in Pyrite[31].

If the ore contains suplhur compounds other than pyrite the available sulphur for the manufacture of sulphuric acid will be proportionately reduced. For instance, if a pyrite

(31) After "Pyrites in Canada," A. W. S. Wilson; Canada Geol. Survey.

ore contain the impurities zinc-blende, galena, chalcopyrite, and other metallic sulphides, the value of the ore to the purchaser is reduced by the quantity of the sulphur contained in these impurities. Assuming a price of one shilling per unit of sulphur in a pyrite ore this can be illustrated in the following manner:—44 per cent. sulphur at 1s. per unit = 44s. per ton, but as the manufacturer can only recover 38 per cent. sulphur owing to the remaining 6 per cent. being combined with the zinc, lead, and copper impurities and not available for recovery, he is really paying nearly 1s. 2d. per unit for the recoverable sulphur. Moreover, if an ore containing 40 per cent. sulphur and free of impurities is compared with one containing 44 per cent. sulphur with 6 per cent. unrecoverable on account of impurities, and deducting 2 per cent. for losses in burning, then the ratio is not 40 to 44 but 38 to 36. The value of an ore, then, is not necessarily determined according to the total sulphur content, but to the percentage of recoverable sulphur it contains.

The necessity for increasing the sulphur content of an ore by concentration of the pyrite is apparent, especially when the sulphuric acid works are located at a distance from the mine, on consideration of the proportional value of sulphur of different grades. One ton of 44 per cent. sulphur ore contains an amount equal to 1·16 tons of 38 per cent. ore. Assuming freights to market to be at the rate of 10s. per ton, then the extra proportional cost of freight on 38 per cent. ore compared with 44 per cent. ore is at the rate of over 1s. 7d. per ton. The proportion between 44 per cent. and 38 per cent. ore is 1 : 1·16, and this same ratio applies to handling, storing, burning, and the removal of the residual cinder after the roasting operation.

It has been pointed out that under conditions otherwise equal the unburnt sulphur in the cinders is the same by weight. If, for instance, 5 per cent. of sulphur is left in the cinders, this amounts with a 35 per cent. ore to $5 \div 35 = \frac{1}{7}$, with a 45 per cent. ore to only $5 \div 45 = \frac{1}{9}$; the proportion to be kept in view is, accordingly, not 35 : 45 = 7 : 9, but 30 : 40 = 3 : 4.

(5)—Value of Pyrite Ore.

The lowest grade of ore saleable in Australia at the present time is 38 per cent. sulphur ore. This is purchased at the rate of 10d. to 11d. per unit of sulphur in ore delivered on the Melbourne Wharf. Payment is made for copper if the ore contains over 1 per cent. of that metal. Penalties are imposed in cases where ores contain deleterious impurities.

(6)—Production of Sulphur.

Sulphuric acid is used in many branches of industry and has so many applications that it is of the utmost importance to secure ample supplies of pyrite or elemental sulphur for its manufacture.

Japan, United States of America, and Sicily produce large quantities of elemental sulphur, while Spain exports from its famous Rio Tinto mines enormous quantities of pyrite. Recently, owing in a measure to the lack of shipping space consequent upon the demands for the carriage of more essential products and the greatly increased freight charges, the supplies from Spain have been cut off. Manufacturers now receive very large supplies of elemental sulphur from Japan, and they have turned their attention to the development of the many large bodies of pyrite known to exist in Australia. There are several large pyrite deposits in Tasmania which could be profitably exploited if sufficient shipping space were available for its carriage to market.

(7)—Fertilisers.

One of the main uses of sulphuric acid is for the conversion of natural phosphates of lime into superphosphates for fertilising.

There are no known deposits of mineral phosphate of lime (apatite) in Tasmania, although this mineral is very widely distributed as an accessory constituent of certain igenous rocks, especially the granites. Supplies of rock phosphates and guano are derived mainly from the South Sea Islands, where very large quantities are mined.

Superphosphates are the product resulting from the treatment of phosphate rock with strong sulphuric acid in such a manner that the maximum amount of mono-calcium phosphate, soluble in water, is obtained, together with a little dicalcium phosphate mixed with the crystalline gypsum which results from the reaction.

Tricalcium phosphate, however finely divided, being insoluble in water, only comes into contact with or is absorbed by the roots of plants very slowly, and it is therefore advantageous to transform it into monocalcium phosphate, $CaH_4(PO_4)_2$ (superphosphate), which is soluble in water, and therefore easily dissolves in the soil. In contact with the lime in the soil it is transformed into dicalcium phosphate and also into tricalcium phosphate insoluble in water, but it is then so uniformly divided that the organic acids generated by plants render the compound suitable for their assimilation.

The local production of artificial manures has assumed large proportions during the last few years, though considerable quantities are still imported. The importation of fertilisers has increased over 200 per cent. since 1901, and during that period exportation has increased as much. The local consumption in 1916 of artificial manures amounted to 381,336 tons; imports amounted to nearly 200,000, and exports to nearly 60,000 tons. The importation of superphosphates between the years 1911 and 1916 fell from 63,000 tons to 2900 tons, and exports increased from 10,000 tons to nearly 42,000 tons. Practically the whole of this fertiliser is manufactured locally, and is shipped mainly to New Zealand, Java, and Japan.

(8)—Land Production.

The productivity of the soil depends upon the nature and quantity of chemical material available, which is essential to the requirements of plant life, and also to the bacteria developed in the soil. The essential elements required for plant growth are phosphorus, calcium, potassium, nitrogen, iron, sulphur, magnesium, &c. These elements are not found in their simple condition, but in the particular chemical compounds necessary for their assimilation by plants.

In the ordinary course of their life, plants, under normal conditions, grow from seeds to maturity, die, and decay, giving back to the soil the chemical compounds employed in their growth. The organic acids generated by the plant are carried in solution to the subsoil and become active agents in the disintegration and decomposition of the rock of which it is composed, and incidentally replenish the soil with those compounds used up by the plant.

On "new" lands certain plants suitable for the soils may be grown successively for a period depending upon the richness of the soil in those elements required by the plant, but each cropping depletes the soil of a portion of its life-giving nourishment, and ultimately the land becomes too poor to cultivate. The only remedy is to replace the compounds used up by the addition of suitable manures. In populous centres the high valuation placed upon the land renders it necessary to intensely cultivate the soil, so that the greatest possible production is made therefrom. This necessitates continuous cultivation, which is rendered possible only by the addition of fertilisers to replace artificially the chemical compounds extracted from the soil by the plants which have been removed. The widely divergent character of soils and their degeneration by repeated cropping render it essential to make them reproductive by the addition of fertilisers containing those elements in which they are deficient. It is not always practicable to follow the recognised order of rotation of crops, as the demand may be far greater for one particular product; and, again, climatic conditions may be such that it is necessary to enrich the soil in order to get the quickest return therefrom.

The whole basis of land production is to get the greatest development of plant life per acre. It is far better, for instance, to get a big crop on a small area than five times less crop per acre on an area five times as large.

X.—CONCLUSION.

The greater part of the North Pieman and Huskisson district has been only superficially prospected, and in only one instance has development reached the productive stage. At the present time preparation is being made for the resumption of work on a considerable scale at the Chester Mine. At Pinnacles very little work has been done since the cessation of exploratory work by the Mt. Lyell Company. In fact, with the sole exception of the few men employed at the Chester Mine, the district is deserted.

In view of the natural advantages of location and transportation, it is evident that there must be some cogent cause to account for the retarded progress of the district.

In recent years the rapid development of the fertiliser industry has led to a greatly increased demand for sulphuric acid, and incidentally iron pyrites, the sulphur content of which is employed in the manufacture of the acid. The large demand and the higher prices ruling for pyrites are causes which were directly responsible for the exploitation of the Chester pyrite mine.

The Pinnacles ore is regarded as being a very complex mixture of zinc, lead, copper, and iron sulphides, so intimately mechanically mixed that the finest comminution is necessary to effect their separation. Until quite recent time no metallurgical process had been evolved for the separation of the mineral components of such ores that could be considered an economic success. The progress made in the application of flotation and electro-chemical methods to the treatment of ores of this type has been so great that there can be no doubt of their successful operation. The decision of the Read-Rosebery Mines Limited to erect large electro-chemical works in the vicinity of Zeehan to treat low-grade complex ore such as occur at Pinnacles, will greatly stimulate exploration, and will probably be the means of their profitable exploitation. The difficulty experienced heretofore in the successful treatment of the Pinnacles ore has been the main causal factor in the retarded development of the district.

The occurrence of another mineral belt on the western boundary of this area has long been known, but the discovery so far south had not been reported. This mineral belt is one of decided promise, but until some exploratory work has been done it is impossible to form an opinion of its value with any degree of certainty. Prospecting along this belt is strongly advocated, as it offers exceptional opportunities, and is now only in the very earliest stage of development.

Considerable areas still remain unprospected, and although they are difficult of access, are worthy of examination. Future exploration will probably reveal ore-bodies comparable with, and perhaps even richer and more extensive than, those already known. The search for new ore-bodies along the porphyroid schist junction should be vigorously prosecuted, and the narrow bed of calcitic schists so highly developed southward is a favourable *locus* for ores. The calcitic schist bed in the North Pieman and Huskisson district is very narrow, and is covered for a considerable distance by the fluviatile deposits of the Pieman flood-plain. Probably the greatest concentration of zinc-lead sulphide ores in the eastern portion of the district will be found in the calcitic schists. Outside of these it is not anticipated that deposits of much higher grade than those already developed will be found.

In the Sterling Valley area the recent discovery of Midson's Copper lode attracted attention to this portion of the Murchison District; but now all work has ceased, and the area is practically deserted. Operations at the Sterling Valley Mine were suspended owing to the lack of sufficient working capital. It is to be regretted that this company has not been able to take advantage of the very high prices ruling for lead and silver. The greatest drawback in the successful operation of the mine is the very high cost of transport on ore, machinery, and produce.

Now that the utilisation of low-grade complex ores has become feasible, it is safe to conclude that many of the known deposits will be further exploited, and that greater attention will be given to these areas by prospectors and mining investors.

A. McINTOSH REID,
Acting Assistant Government Geologist.

Launceston, 12th June, 1918.

GSB 28
Plate VII

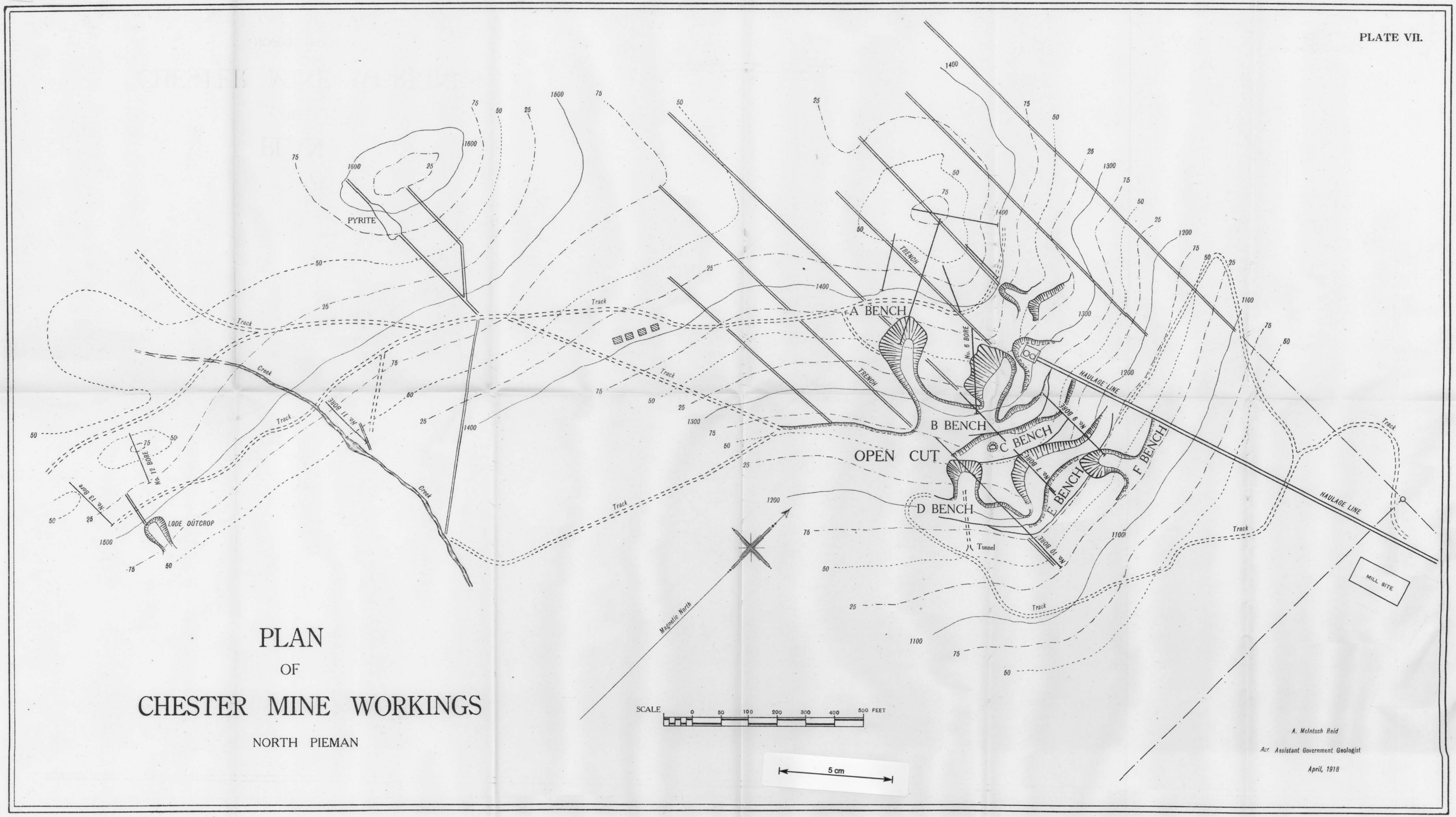
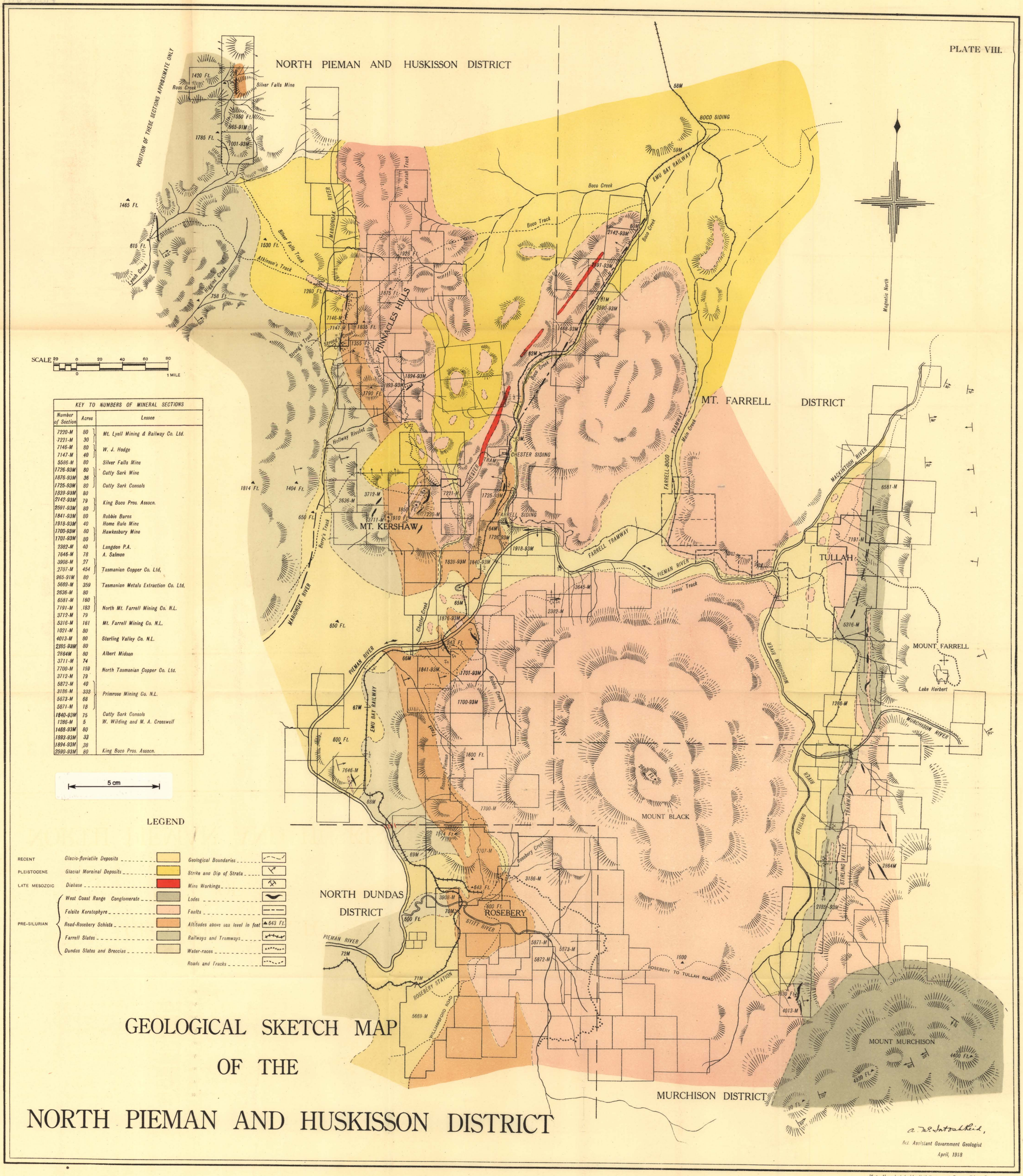


Photo Algraphed by John Vail Government Printer Hobart Tasmania



KEY TO NUMBERS OF MINERAL SECTIONS

Number of Section	Acres	Lessee
7220-M	80	Mt. Lyell Mining & Railway Co. Ltd.
7221-M	30	
7146-M	80	W. J. Hodge
7147-M	40	
5586-M	80	Silver Falls Mine
1726-93M	80	Cutty Sark Mine
1876-93M	36	
1725-93M	80	Cutty Sark Consols
1839-93M	80	
2142-93M	79	King Boco Pros. Assocn.
2591-93M	80	
1841-93M	80	Robbie Burns
1918-93M	40	Home Rule Mine
1700-93M	80	Hawkesbury Mine
1701-93M	80	
2382-M	40	Langdon P.A.
7646-M	78	A. Salmon
3908-M	27	
2707-M	454	Tasmanian Copper Co. Ltd.
965-91M	80	
5669-M	359	Tasmanian Metals Extraction Co. Ltd.
2636-M	80	
6581-M	160	
7191-M	183	North Mt. Farrell Mining Co. N.L.
3712-M	79	
5316-M	161	Mt. Farrell Mining Co. N.L.
1021-M	80	
4013-M	80	Sterling Valley Co. N.L.
2185-93M	80	
2864M	80	Albert Midson
3711-M	74	
7700-M	159	North Tasmanian Copper Co. Ltd.
3712-M	79	
5872-M	40	
3186-M	333	Primrose Mining Co. N.L.
5873-M	68	
5871-M	18	
1840-93M	75	Cutty Sark Consols
1286-M	5	W. Wilding and M. A. Crosswell
1468-93M	80	
1893-93M	33	
1894-93M	38	
2590-93M	80	King Boco Pros. Assocn.

GEOLOGICAL SKETCH MAP OF THE NORTH PIEMAN AND HUSKISSON DISTRICT

A. McIntosh Reid,
Act. Assistant Government Geologist
April, 1918