

1894.
NEW ZEALAND.

DEEP QUARTZ-MINING IN NEW ZEALAND

(REPORT ON).

Presented to both Houses of the General Assembly by Command of His Excellency.

SIR,—

Invercargill, 15th March, 1894.

Having completed the examination of various quartz-mining districts in New Zealand, to execute which inspection my services were placed at the disposal of your Government by that of Victoria, I have now the honour to submit my report, which embodies such advice and conclusions as to future prospects and prospecting operations as are warranted by the observed local evidences in the mines compared with quartz-mining experience on the Australian goldfields.

As I apprehend my instructions, the main duty required of me is to advise with respect to the probabilities of success in deep mining for auriferous lodes and reefs on the various fields visited, of which some yielded richly in the past but are at present in a languishing condition, and my remarks are therefore directed to the practical mining rather than to the scientific geological aspect of the subject, only touching on the latter where it has immediate bearing on the former.

Towards arriving quickly at an acquaintance with the principal geological conditions of the country visited, the admirable work executed by and under the supervision of Sir James Hector, K.C.M.G., F.R.S., &c., and the information willingly placed at my disposal by that gentleman, proved of the greatest service.

Mr. H. A. Gordon, C.E., F.G.S., Inspecting Engineer, and Mr. A. McKay, F.G.S., Mining Geologist, both accompanied me in the inspection, affording the full benefit of their long personal local and scientific experience, and in every way facilitating my work.

The quartz fields examined can be divided into three main groups, according to the geological age and the lithological character of the rock-formations containing the reefs.

1. The group contained in the Cape Colville Peninsula and southward, comprising the Thames, Coromandel, Tokatea, Karangahake, Waihi, and Waiorongomai quartz workings, wherein the gold-bearing quartz reefs traverse rocks of Upper Secondary or Lower Tertiary age and of volcanic origin.

2. The Reefton group of quartz reefs in sedimentary rocks of Carboniferous age, with which may also be included the reefs of Lyell, though the rocks there are regarded as Devonian.

3. The reefs occurring in rocks of the old metamorphic series (Archæan)—mica and quartz schists, &c.—as at the Ravenscliffe Mine, on the Waikakaho Creek, near Cullensville, in the Marlborough District, and Waipori, Bendigo, Macetown, Arrowtown, and Skipper's, all in Otago.

FIRST GROUP.

The Thames Goldfield.

In acquiring a grasp of the leading features of this field I obtained most valuable assistance from the excellent map and sections prepared by Mr. James Park, F.G.S., director of the local school of mines. These have, I understand, been forwarded to the Mines Department, and will be published for general information. I was able to verify their general correctness by personal observation, and they will furnish an excellent illustrative accompaniment to this section of my report.

With respect to early workings and general features, much useful information was contributed by Mr. R. McDonald Scott, who came over specially to afford assistance.

Mr. George Wilson, District Inspector of Mines, exerted himself to bring together the mining managers of the field to contribute their experience and suggestions, which they willingly did. Amongst these Messrs. Dunlop, Clarke, Smith, and Radford may be specially mentioned as having greatly facilitated the acquisition on my part of a knowledge of the leading mining features.

The geological formation of the Thames Goldfield is of volcanic origin, and its age is placed by your geologists as about Upper Secondary or Lower Tertiary. The rocks occur on three main classes, as observed by myself, and also indicated on Mr. Park's plan and sections by the numbers 4, 5, and 6, which, for brevity's sake, will be used to distinguish the respective classes. The first

(No. 4) consists of hornblende andesites and tuffs, forming the "hard country" of the miner; the second (No. 5) of decomposed andesites and tuffs, forming the soft or "kindly country" of the miner, and often locally termed "sandstone"; the third (No. 6) of hard tuffs, andesite-breccias, and agglomerates, made up principally of ejected volcanic fragments with occasional pieces of the underlying sedimentary slates. These slates, near the Thames, only outcrop over a small area at Rocky Point, near Tararu, though they doubtless form the rock-foundation of the whole Cape Colville peninsula, as they outcrop at various localities.

Leaving the slate outcrop at Rocky Point, and coming along the coast southerly towards the Thames, the rocks as far as Kurunui Creek consist of the third class (No. 6 on Mr. Park's map), which have seldom, if ever, been found to contain auriferous reefs.

From Kurunui to Karaka Creek—about a mile—occur the andesites and tuffs (overlying, and younger than No. 6) which are described under Nos. 4 and 5 on Mr. Park's map, and contain the gold-bearing reefs. These evidently extend southward under the newer sedimentary deposits which form the surface from Karaka Creek to Hape Creek, a further distance of about three-quarters of a mile. Near Hape Creek breccias reappear—whether No. 6 or not is uncertain; but there clearly exists between Kurunui and Hape Creeks an area, nearly two miles wide, occupied by Nos. 4 and 5, which, from the surface to various depths, have been proved to be traversed by auriferous-quartz reefs, and the deepest extent of which has not yet been ascertained, while the portion concealed by the newer sedimentary rocks is practically unprospected—*i.e.*, from about Karaka Creek to Hape Creek.

There is thus a basin or channel in No. 6 occupied by the auriferous andesites and tuffs (Nos. 4 and 5), the northern margin of which is represented by the outcrop of the non-auriferous breccias (No. 6) rising from beneath near the Kurunui Creek. The auriferous rocks occupying this basin also appear to shallow out upward in an easterly direction, and to deepen westerly or seaward, while their southern margin is so far undetermined, being obscured by Post-tertiary deposits. The auriferous-quartz reefs and veins traversing Nos. 4 and 5 form a wide belt having a general direction north of east and south of west. The quartz veins nearest to the north margin gave out, as regards gold, at comparatively shallow depths; but each succeeding reef or stockwork of veins southward has proved gold-bearing to a greater and greater depth.

This dip of the floor of the gold-bearing rocks has been noted as amounting to 462ft. in 37 chains by those conversant with the workings.

Mr. Park's cross-section shows, from the Kurunui to the Karaka Creek, over thirty notable reefs and veins, apart from the network or stockwork of veins occurring between them in many places, such as the Shotover ground, &c.

It is noticeable that of these principal reefs all to the northward of a point between the Saxon and Queen of Beauty shafts underlie northward, while southward of that point the majority of the reefs show a southerly inclination.

I observed, however, nothing in the structure of the rocks to account for this, which may, after all, be a coincidence, though suggestive at first glance of a "saddle" formation on a large scale.

The rocks of this basin have been subjected to at least two great dislocating movements. The great Moanatairi fault or slide has caused a downward slip of a large portion of the rocks towards the sea and the line of the fault is clearly traceable on the ground by the physical configuration of the country, and by the actual attrition-marks on its exposed wall-surfaces, while it is also distinct in such tunnels or drives as have reached or cut through it underground.

The vertical displacement caused by the fault has been estimated at from 300ft. to 600ft., but whatever it be, by so much lower are the rocks and their contained quartz-reefs on the coast side of the fault than their equivalents on the inland side. Another fault known as the "Collarbone" acts in a similar manner, but curves round and meets the Moanatairi fault to the south-west near Karaka Creek, and whether the two intersect and continue in independent courses or coalesce in one is as yet undetermined.

In some of the underground workings near and extending in the direction of the coast-line there has been struck what has been termed the "Beach slide"; but it is questionable whether this is really a fault or only the ancient coastward slope of the rocks when the land was more elevated, since banked up with recent accumulations.

Owing to the nature of the ground it was considered unsafe to explore further seaward beyond this assumed fault, but, if it really be one, it implies the existence beneath the gulf of a considerable section of rock, the down-thrown continuation and equivalent of the present exposed portion between the Moanatairi fault and the coast-line, in which the richest reefs and veins have hitherto been found.

Going up the Waitotahi Creek and crossing the Moanatairi fault, the junction of two great reefs is met with—the southern known as the Waitotahi, the northern as the Golden Age.

The latter reef in the Fame and Fortune Mine is 30ft. in thickness in places, and, though auriferous, has not been much worked, the "droppers" or branch veins on either side yielding the principal gold. This reef is regarded by some as the continuation of the main reef formerly worked in the Caledonia ground with such exceptionally rich results.

Dixon's reef is about the most northerly line on the field, except some detached workings of small extent to the northward, near the Tararu Creek, and is accompanied on the hanging-wall side by one of the hard undecomposed andesite bands. This reef has been worked to as much as 10ft. in thickness, and, where joined by the Sons of Freedom line, was very rich.

The Orlando Mine is on a reef known variously as the Orlando, Bendigo, and Reuben Parr; a tunnel here follows a strong well-defined reef bearing north-north-east and nearly vertical, with leaders coming into it. It has not here been worked underfoot, though stoped at deeper levels to the south-west. It is expected in this tunnel to meet the gold-shoot worked by the old Bendigo Company some distance ahead.

The Sons of Freedom, on the same line, shows a similar reef, which was very good above, but poorer below.

The Moanataiari tunnel has been driven 3,070ft., passing through and beyond the Moanataiari fault. On the seaward side of the fault adjacent ground has been worked below the tunnel-level, but on the inland side no payable gold has been yet discovered so deep.

Immediately beyond the fault the tunnel passes into the hard breccias (No. 6), but towards the present extremity enters a rock of the softer and more "kindly" description.

The continuance of this tunnel would be a desirable prospecting work, to which further reference will be made hereafter.

The Hazelbank Mine comprises the ground of the old Caledonia claim, so fabulously rich in early times. The shaft is 340ft. deep, and the No. 1 or Caledonia lode, though continuous, has ceased to be payable auriferous where it passes into the old Tookey ground. Work is now being principally directed to "droppers" on the hanging-wall side of No. 1 lode.

In the Waiotahi Mine there are several reefs, of which that known as No. 5 is the principal, with "droppers" or branch veins above and below them, the latter being the most auriferous. There is a complete ramification of veins in this ground.

Coming southward to the deeper workings, the Saxon shaft of the May Queen Mine is about 490ft. deep to No. 5 level.

According to the working-plans the lodes have been regular down to that level.

The northern or No. 1 reef has a northerly, and the southern or No. 2 a southerly underlie; a new reef joins No. 2, and the line of junction pitches eastward. There are various other veins and leaders, and the gold-bearing shoots are stated to be continuous under foot.

The old Queen of the May shaft is about 424ft. deep to No. 3 level. Driving was in progress on the lode, which is faulted in places, and is intersected diagonally by another lode; good gold being obtained along this intersection. The lode is stated to have been as much as 20ft. thick in places, and some of the gold-shoots are described as pitching seaward and others inland.

At the May Queen shaft, to the north-east of the last mentioned, the rich gold is reported to have commenced at about 300ft. from the surface, and continued to 480ft., the lodes being the same as those in the Queen of the May and the Queen of Beauty workings.

The Queen of Beauty shaft could not be descended, having been abandoned owing to some collapse of the machinery and difficulties of drainage, but the following particulars were supplied: The shaft is 748ft. deep to No. 11 level, and the same system of reefs was worked from it as those in the May Queen Mine. These were auriferous as far down as the workings extended, and a good large reef was left at the bottom. There was a poor interval about No. 6 level, but the gold made again from No. 8 level downwards; the rock at bottom was the "kindly sandstone" of the miners—decomposed andesite or tuff. The drives at the 460ft. level extended seaward to the so-called Beach fault.

Una Hill, south of Karaka Creek, is traversed by a large low-grade reef known as the Hague Smith line, and, in addition, there are numerous auriferous stockwork veins in the rocks on the southern and western slopes. These stockwork veins are rather a feature on this field, as they frequently carry rich gold while the larger reefs are poor. The Shotover ground, and in fact most of the area between the Kurunui and Waiotahi Creeks, is intersected by such veins, in addition to the larger reefs.

To describe in detail all the reefs of this field and their features would be a work of no ordinary magnitude, but the foregoing sketch is sufficient for the purposes of this report. The question of most serious moment at present is whether there is a fair chance of valuable developments being effected by means of deeper explorations.

Most of the easily-accessible auriferous ground is exhausted, or rapidly becoming so, and the great difficulty attendant on deep sinking is the water, which would necessitate the erection of a powerful and costly plant before deeper sinking could be attempted, the present pumping-plant, which effects the drainage for a number of mines, although being efficient to 640ft., is only lifting from a depth of 400ft.

No single company on the field appears to be able to undertake the erection of the necessary plant, nor does it even seem that there is the ability to effect it by combination of a greater number or the whole. Some assurance of success is, at all events, needful before enterprise in this direction is likely to awaken, though I should imagine the information already possessed with respect to the deeper shafts in the south-western part of the field should afford reasonable encouragement.

It appears evident that in that locality the bottom of the soft andesites and tuffs has not yet been reached, and so far as they extend downward so far are auriferous reefs or veins likely to occur.

I have no hesitation in expressing the opinion, based on personal observation and reliable information, that exhaustive testing by means of deep sinking is most advisable, and that the expenditure on the necessary pumping appliances would be fully warranted by the general indications.

As a precautionary measure, however, and in view of the great cost of sinking a deep shaft and erecting the necessary plant, I would advise preliminary boring, not by any means to prospect for auriferous quartz, for no method is more unreliable with such an object in view, but as a means to ascertain whether the soft tufaceous rocks really do continue to any considerable depth below what has been reached in the deepest mines. If this prove to be the case, then deep sinking will be amply justified, but if, on the contrary, the hard breccias be shortly met with, the project of sinking will wear a less promising aspect.

One or more deep bores with a diamond drill would throw much light on the matter; the cost as compared with sinking would be infinitesimal, and all necessary information would be obtained from the cores with respect to the character of the rocks passed through.

As a locality for such boring I would recommend the vicinity of the Queen of Beauty shaft, and, should the results be favourable, that shaft, from its position and size, seems the most suitable to select for deeper sinking, provided it be in proper condition.

Another highly important work would be the continuance of the Moanataiari tunnel, as this will afford a highway to, and the facilities for prospecting, a large area of likely ground, the upper portions of which were very rich. As to whether the tunnel should be continued as at present projected, or deviated somewhat to the north-east, there is likely to be a diversity of local opinion. From what I saw, the latter course would appear preferable; but this question is one which should be decided according to local experience and judgment.

I would also recommend prospecting the country between Karaka and Hape Creeks by sinking through the Post-tertiary deposits into the tufaceous rocks and then cross-driving in the latter.

If a deep shaft be sunk at or near the site of the Queen of Beauty shaft, exploring drives should be extended southward towards Hape Creek, and westward towards the gulf, as it is quite possible that the auriferous rocks may extend far under the sea and the recent accumulations in its bed, and may be worked at such depths that no danger from influx of water need be apprehended.

Coromandel.

The mines visited near Coromandel were the Kapanga Mine and the workings at Tokatea Hill. The rock-formation is tufaceous, of volcanic origin, and about the same geological position as that of the Thames.

In the Kapanga Mine, the depth of which is 600ft., there are two nearly parallel reefs about 60ft. apart, having a general strike north and south, but somewhat sinuous, and an underlie to the west. The upper or western is the Kapanga, the lower and eastern Scotty's Reef.

The foot-wall of Scotty's and the hanging-wall of the Kapanga reef are tolerably hard, the country between being of a softer character; the lodes occasionally split up and meet again, and the gold-shoots are patchy and unequally distributed, giving out quite suddenly at a cross-course or change of country, or a deflection in strike or underlie. The portions having the normal north and south strike and the steepest underlie are usually richer than those deviating in strike or having a lower rate of inclination. These two lodes are supposed to be separate portions of one, separated by a "horse" and likely to come together at depth. So far there appears no sign of their dying out downwards and their tracks are continuous longitudinally as far as followed, though very little exploration has been carried on in the way of driving along them in search of other blocks of stone.

The Tokatea workings show one large reef and a great number of smaller veins. The large reef is auriferous but poor, the bulk of the gold being contained in the smaller veins adjacent to it. In some of the upper workings on the east side of Tokatea Hill there are vertical veins intersecting flat ones, and these are frequently very rich along the lines of junction. There is a certain analogy between this feature and that observable in some of the quartz-mines of Ballarat East, in Victoria, where the intersections of flat "spurs" of quartz by their vertical veins of pyrites (indicators) are sometimes exceedingly rich. The rock-formations and other conditions of the two localities are, however, very dissimilar.

Lower down Tokatea Hill are thin crystalline vertical quartz veins which are rich where they are intersected by one another or by joints or heads.

Towards the foot of the hill is a low-level tunnel—inaccessible at the time of my visit—which is stated to have passed through the tufaceous rock into a projection of subjacent slate of the Maitai or Carboniferous series, and it is reported that a reef was followed down from the superincumbent tufaceous rock into the slate; that a winze was sunk on it from the tunnel and good gold obtained, but that it was abandoned on account of the large influx of water.

Mr. W. H. Argall, manager of the Kapanga Mine, made inquiries concerning this, and wrote to me stating that he had learned that the depth of the winze in the slate was 35ft. at 1,500ft. in from the mouth of the tunnel; that gold was visible in the bottom of the winze when work was suspended, and was the continuation of a shoot worked the whole way down from the outcrop of the big reef on the hill. The absolute verification of this statement would be most important, and encouraging to further exploration.

Karangahake.

At Karangahake, in the gorge of the Waitawheta Creek, a large reef is being worked from a tunnel near the creek-level. The rocks are very similar to those of the Thames, but rather harder. There is nothing visible militating against the probability of this reef continuing to great depths.

Waihi.

The Waihi Reef, near Waihi, is one of great size and importance. Its outcrop is on a hill composed of tufaceous rock or decomposed andesite similar to that of the Thames, and is about 30ft. in thickness, the whole being taken out by open quarrying for treatment at the mill. A large main shaft is being sunk near the base of the hill, and has been connected with an adit driven to the reef, which shows a thickness of from 8ft. to 45ft., with no sign of dying out; its bearing is north-easterly and its underlie south-easterly.

The quartz is "ribbony" and jasperoid or agatiform in many places. The cyanide process, for which a large plant has been erected, appears to have proved highly successful in extracting the gold. The flat country around the hill is composed of a rhyolite-tufa, a volcanic product here, more recent than and overlying the andesite, which slopes away under it. The quartz reef does not extend upwards into the rhyolite, which is evidently a newer formation, but has every appearance of continuing downward and longitudinally in the andesite. It would be worth while to prospect for the continuation of this reef in both directions by sinking through the rhyolite down into the andesite.

Waiorongomai.

From Waiorongomai, near Te Aroha, I went up the mountain to the reef known as the New Find. The rocks are volcanic products, andesites, &c., like those of the Thames, but harder. Numerous rich patches of gold-bearing quartz have been worked along the mountain-side, but they have not been traced to any great depth. In the lowest tunnel two reefs have been cut—a large one but poor, and a smaller one, which was rich above but poor at the tunnel-level.

The big reef has hard andesite on the outside wall, but beyond the small reef the tunnel passes into soft "kindly" tufaceous rock, which may possibly pass under foot, in which case the reef, on intersecting it, may again be found to contain payable gold.

SECOND GROUP.

The Reefton and Lyell Reefs.

The situation of the Reefton field, its physical character, and geological structure, have been exhaustively described by Mr. McKay in his report, published with the general report of Sir James Hector for 1882. Mr. McKay showed me the various points where the relations of the different formations could be observed, and enabled me to personally verify the conclusions arrived at, which are briefly: that the auriferous quartz-bearing rocks of the locality are those named by Sir James Hector the Maitai series—geologically of Carboniferous age, though not here actually containing coal—and that these rest unconformably against Devonian rocks, of which a long narrow insulated outcrop protrudes through them, extending northward and southward from the head of Murray's Creek.

Both formations are overlaid in patches by Cretaceo-tertiary rocks, accompanied by coal-seams, and, in addition to these, the Maitai rocks are flanked along their western line of exposure by Tertiary and Recent formations, beneath which their downward and westerly extent is unknown.

The Devonian rocks in this region have not yet been proved to contain any auriferous veins, and, though distinctly outcropping in the locality above described, have not yet been met in the deepest mine-workings commenced in the Maitai rocks at even comparatively short distances away from the lines of contact.

The Cretaceo-tertiary, Tertiary, and Recent deposits are more or less auriferous, and have in places been worked for alluvial gold with varying success, though the best yields have been obtained in the Recent formations, or natural concentrations of the older detrital deposits.

Having grasped these general features, my investigations were directed principally to the Maitai or Carboniferous rocks and the mining features of the various reefs or lodes traversing them.

Little could be seen of the upper worked-out portions of these reefs, and observations were only practicable as regards the deeper workings now in progress, so I devoted most attention to the lowest levels of the principal mines, which afforded visible data as to the typical characteristics of the reefs and their containing rocks.

The rocks themselves consist throughout mainly of bluish- or greenish-grey, slaty, and rubbly shales, with occasional bands of both gritty and earthy sandstones. The bedding of the respective layers, though occasionally discernible in open sections and in the mines, is most frequently obscure and obliterated by the crushing, jointing, and faulting processes to which the rocks have been subjected. The cleavage at several places observed does not coincide with the bedding. There is evidence of general anticlinal and synclinal folding of the beds, but on a broad scale and not in a frequently-recurring series.

The reefs examined in the Reefton District may be described as existing in three groups occupying a belt of the Maitai rocks, having a direction somewhat east of north.

The northern of these groups is that at Boatman's Creek, where I inspected the Welcome United and Fiery Cross Mines. Next to the south is the group near Reefton, where I visited the Keep It Dark, the Keep It Dark No. 2, the Wealth of Nations, the Inglewood Extended, the Ajax (now the Golden Fleece Extended), and examined the Low Level Tunnel as far as accessible, which, however, was only a few hundred feet. Further southward I saw the Progress, the Globe, the Cumberland, and the Golden Lead workings, near Merrijigs. Most of the above-named mining properties comprise in each case several smaller holdings formerly worked at shallow depths.

Without entering into a special description of each mine, a few brief notes will serve to show the noticeable features. The Welcome United and the Fiery Cross, at Boatman's Creek, appear to be on the same line of reef, which carries different blocks or shoots of quartz connected by "tracks" or fissure-planes. One block in the Fiery Cross Mine was worked to 700ft., where it is said to have run out, but this part of the workings was inaccessible at the time of my visit. To the northward of this block, and between it and the old Welcome block, an intermediate block was being worked from the 200ft. level. This block is about 100ft. long, with good walls; it has a north and south strike, a northerly pitch, an easterly underlie, and a thickness of as much as 5ft., thinning out either way to a track. This block, if it be continuous, should be struck by extending the lower level further northward.

In the Welcome Mine an inclined adit of 1,800ft., and a level thence of 800ft., reaches the No. 9 level of the old Welcome workings, where there is visible a strong and well-defined track about 2ft. thick, going downwards, and composed of black mullocky material and quartz, from which a crushing of 60 or 70 tons is said to have yielded 3oz. of gold per ton. A blind shaft had been sunk to 245ft. below the level, and drives extended therefrom; but the Welcome track had not been struck as a matter of certainty, though one or two apparent tracks had been met with.

There is, however, nothing in the character of the rocks at the deeper levels here to warrant any fear as to the absolute dying-out of the reef, or that there may not be more blocks of quartz to be met with by means of further sinking or driving.

Coming to the Reefton group, the Inglewood Extended tunnel, on the eastern portion of the belt, has been driven 1,300ft. easterly to the Inglewood and Phoenix line of reef, which has been worked from the tunnel-level up to the surface, some 500ft. in vertical height, and about 100ft. below the tunnel. This deepest portion could not be examined, being filled with water, but from the description given me it appears that the reef becomes smaller and poorer there. The length of the block of stone is about 100ft., and it thins out either way, though at the south end, in the tunnel-level, it merges into a dark-green dyke-stone, containing quartz and calcite veins, and said to have proved auriferous.

At the Golden Fleece Extended Mine, on the Ajax line of reef, the shaft is down 500ft. to the No. 5 level, where a tribute party—after draining the mine, which had for some years lain idle—have started work on a block of stone hitherto neglected on account of its being considered rather poor, the yield being stated at about 9dwt. per ton. This block probably extends to the surface, and in the stopes shows a very good formation of lode, having a strike north-north-east, a west-north-west underlie, and very well-defined walls, between which the stone is 2ft. thick, and of excellent appearance. Some of the quartz in the worked-out blocks was as much as 10ft. in thickness. This reef generally makes in blocks, some of which do not come to the surface, but are connected with one another by tracks.

The Keep It Dark Mine is the deepest on the field as regards sea-level. The main shaft is down 475ft. to the No. 3 level, and thence a blind shaft descends 350ft. to No. 5 level. The course of the reef takes nearly a horse-shoe shape, turning from north and south to east and west. The quartz makes in blocks which seem to have a generally westerly pitch, and where the stone is absent a pretty-well-defined track is visible. The containing rocks are slaty rubbly shales, much jointed and "shook," and show some signs of synclinal folding, but no marked change in general character with the increased depth.

The shaft of the Keep It Dark No. 2 Mine is 450ft. deep to the lowest level, at which the drive along the lode shows a large well-marked track, but little stone; the dark slaty hanging-wall shows evidence of friction. This drive is being extended to meet the block of stone worked above, which averaged 3ft. thick, and was left passing under foot. The reef in the upper stopes is well-defined.

In the Wealth of Nations Mine the lowest workings—320ft. below tunnel-level—show several great bodies of quartz—one about 8ft. thick at top of drive and thinning to a wedge at the bottom underlies north-westerly; another close to it swells to a great width in one place, and rests on a sort of floor, pitching to the south-west, the underlie being south-eastward, where the stone takes its normal width. The containing rock here is of the ordinary character.

Coming to the southern group of workings, there is very little variation as regards general features. The Progress, the Cumberland, and the Globe Mines all show quartz making in blocks, sometimes swelling to many feet in thickness and then thinning out into tracks.

The Golden Lead Mine, at Merrijigs, is somewhat exceptional as regards its features, the gold being contained in certain soft clayey or "pug" veins from an inch to a foot thick, carrying gritty quartz and traversing sandstone. A low-level tunnel is being driven to strike the Golden Lead reef 400ft. below present workings; it was in about 400ft. at the time of my visit, and had to be driven some 1,300ft. further to reach the reef. A large quartz reef and also a wide "track" containing a little quartz had been passed through, but had not been proved auriferous. This tunnel is an excellent prospecting work.

Having so far stated the leading features of the mines, it may be advisable to point out the difference between the conditions obtaining in the Reefton auriferous rocks and in those of Victoria. In the first place, the geological age of the former is, as before stated, Carboniferous, while that of the latter is Silurian, or very far lower in geological sequence. The Silurian rocks of Victoria, especially the Lower Silurian, are usually easily fissile and definable, band from band, the slates or sandstones respectively being frequently traceable in strike for miles. They are folded in well-marked successions of more or less acute anticlinal and synclinal curves, and, though by no means free from faultings and joints, do not show the evidence of such crushing and repeated movements as do the Reefton Carboniferous beds, and have consequently afforded good natural facilities for the formation of well-defined reefs or lodes. Even under these favourable conditions, however, the Victorian reefs alternately pinch to mere tracks and enlarge to varying-sized bodies of quartz, or die out in strings of quartz longitudinally or downwards. The gold occurs in shoots greater or less distances apart, and these shoots often die out in every direction. On the other hand, it has been found that in many cases the reefs and gold-shoots make again in depth, and this fact has of late years largely tended to stimulate Victorian mining enterprise, with very gratifying results.

In the Reefton rocks, the bedding and general structure is less easily discernible than in the Silurian rocks of Victoria; and whereas the latter—especially the Lower Silurian—are traversed by great belts of quartz reefs traceable for scores of miles, and by innumerable veins, leaders, and strings of quartz in the country rock between the major lodes, the lodes in the former are comparatively few and there is a great paucity of minor veins of quartz.

The prevailing feature of the Reefton lodes is that the auriferous stone occurs in blocks at greater or less intervals apart. These blocks are of varying length and pitch, or dip in their strike. The direction of strike of the reefs varies from north and south to nearly east and west, though the general bearing is between north-west and north-east, and, with exception of the Boatman's Creek reefs, the underlie is to the westward. The blocks of stone have in places been worked to a great thickness—as much as 10ft. to 30ft. in some instances—and they thin out either way to mere tracks or fissure-planes, usually carrying a "dig" of soft material with more or less quartz, sometimes easily distinguishable, sometimes indistinct and traceable with difficulty.

Though the first discovered blocks of quartz outcropped at the surface, several instances have occurred where, during mining operations, others have been found which did not extend to the

surface, but passed away into tracks upward, downward, and longitudinally: these, however, were connected by the "tracks" with the outcropping bodies of stone. In many cases the lodes or their "tracks" have been faulted either laterally, vertically, or longitudinally, but have usually been recovered again by means of proper exploration.

Approaching now the great question as to whether the reefs are likely to prove remunerative at greater depths than those reached, it cannot be denied that the evidence obtained shows a general falling-off at lower levels as regards the actual yield per ton, and the pinching and dying-out of blocks of stone large and highly productive near the surface. During my whole inspection of the Reefton field I saw but few cases where permanent-looking shoots were being successfully mined at the lowest levels. This certainly is discouraging, and, looking back at Victoria for example, it can be seen that even there, though quartz-mining is being successfully carried on at over 2,000ft., and exceedingly rich stone is sometimes found at that depth, the average yields from great depths are not equal to those once obtained from the surface outcrops. This may be in part due to the greater ease of selecting choice stone near the surface than at depths where the rich and the poor stone have frequently to be taken together to make up a common average; but the general tendency has been to a diminution—if only a slight one—of the richness of quartz with increasing depth, though the limit to which it can profitably be worked has certainly not yet been reached in Victoria.

In the Reefton district there is visible nothing whatever in the character of the rocks themselves at depth affording any reason to suppose that the limit of productiveness has been reached. The tracks of the lodes appear to continue downwards in all cases, and little or no exploration has been carried on to prospect for new "makes" of stone below those that have become poor or attenuated.

There is no recognised level at which such impoverishment takes place, as it appears that productive stone has been worked at elevations varying from 2,300ft. above sea-level—at the Ajax Mine—to 100ft. below sea-level—in the Keep It Dark—a range of 2,400ft. in vertical height. There is absolutely no discernible cause why the Ajax and other reefs outcropping at high elevations should not continue productive to as low levels as have been reached in the Keep It Dark, the Keep It Dark No. 2, and the Wealth of Nations Mines, nor is there any apparent reason why in the three latter, and all other mines on the field, the payable stone should not exist at still greater depths than those hitherto attained. In my opinion, the great national importance of the matter and the negatively favourable indications should outweigh the positively unfavourable evidences; and I consider it well worth while, at the risk of possible failure, for those interested to incur the expense of well-directed systematic further exploration. As to the directions of such exploration, there may be considerable local diversity of opinion, but I would certainly indicate two as being particularly suitable. One is the deeper sinking of the Keep It Dark Mine, already the deepest on the field, and cross-cutting at lower levels, especially westward; another is the extension of the Low Level Tunnel, which has already been driven a long distance, and if continued as originally projected will cut the Venus, Ajax, and other lines of reef at deeper levels than have yet been reached, besides affording a useful highway to facilitate mining operations and general prospecting work.

In the Welcome Mine at Boatman's the track of the reef should be accurately ascertained and followed both downward and longitudinally, while at Merijigs the continuance of the Golden Lead tunnel would be genuine prospecting work. The success of any one of these operations would stimulate enterprise throughout the whole field, and afford general grounds for encouragement to deep exploration in all the other mines.

Lyell.—I include the quartz mines of this locality with the Reefton group on account of the similarity in the lithological character of the containing rocks, though those of Lyell are regarded as being of Devonian age, or older than the Maitai series of Reefton.

Near Lyell township the rocks are metamorphic in character, and associated with gneissic granites; but at the mines, some three miles up Lyell's Creek, the rocks are nearly unaltered clay-slates, somewhat crushed, and very similar in appearance to those of Reefton, though showing more defined bedding and lamination.

At the United Alpine Mine, Lyell's Creek, the strike of the reef is north-westerly, and the underlie north-easterly, the "pitch" of the quartz shoots being north-westerly with the strike. There are two blocks or shoots of stone—the southern and the northern. The southern block has been worked from the surface, but is described as poorer than the northern, the upper edge of which was only met with some hundreds of feet below the surface. About 60ft. of blank ground, traversed by a "track" of broken country, intervenes between the two blocks. The No. 7 or lowest level has been driven to the lode, which shows a thickness of as much as 14ft., some of the upper portions being reported as up to 40ft. thick. The northern block of stone is about 225ft. in length, and yields about 2oz. of gold per ton, and from its north-west edge or termination a track continues into the country rock. This track, if followed, might lead to other blocks. The southern block is 300ft. long, and is expected to be good when reached at this level, as it showed some improvement downwards in the upper workings.

The low-level tunnel of the Lyell Creek Extended Mine has been driven 3,400ft., but has not yet reached the lode. The country is slate, with occasional bands of sandstone, very regular, and "kindly-looking."

Generally, the rocks of this locality present most favourable conditions for the downward and longitudinal continuance of the lodes, and exploration in those directions is fully warranted.

THIRD GROUP.

Reefs traversing Metamorphic Schists.

The precise geological position of the Archæan metamorphic schists of New Zealand is so far undetermined, but they are undoubtedly among the oldest stratified rocks of the world, and constitute the principal visible rock-foundation of the country. They consist mainly of quartz and

mica schists, composed of alternating laminae of pure quartz and micaceous earthy material, the former usually predominating. There are also occasional bands of chlorite and mica-schists of silky texture and more argillaceous character. These metamorphic rocks form the bed-rock at Cullensville, in Marlborough, and all the Otago goldfields visited by me. The comparative paucity of large defined auriferous quartz reefs traversing these rocks renders it difficult to account for the vast quantity of alluvial gold obtained where they prevail, but the most feasible explanation appears to be that gold exists, though sparingly, in the quartz laminae of the rocks themselves, and in the numerous small veins, nests, and bunches of quartz which also occur in them, and that the enormous and oft-repeated degradation and denudation of the rocks, and the final concentration now appearing in valleys, rivers, and creeks of the more durable and weighty materials, brought about the accumulation of alluvial gold in such large and easily-won quantities as rewarded the early prospectors.

The quartz reefs in this series of rocks present similar features to those of Reefton, inasmuch as they form in blocks or shoots, which in some cases become attenuated or poor with increasing depth, while in others their downward limit has not been reached. Of the mines visited in this group the first was the Ravenscliff Mine, on the fall towards Waikakaho Creek, in the Marlborough District. Here the rocks are foliated quartz and mica-schists, much corrugated in parts. The mine was not being worked; but in the lower tunnel, some 600ft. below the crest of the range, there were visible some "makes" of quartz, much of which appeared to be simply segregated quartz veins and bunches belonging to the country rock. The so-called lode lies between bands of strongly foliated rock, more argillaceous than the bulk of the formation, and has usually a good foot-wall, but an indistinct hanging-wall. I was informed that numerous assays made of the stone indicated fair yields, and that some trials of small parcels gave results representing 1oz. of gold per ton, but that the actual bulk returns from the battery did not exceed 4dwt. per ton.

In Otago the first reef visited was the O. P. Q. reef, near Waipori, twelve miles from Lawrence. The outcrop of this reef is a large body of stone running north-north-west, with an easterly underlie. Shallow workings along the line extend for more than half a mile, and the yields are stated to have been at the rate of 9dwt. or 10dwt. per ton. In a tunnel along the reef from a gully the face shows a wide track with quartz in it, and a well-defined hanging-wall, the country rock being the prevailing quartz and mica schist. Much of the ground above this tunnel has been stoped out, and there is close to it a shaft said to be 200ft. deep, now full of water, whence a considerable quantity of stone was stoped, yielding from 1oz. to 1½oz. per ton, and good quartz passing underfoot. This was abandoned on account of the great cost of fuel when work was last in progress, but from the information given there seems no reason why the reef should not be payable under the existing more favourable conditions. Other reefs, as Gairs, the Sheba, and Solomon reefs, have been worked from the surface to as much as 100ft., but at present lie neglected.

The Cromwell Reef, Bendigo, is on a high range east of the Clutha Valley, about twelve miles above Cromwell, and has been extensively worked along the surface for a length of fully 1,000ft. and to a depth of 420ft. in the principal workings. The lode is very regular, between two good walls bearing west by north, and underlying northward at a steep angle. The width in the adit-level averages 3ft., sometimes increasing to 6ft. At the 520ft. level in the shaft a cross-cut 187ft. south reaches the lode and drives thence along, it having been extended 250ft. in each direction. The lode is only a few inches thick at the east end, increasing to nearly 3ft. under the old workings, and then pinching to a "track" at the west end. At this level the stone is stated to be auriferous but poor. It appears that this alternate widening and narrowing has been a feature of the lode all the way down. Considering that the reef certainly continues downwards between well-defined walls, and that £500,000 in dividends is stated to have been won from the workings down to the 420ft. level, it appears highly advisable to exhaustively prospect the downward continuation.

Near Macetown, up the Arrow Valley, the mines visited were the Premier and the Tipperary. In the Premier Mine, 3,400ft. above the sea, there are the main or No. 1 lode; No. 2, carrying a short shoot of auriferous stone; No. 3, or Moyle's reef, nearly parallel, and close to the main lode; and No. 4, or Loop lode, so called because it curves upward like an inverted saddle reef. The main lode has a well-defined hanging-wall, striking north-west and underlying south-west, and the shoot of auriferous stone is about 60ft. long, with a pitch north-westerly. The best stone appears to have been found where the several reefs closely approach one another, and there is known to be good stone going underfoot at the lowest tunnel-level. The tunnel was being extended to meet another shoot known to exist in the upper workings, and exploration downwards was in progress to find the continuation of the main shoot. Moyle's reef has two good walls, but the filling is principally crushed schist, without any regular quartz-formation.

The Tipperary Mine is some 800ft. below the level of the Premier. Here there is a large shoot underlying south-west and pitching north-west and passing away in the latter direction to a mere track, the foot-wall is the best defined. From the upper workings quartz has been stoped to as great a thickness as 36ft., the yield at the lowest portion being stated at from 7dwt. to 9dwt. per ton. Another shoot, known as No. 2 shoot, occurs to the south-east, but does not extend to the surface, and both shoots pass underfoot. A deep-level tunnel is being driven to cut the reef at a lower level.

A mine known as the Sunrise in this vicinity is described as being 5,000ft. above sea-level, and as consisting of a single block or shoot of auriferous stone, extending downwards, but not being worked on account of the cost of cartage.

Close to Arrowtown, at about 1,100ft. above sea-level, is the Criterion Reef, worked thirty years ago. Nothing definite can at present be seen, but by the old workings the strike appears to be north-north-west and the underlie west-south-west. The stated size of the reef is from 18in. to 3ft., the pitch of the shoot being to the northward, and the yields obtained were at the rate of 1oz. per ton to the amount of 1,300oz., but work was discontinued on account of the heavy expenses at the time. Assuming the correctness of the above information, obtained and communicated to me by Mr. Healy, of Arrowtown, there appears to be reasonable inducement to further explore this reef.

At Bullendale, near Skipper's, in the Shotover Valley, the Achilles Mine is about 2,300ft. above sea-level. The main lode has a bearing of east by north and an underlie to the northward, and a branch of it is known as the South lode. The north and middle lodes come together eastward, and the north and main lodes are approaching one another in underlie, and are likely to come together at depth. The main shaft is 150ft. deep, and an incline thence follows the main lode down for 97ft. at an angle of 39°. The gold occurs in shoots, which dip or pitch westward, and the main lode at its full size is 8ft. thick. Between the north and main lodes, where they approach one another, the manager, Mr. Evans, informed me that gold occurs in the intervening country rock, occasionally in sufficient quantity to make the stuff worth crushing.

The Gallant Tipperary or Nugget Mine is about two miles up the Shotover from Skipper's. The reef strikes west-north-west and underlies south-south-west. The shoot of auriferous stone, as worked from the lowest tunnel upwards, is 300ft. long, and pitches east-south-easterly towards the river. Its thickness in the upper workings has been as much as 30ft., and the average yield about $\frac{1}{2}$ oz. per ton. Some hitherto-neglected stone is now being stoped out, and is stated to be yielding 12dw. per ton; and another shoot, worked above, is expected to be met at 150ft. further in the tunnel. The shoots would be accessible at nearly 400ft. lower level by driving a tunnel from near the river, where the large and well-defined track of the lode can be seen crossing the bed and passing into the opposite bank.

It will be observed from the foregoing notes that auriferous quartz has been proved to occur in the metamorphic rocks of Otago at all elevations from 5,000ft. down to 1,100ft., and probably less, above sea-level—or a range in vertical height of nearly 4,000ft. Throughout the whole investigation I saw no instance of a reef having one or two well-defined walls absolutely disappearing, and, though doubtless the blocks or shoots of auriferous quartz may occur at wide and irregular intervals, I saw no evidences tending to preclude the hope that other shoots may be found by means of deeper sinking and further driving along the proved tracks of the lodes, while in so great an area and so difficult of access, off the regular roads, it is likely that many other reefs remain to be discovered by means of close and careful prospecting.

GENERAL SUMMARY.

The foregoing brief descriptions have, I believe, been sufficient to show the data on which my recommendations are based, and I conceive that these recommendations fulfil the actual objects of my inspection.

As regards the future of deep quartz-mining in New Zealand, I must confess to feeling less confident than I would were the rocks more similar to those wherein quartz reefs have so successfully been worked to great depths in Australia, but at the same time the evidences are such as to warrant me in the recommendations with respect to the fields where at present a feeling of uncertainty exists as to the probability of success in deeper explorations.

These recommendations, briefly summarised, are as follows:—

1. Thames Goldfield: (a) Boring in the vicinity of the Queen of Beauty shaft, and deep sinking should that boring show that rocks of favourable character continue downward; (b) extension of the Moanataiari tunnel; (c) prospecting ground beneath Post-tertiary deposits between Karaka and Hape Creeks.

2. Reefton Goldfield: (a) Deeper exploration and cross-cutting at the Keep It Dark Mine; (b) extension of the Low Level Tunnel; (c) deeper exploration at Welcome Mine at Boatman's Creek; (d) extension of Golden Lead low-level tunnel near Merrijigs.

3. Otago Goldfields: General, deeper, and longitudinal exploration on all the proved reefs. No particular one can be said to demand more special attention than others.

In many of the mines visited there is sufficient visible inducement to further working, and operations in that direction are in progress, but throughout all of them the following-up of "tracks" of reefs in search of other shoots than those already known is very advisable.

There is one more subject on which a few remarks may be permissible, and that is the recklessness as to the future which seems to have prevailed during the dividend-paying times of the various mines. All the inquiries made by me failed to elicit information as to a single instance where, during a prosperous period, there was a reserve fund established for future dead-work, or where such dead-work was steadily kept in progress during the working of rich blocks of stone. It would appear that in a large proportion of the mines the good quartz was stoped out from level to level, all the available proceeds beyond current expenses being divided, and nothing kept in hand for any future works of an extensive or costly character. This system, or want of system, has been in past times, and I fear often still is, followed in the Australian quartz-mines; and the sooner that mining directors and managers appreciate its ill effects the better. Assuming a mine to be dividend-paying, a moderate percentage deducted from the divisible profits would be missed by no one, and if placed to a reserve fund for future exploration, or directed immediately to dead-work, would tend to maintain confidence, and to prevent the subsequent tooth-drawing process of extracting calls from shareholders during periods of depression.

In conclusion, I beg to express my thanks to yourself, to the officers of your department with whom I have been associated, and to the mine-managers on the various fields, for the unvarying courtesy and consideration shown me during my investigations.

I have, &c.,

REGINALD A. F. MURRAY, F.G.S.,
Government Geologist for Victoria.

Hon. A. J. Cadman, Minister of Mines, Wellington.

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