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Surface Geology by C. Nay, 1942

McConnell's report on Texada Island gave a map of the Vananda section on a scale of 2000 ft. to the inch. This showed the distribution of the formations, but no dykes or any structural features. There appeared to be considerable data to be found which might have a bearing on the location and form of the ore deposits, so a map on a scale of 300 ft. to the inch, covering an area embracing the four important mines of the district, was undertaken in November and December, 1942.

In the time available, only a fraction of the map-area was covered in 300 ft. to the inch detail, this being territory adjacent to roads and clearings, suitable for plane-table work. Intervening wooded areas would have to be done by compass traversing. Some of this was done, but considerable area was left with only a general knowledge of the geology. On the map this latter area is distinguished from mapped outcrops by lighter colouring.

Outcrops are good. There are no large areas of drift, and only a few acres of lake and swamp. However, much of the outcrop is broken down into scattered rock-piles, thickly wooded and heavily moss-covered, so that mapping in detail is tedious.

In addition to the lithologic units mapped by McConnell, dykes and pyrometasomatic replacements were mapped. An attempt was made to map color, grain-size, and any other conspicuous features of the limestone. A fair amount of data on bedding, shearing and faulting was recorded.

Marble Bay Limestone:

About ninety percent of the area mapped is underlain by Marble Bay Limestone. Most of this is light grey in color, moderately crystalline, and pure and uniform in composition, belonging to a single uninterrupted unit of sedimentation. Local variations from the mean in color and grain-size involve most of the area in some degree.

The coarsest limestone is generally the whitest, the impurities evidently having been expelled. Local patches were noted, which were exceptionally coarse but dark colored, indicating that recrystallisation could take place without loss of impurities. It was conjectured that in the one case, heat caused the recrystallization, while in the other case, stress caused it.

Very fine-grained or visibly uncrystallized limestone, noted ina few places, may be dark or light colored, but the dark color predominates. Along the skipway west of Copper Queen, fine-grained dark and light bands alternate, and evidently represent original bedding.

The extensive fine-grained areas between Copper Queen and Cornell, east of the Security Ground, and at the end of the Lower Gillies Bay road, are all very dark colored, practically unaffected by recrystallizing influences.

There is no simple relation between grain size and proximity to an intrusive contact. Coarsening depends on the size and type of the intrusive as well as proximity. The limestone surrounding the quartz-diorite is consistently moderately coarse-grained and light-colored. On two quarry walls, one near the quartz-diorite contact about 1200 feet northeast of Copper Queen, the other on the east side of Marble Bay near a diorite contact, pure white coarse marble lies below grey moderately coarse limestone, the two being separated by a definite plane along which impurities are concentrated in a narrow dark band, which generally shows a lot of pyrite. This shows that pure white marble advances into the limestone away from the intrusive, the impurities being removed on the way.

Around the basic stocks recrystallization is not pronounced nor is it consistent. The limestone coarsens and whitens nearing the Cornell stock from the east, but the limestone on the western borders of the stock is mostly fine. The limestone around the Florence stock is white but of fine grain, but some areas to the north and south of the stock, and several hundred feet removed, are coarsened. Limestone on the southeast contact of the stock west of the Marble Bay mine is noticeably white and coarse except for a narrow band on the immediate contact, which is fine and siliceous. Limestone off the northwest contacts is unaffected, but there is an extensive coarse area 200 to 300 feet northeast of the stock. The larger stock 1000 feet northwest of the mine shows no noticeable coarsening, but the limestone in general bordering Sturt Bay is moderately coarse. The large Sturt Bay stock has done considerable coarsening wherever the contacts are seen.

Dykes sometimeshave definite marble bands a few inches wide bordering them. Other dykes of the same size or larger may not have any effect.

On quarry walls along the B.C. Cement road flat lying fractures were noted with 2 - 4 inch bands of marble on each side, and a band heavy with pyrite occupied the centre.

Several conspicuously white and coarse areas lie quite apart from known intrusives. For example, off the lower end of the Copper Queen skipway, around the Charles Dickens shaft, and southeast of Vananda wharf. Also there are scattered areas suggesting a belt through Charles Dickens shaft and Security ground. On the continuation of this belt northwesterly beyond the Charles Dickens, along the Blubber Bay road, the coarsened areas are thought to represent the zone of a strong shear, and to have developed by dynamic recrystallization. It is possible that these coarse areas may be due to an intrusive not yet exposed, but it would not be at all safe to predict an intrusive on that basis.

In the ore from the Marble Bay and the Copper Queen mines, where the gangue is limestone it is usually white and coarse, though some of it is fine and siliceous, passing into garnetite. Some of the Marble Bay gangue is a breccia of dark lime veined by white secondary calcite. The ore solutions were evidently able to coarsen and purify the lime to a limited extent. The average surface limestone around the Queen is not conspicuously, coarse. Around the Marble Bay there are many coarse patches, but the pattern does not relate to the replacement pattern below.

In several places moderately coarse limestone shows a banding of dark and light layers, an inch or two thick. This was first thought to be bedding, but other evidence showed that the banding was caused by stresses in shear zones.

Many sections of the limestone are buff colored. The color can usually be traced to a slight visible content. It was common in the sandy textured limestones to the northeast of the Queen, and here the pyrite is evidently original. It was found in some places that the limestone became buff-colored as an intrusive contact was approached, but this does not happen in all cases. In several places the rusty coloration is associated with fracture zones. Apart from restricted places where pyrite occurs in shear or fracture zones, as at the Charles Dickens shaft and the small shaft on Emily Lake, the rusty coloration extends into unmineralized areas along bands which are thought to be shear zones.

To summarize, the texture and color data are not of much value in locating intrusives or mineralized areas, but may be helpful in tracing shear zones.

Diorite Intrusives:

In the present mapping some changes in the size and shape of these intrusives from McConnell's mapping were made. In some cases the earlier mapping may be more accurate because of their being better outcrops in that time. The Cornell stock was not completely traced out in detail. The northern end of the Florence stock disappeared under swampy ground. The small stock on Security ground is represented from a few scattered outcrops. The soutwest boundary of this and the outline of the nearby porphyrite are poorly known. The small pointed stock which McConnell mapped as lying south of the Marble Bay shaft was not located at all. Either all outcrops of this are obscured under Marble Bay dump, or it lies several hundred feet back of the indicated point in ground not thoroughly explored. The stocks northwest of the mine are accurately represented and differ only slightly from the earlier mapping.

The stocks vary in texture and composition. The average rock is dark and coarse grained porphyritic, the phenocrysts being hornblende. Some parts are uniformly fine grained, others are coarse and equigranular like gabbro. These variations occur in the same stock. Dark constituents preponderate in all except the large Sturt Bay stock, parts of which are as light as quartz-diorite.

The diorite is almost invariably rich in pyrite. This is both disseminated through the rock and localized along planes. Chalcopyrite was never seen in unaltered diorite.

The outcrop shape of the stocks suggests nothing but lack of any control. Underground the shape is very irregular with reentrant angles, points, offshooting dykes etc. The small stock reached in the Marble Bay workings on the twelfth level was preceded on the ninth, tenth and eleventh levels by a great number of dykes. Surface shapes would no doubt show a more angular character with more detailed outlining.

Walls of the stocks must be steep. The stock 250 feet west of the Marble Bay shaft must slope 1:5 to clear the fifteen hundred level some 1400 feet below. The pointed stock south of the shaft as mapped by McConnell must be vertical or overhanging to clear the workings. The stock on the twelfth level does not expand below into abody, but maintains an irregular dyke-like form to the thirteenth level and does not appear at all on the fifteenth level, almost directly below.

It is clear that the exposed stocks are not, as might be suspected, the protuberances of a large mass below. They are independent masses, vertically extended bulb-shaped, that have formed largely by replacement rather than plugging. They are no doubt related and deviously connected to the underlying quartz diorite mass. Parts of the large Sturt Bay stock are transitional to quartz-diorite.

Considered together, the group from Cornell to Sturt Bay lie in an arcuate line bearing N 40° W at the south to N 20° W at the north. The average trend is parallel to that of the folds of the district. Considered singly, the bodies have no features of shape conforming to this trend.

There is no positive evidence for the age relation of the diorite and quartz diorite. Certain of the diorite dykes were seen to be intruded by quartz diorite, but other diorite dykes at the Little Billy are said to cut the quartz diorite, and it was not possible from field examination to relate one or the other set of dykes to the diorite. The garnetite replacement is definitely later than the diorite, and this is a contact phenomenon, only slightly later than the quartz-diorite intrusion. On this evidence, the diorites are regarded as early iron-rich differentiates of the quartz-diorite magma.

It is clear that the ores, except in a few local cases, are not caused by direct contact metamorphic effect of the diorite. The garnetite replacement, with which the ore is intimately connected, only approximates the contact in a few places. The replacement pattern at Marble Bay mine is practically independent of the diorite, and there are no bodies larger than dykes anywhere near the Copper Queen. The Little Billy ores are close to or on the quartz-diorite contact. In the Cornell there is an apparent close relation, but most of the diorite contact is unaltered, the replacement affects both diorite and limestone, and often runs well off into pure limestone. At many places on the surface diorite has clearly suffered transitional replacement by garnetite. At the Florence, such a band of replacement penetrates nearly through the diorite stock. The lack of copper is unaltered diorite, but the presence of it in the quartz-diorite on the lowest level of the Marble Bay mine, emphasises the point.

The apparent relation between diorite, garnetite and ore may best be explained by regarding the early diorite replacement and the later garnetite replacement as being phases of one general process, originating at the same points in the underlying quartz-diorite batholith, and in their ascension into the limestone, being subject to the same regional controls. There is good evidence that the solid diorite mechanically controlled the ore solutions. One orebody in the Marble Bay mine expanded out on a floor of diorite. The ore-shoots at Copper Queen closely followed a diorite dyke footwall. The steep-walled reentrants in the diorite at Cornell no doubt were effective in guiding the solutions.

The Quartz-Diorite:

Quartz-diorite outcrops over a restricted portion of the map-area. Another smaller area, lies off the map 3/4 miles west of the Florence. Very similar quartz-diorite is exposed in the lowest levels of the Marble Bay mine. Several larger areas are mapped on Texada Island a few miles to the south and southeast, and enormous areas underlie the mainland eight to ten miles to the northeast. It is very probable that quartz-diorite underlies the entire map-area at a depth of less than 2500 ft.

The rock is very uniform. It is medium-grained light colored, with about twenty percent of biotite, the only abundant dark mineral, and about 10-15% quartz. It is readily distinguished from any of the diorites but parts of the diorite stock on Sturt Bay. These however do not have quartz.

Normal looking quartz-diorite is reported to be mineralized with chalcopyrite, epidote, and extra quartz in the Marble Bay mine. Certain areas near the contact around the Little Billy have considerable evenly disseminated fine molybdenite.

With closer mapping the quartz-diorite limestone contact became a little more complex than shown by McConnell. Several apopheses and small separated bodies were mapped. The contact is characterized by acute projections into the limestone. This is well shown at the northwest point of the area. McConnell's underground plans of the Little Billy mine also bring out the angulated form of the contact. Both acute points and acute reentrants in the quartz-diorite are shown. A north-south section through the mine suggests moderately dipping apopheses rising away from the main body, so that limestone lies beneath quartz-diorite in many places.

Little can be said about the shape of the quartz-diorite in the Marble Bay mine. Several dyke-like bodies appear above the seventeenth level. Below this level, uniform rock is exposed for fifteen feet in the winze. Dolmage expressed the opinion that the top of a good sized body was reached.

Part of the angular character of the contact may be due to dislocations along joints after consolidation. No evidence one way or the other on this point can be given.

There is an evident relation between the location of orebodies and the apexes and reentrants in the contact in the Little Billy mine.

The Porphyrite Group:

Rocks of this group underlie most of Texada Island. In specimen, and in outcrop appearance, they would be classed as volcanics without hesitation. McConnell however, through lack of evidence of flow origin, and an apparent intrusive relationship to the limestone and other sediments, classed them as an intrusive igneous formation. A tongue of Porphyrite extends from a large area to the west into the map-area between the Security and the Florence ground. The mapping here is considerably different from McConnell's. The area around the Security with very few outcrops may not be correctly represented. Some of the replaced rock here may have been porphyrite rather than limestone or diorite.

Most of the rock is aphanitic and dark green to black. There are some areas of a distinctive feldspar porphyry. In a few places the fine grain rock had small black amygdules. Pyrite is generally scattered through the rock.

In the area just beyond the end of the road west of the Florence shafts, the rock has a persistent gneissic structure with irregular bands of epidote and more rarely of quartz-garnet-epidote running through. The direction of this structure is uniformly S 40^{o} E, dipping steep northeast or vertical. It is coincident with a banding in the adjacent limestone.

The shape of the limestone contact in plan suggests an intrusive relation. However there is no noticeable alteration at the contact that can be ascribed to the porphyrite alone. The *irregular form of the contact may simply be due to the fact that both formations have been deformed, the limestone flowing easily into irregularities produced in the volcanic mass.*

Dykes:

Dykes are fairly common in the area, and comprise a great variety of lithologic types. In the present mapping an attempt was made to group them in three classes according to megascopic appearance only. This classification seems to approximate a genetic classification as well.

The three classes are:

(A) Light colored felsitic dykes with few or no phenocrysts.

(B) Dark felsitic - non porphyritic or with dark phenocrysts.

(C) Feldspar porphyry. Several types in which feldspar phenocrysts predominate.

A Class- *These constitute a distinctive group. They are light colored, aphanitic, hard and siliceous, with an abundance of disseminated pyrite. They weather out above the limestone.*

All sizes from six inches to twenty feet occur, and some larger masses. They are characterized by irregularity and lack of continuity. A dyke one or two feet wide may disappear in twenty or thirty feet. Several were noted to be sharply curved. Frequently they come in groups of three or four small, short, parallel dykes separated by several times their width of limestone.

There is no appreciable alteration of the adjoining limestone, but often a slight development of garnetite is noted at their borders. At the Copper Queen they seem to be directly related to the garnetite replacement. Fine-grained rock almost identical to the dyke rock is seen to grade into massive garnetite. Because of their irregular form, these dykes are thought to be replacements rather than injections. Possibly they represent a phase of the same activity that produced the garnetite replacements.

Most of these dykes were found along the road northwest of the Copper Queen mine, but they are apt to turn up anywhere in the area. Only a few were found west of Emily Creek. A doubtful outcrop of one was found 200 feet northwest of Marble Bay shaft.

Two were notably large irregular masses rather than dykes. These are 900 ft. and 1300 ft. along the road northwest of the Queen. The last measured 100 ft. by 50-60 ft. This body was made up of a rock with dark phenocrysts as well as the felsite. Small spots of garnetite occurred around the edges. Pyrite was abundant, but no chalcopyrite.

B Class - These do not form so distinctive a group as the A class. They include felsitic dark pyritous rocks, dark mineral porphyries and some dark feldspar porphyries. Most of them look to be equivalent in composition to the diorite stocks. Some may be younger basalt dykes. Occasional dykes are gray fine-grained, and could be either A or B, but there does not seem to be a complete transition.

They are not so abundant as A class. Small irregular felsitic types are common northeast of the Queen. Where exposed on quarry walls they may be seen to pinch, swell, and terminate abruptly in the limestone. Like some of the A class, they are no doubt replacements rather than injections. A small amount of garnetite occasionly occurs along the walls of these, but it looks to be mechanically associated, not genetically as was the case with the A class dykes.

In several open cuts along the B.C. Cement road south of the Little Billy, and at the Little Billy itself, hornblende porphyry dykes have garnetite and some copper mineralization associated with them. Here also the association is structural, and not genetic. These are very likely the same as the dykes in the mine itself, where they cut the quartz-diorite and in places have tabular masses of garnetite along the walls. Dyke rock of this type was conspicuous on the Marble Bay dump.

C. Class - This class includes various types of feldspar porphyry. They are larger and more persistent than the others, though still quite irregular. Most of them lack pyrite.

Some are no doubt related to the porphyrite group, others may be related to one of the other classes. Some of the larger may be porphyritic offshoots of the quartz-diorite.

On the shore 400 ft. east of Vananda wharf, feldspar porphyry dykes cut smaller dykes of the B type, the latter being fractured and dislocated. The feldspar porphyries are here pyritous in places.

Folding: Attitudes are difficult to determine in the ordinary surface exposures of recrystallized limestone. Only a few reliable ones were obtained from quarry walls and shore cliffs.

Most strikes are N 20-40° W, and dips at moderate angles either way. It was not found possible to map out any definite persistent folds, but the general structure in the map-area is a northwest trending syncline with minor flexures on the limbs.

The attitudes around the stock on the north shore of Sturt Bay conform to the contact. They are off the general strike and unusually steep. This suggests a plugging action in the emplacement of the stock, or a later folding around it. No attitudes were found around any of the other stocks, and it is thought from other characteristics that they are simple replacements.

No attitudes are recorded from any of the underground workings, so there is not data on the control of ore by bedding.

The banded structure seen in several places in coarse limestone was at first thought to be bedding. It always occurs at a very steep angle of dip, and if bedding, would indicate a steep folded structure along the arc from Florence to Marble Bay. Shearing seems to be the more logical explanation.

Shearing and Faulting: It should be noted that shears, fracture zones or faults in isotropic limestone would be rather easily missed. The limestone would have a greater tendency to shear under stress than to fracture, the only visible effect of which would be recrystallization. What small indications of shearing and fracturing have been picked up are thought to be of relatively great importance.

A separate skelton map shows shears, fracture zones and faults under the one convention. The length of the symbol is made to indicate the importance of the structure. The black arrowhead lines indi ate the trends of the principal orebodies in the Marble Bay mine. Hachured lines indicate topographic trends.

No underground work was done in the present instance, and there is little in the reports to indicate to what extent shearing etc. controlled the ore. Carmichael in the Minister of Mines reports, stated that 'mudslips' along garnetite (felsite') contacts were followed in development. Dolmage described one important fault, indicating a relation to the 1313 orebody. It is evident from the ore that brecciation was frequent and important.

The two structures in the northwest corner of the map near St. 13 are simple faults. The small east-west one fits the description of the mud-slip in the Marble Bay mine. The larger at N 70° E is a reverse fault. A small amount of fibrous tremolite is associated with it. Another small clockwise fault offsets a B class dyke near St. 52. It is unmineralized. Near St. 127 a low-dipping unmineralized fault follows the limestone-diorite contact.

The zone along Blubber Bay road striking northwesterly, showing up again at St. 150, and continuing past the Security to the area west of the Florence, is thought to be a shear zone of considerable importance. Along the Blubber Bay road it is marked by irregular coarsening in the limestone accompanied by a rusty coloration. In some places there is fracturing and veining with white calcite. At the extremity of the road as mapped, fracture cleavage in the zone indicates a clockwise slip. Between the Security and the Florence, around St. 164, the apparent continuation of the zone is marked by a gneissic banding in the porphyrites, with introduced quartz, epidote, pyrite, and a little garnet. Continuous with this is the banding in the limestone. A parallel structure is found in the limestone at St. 132. The same banding occurs 400 ft. southeast of the Marble Bay shaft, here with a more northerly stike. Projected, this would cut through the twelfth level orebody.

There is no evidence for a connection between these shears and the orebodies. It is notable though that the banding near the Marble Bay shaft is parallel to the long axes of orebodies on seventh, eighth, eleventh and fourteenth levels.

Several fracture zones of smaller extent appear to directly control garnetite. A small fracture plane along a B class dyke near St. 47 contained a small amount of garnetite with secondary calcite. It's attitude is N 75° E 40° SE. At St. 51 a well defined fracture at N 80° W 70° S cuts a B class dyke along a granite limestone contact. The zone contains a mass a foot or more wide of dark garnet with a little copper and molybdenite. Just south of St. 130 a lenticular mass of garnet-diopside rock extends into a diorite body for 100 ft. or so. The rock is mineralized with much magnetite, chalcopyrite, and a little molybdenite. Fracturing, with quartz veining, is in evidence, but the main shear may not be just as indicated. Florence - N shaft

Underground, two fracture zones or faults are known to be important. One in Cornell, at N 80° W, follows the limestone diorite contact and carries garnetite and some ore. The other is the fault mapped by Dolmage on the thirteenth level of the Marble Bay mine. This strikes E-W at the east end, dipping 80° south, and N 60° W at the west end with smaller angle of dip. A diorite mass is offset about ninety feet in a clockwise direction. Dolmage indicates, as is apparent from the plan, that the great 1313 orebody follows this fault, but the actual genetic importance of the fault is not made clear.

A St. 124 a recrystallized zone in limestone contains a pocket of heavy quartz-pyrite mineralization. It strikes vaguely N 60° W, and a similar and perhaps continuous zone is found at the southernmost Florence shaft. The latter has zinc mineralization as well. Another small fracture in limestone with a northerly strike near St. 99 is mineralized with pyrite, sphalerite and galena. In all these three cases the usual pyrometasomatic minerals are not present. Pit on Emily Lake NW shore on fracture

The limestone shows pronounced topographic ridges and valleys with quite definite trends. No attempt was made to map them completely or correlate them with lithology. In most cases, lithologic units seemed to transgress these topographic features. Possibly they are due to young fault zones offering zones of weakness to weathering. The indentations of the shore line show them well. In Marble Bay a valley at N 45° W is pronounced and continues inland as a swampy depression for 1200 feet. In Vananda Bay, a pronounced inlet at N 30° W continues inland as a swampy valley nearly to Emily Lake. Near St. 107 and 117 ridges parallel the shore of Emily Lake, in a N 50° W direction. Northeast of Copper Queen they are at N 60° W, and there is a vague correspondence with lithology. These trends are at slight angles to the main shears.

Form and Structure of the Ore-bodies

Marble Bay Mine

In attempting to arrive at the control of the ore-bodies, two distinct but closely related patterns have to be considered. One is of the pyrometasomatic replacement, and the other is of the ore itself.

The first is imperfectly known. Available plans of the levels do not show the complete shape of the replacement. According to McConnell's maps of 1912, workings above the thirteenth level often terminated in garnetite, not defining the limit of the altered zone. In later years of operation, these zones very likely received more exploration.

In general, the replacement has little more regularity than the ore. McConnell states that while the ore-bodies are interrupted, the enclosing replacement is practically continuous. The replacement however does not completely enclose the ore. There are no important ore-bodies entirely surrounded by garnetite. Most of the stoped areas show fifty to seventy-five percent of their outline against limestone. In the lower levels the volume of replacement is relatively small in comparison to the size of the ore-bodies. Much of the garnetite appears to have been in narrow dyke-like bodies.

In general the ore-bodies are small and very irregular, and not outstandingly rich. They turn and branch unpredictably, and include masses of barren gangue. The general form resembles a tooth, with a large elongated lobe above and one or more downward tapering roots.

It is evident that many horizontal sections through the mine would show almost no ore. Few would show any appreciable horizontal extension of ore. Only one or two selected sections would give a two-dimensional picture attractive enough to envision a million dollar operation.

Apparently the surface ore at the shaft amounted to little. The first level, seventy feet down, disclosed an ore-body 100 feet south of the shaft. On the second level (140 ft.) this is split into several bodies irregularly disposed in a large replacement. On the third level (200 feet) these have merged into a single W-shaped body which peters out sharply to the fourth level (260 ft.) From the first to the third level, the centre of the ore-body has shifted sixty feet to the north.

The fourth level being almost barren, the original operators gave up the mine for 150,000 dollars. The succeeding operators paid this off in royalties from the next two year s of operation, the ore for which coming very largely from the fifth level.

The second ore-body was encountered sixteen feet below the fourth level and fifty feet north of the shaft. About at the fifth level it measured 220 ft. by an average of 15 ft. Between the fifth and the sixth levels it divided. The smaller irregular south branch terminated at the seventh level, the larger <u>north</u> branch measuring 100 ft. by 15 ft., continued to below the ninth level, where it terminated in pure limestone.

The trend of the large section on the fifth level was about N 30° E, while the trend of the north root on the seventh and eighth levels was about N 5° to 10° W.

The tenth level was again nearly barren, but fifty feet below it an ore-body was struck which rapidly widened into a V - shaped mass on the eleventh, the centre of which was well east of the ore-body on the ninth level, but only slightly to to the north of it. The arms of the V trend N 70° E and N 10° W, and each measures about 110 ft. by 15 ft. in plan. It was irregular and rapidly tapering below the eleventh level. A root off the northeast arm wound down through limestone to fifty feet below the twelfth level, then looped back up to that level. A root off the south arm went down fifty feet, then widened into a flattish chamber floored with diorite porphyry.

A small disconnected ore-body was found on the thirteenth level after a small amount of exploration of limestone-garnetite contacts. This lies about 200 ft. north and slightly west of the overlying V ore-body. Further exploration on this level found a large east-west fault and the 1313 orebody, the richest in the mine. It was 210 ft. long, 40 ft. thick, and about 40 ft. in average width. Most of it was slightly above the thirteenth level, but the eastern portion extends downward. The appearance in plan is as though the east half is offset its own width northward, but no faulting is recorded in this direction. The large east-west fault follows close to the south wall of the east half of the ore-body, but cuts through the middle of the west half. Dolmage expressed the opinion that the fault is pre-ore and excercised considerable control on the ore. What is likely the same fault is mapped on the fifteenth level seventy feet south. The strike here is S 15° E and the dip 65° SW. If this is the same fault, then the curvature of the fault plane must be very great.

A root from the east half of the ore-body apparently extends down to the fifteenth level. The ore-body mapped on the fourteenth level is a large expansion of this root. From this body an irregular shoot, called the Button Raise, plunges northwesterly at a low angle to the north end of the fifteenth level. The Iron Raise follows a small shoot upward at a steep angle in a north-westerly direction from the east drift of the fifteenth level. From the plans available, it doesnot appear to connect with the fifteenth level orebody.

The orebody on the sixteenth level is a slab-shaped mass dipping 35° northwest, somewhat parallel to the Button Raise.

Scattered pockets of ore are recorded in the winze down to the 17th level. On this level, and in the winze below it, quartz-diorite is exposed. Dolmage noted that it is very similar to the quartz-diorite at Little Billy and at Priest Lake. It carried a considerable mineralization of chalcopyrite.

The 1502 ore-body is entirely separate from the others, lying 200 to 300 feet. southeast of the main shaft. From plans of the tenth, eleventh, and fifteenth levels, it appears to be an irregular pipe extending from the ninth level to just above the fifteenth. Apparently it has its largest cross section near the bottom, there being about 100 ft. by 20 ft., with the long axis trending S 25° E. Between tenth and fifteenth levels it rakes 100 feet southerly.

Some of the general features of the pattern viewed as a whole are: Excluding the 1502 stope, a northerly rake of the orebodies with depth. There is both a rake in the individual shoots and a shift of one shoot below the other. Dips or plunges on individual shoots have lower angles at the lower levels. In the first nine levels the ore pretty well confines itself to a northeast striking vertical plane. Below this level there is more irregularity; the shoots spread over a larger plan. This, in account with the flattening dips, makes it seem as though the ore was confined by a bell-shaped surface. Generally speaking, the other segments of the bell would seem to warrant exploration. The 1502 stope represents a discovery in another segment of the bell.

Copper Queen Mine

No geological plans of the Copper Queen workings were available. An outline of the stopes shows that the orebodies roughly follow a vertical plane striking N 65° W and pitch out in this direction. The ore-bodies were smaller and more irregular than those of the Marble Bay mine, but were quite persistent in the vertical dimension.

There were two main shoots. Both were tabular and followed closely the upper side of a steeply dipping diorite dyke. The first went from an insignificant surface showing to 300 ft. It was seldom over 40 ft. long. The second started 20 ft. above 400 level, and is evidently not bottomed yet at 740 ft. Between the fourth and fifth levels it measured about 30 by 40 ft. Lower down it attained a length of 100 ft., but with corresponding diminution of width.

Cornell Mine

The ore-bodies here look to be small and patternless. They follow roughly a diorite-limestone contact. This contact is very angulated; wedges of diorite head into limestone, and wedges of limestone fill reentrants in the diorite.

The ore is associated with replaced rock, but much of the latter is barren, and much of the ore extends off into limestone. The replaced areas are in general along the contact, replacing diorite as well as limestone. But much of the contact is devoid of replacements, and many of the replacements mapped are off in pure limestone.

McConnell states that the two ore-bodies outcropping at the surface continue downward as interrupted series' of lenses. At this time there was 400 ft. of drifting on the 460 level and no ore developed. Astley (Rpt. Min.Mines 1914) reported a fair sized body of ore stoped up 60 ft. from the 460 level, and bunches of ore in tremolite in brecciated areas on 560 level. He also pointed out that no crosscuts on the fifth or sixth levels go through to the northeast side of the diorite, where on the fourth level there were small bunches of ore.

Successive leasholders are said to have done well on the property, but the records show that the area was much more erratic than in the other mines, and also the proportion of drifting to the volume of ore removed was much higher.

The Little Billie Mine

The ore-bodies are small, without vertical extension, and are separated without pattern. One was a horizontal flat lens.

One outstanding feature from McConnels plans is the location of the ore at the points of limestone wedges in the quartz-diorite. Several diorite-porphyry dykes around the ore-bodies do not seem to have any controlling relation.

The ore-bodies are notably variable in composition. A small mass on the 180 level was reported to be bornite-tremolite below, grading upward into magnetite sprinkled with chalcopyrite. A large ore-body on the same level was bornite on one end, chalcopyrite on the other. Another small mass contained only magnetite and chalcopyrite.

Mineralogy.

Marble Bay Mine.

Dolmage made an extensive examination of the Marble Bay ore, recording 17 metallic and 16 non-metallic minerals. In order of abundance they are as follows:

Metallic: Bornite, chalcopyrite, chalcocite, molybdenite, pyrite, pyrrhotite, magnetite, covellite, sphalerite, argentite, tetrahedrite, gelena, dyscrasite (?), calaverite (?), silver, gold, and electrum. All but the first two are in very minor quantity. All but covellite occur primary: this and some of the native silver and chalcocite are secondary. Most of the minor minerals are closely associated with bornite.

Non-Metallic: Calcite, grossularite, wollastonite, diopside, epidote, quartz, andradite, augite, serpentine, and seven other minor silicates having no particular relation to the ore. Most of the calcite is original limestone. Some of the calcite and all the serpentine are secondary.

There is a notable lack of iron in the ore. Smelter analyses show an average of about 5.5% iron. This would be about equally divided between the metallic and the gangue minerals.

Chalcopyrite is more generally distributed than bornite, but the latter mineral forms the richest orebodies. Chalcopyrite is the only copper mineral in two small orebodies of special character, composed of chalcopyrite, pyrrhotite, and magnetite, and being in close proximity to and likely genetically related to the gabbro-porphyry stocks. It is also the only copper mineral in the mineralized quartz-diorite exposed in the lower levels of the mine. Where mineralization grades off into barren garnetite the mineral is chalcopyrite. Where high grade replaces limestone the mineral is bornite. The relative amount of bornite increases with depth.

Molybdenite, closely associated with chalcopyrite, occurs all through the mine. It is said to be more abundant on the lower levels, but is nowhere in large quantity.

The precious metal tenor of the ore fluctuates, but generally gives a value about equal to that of the copper. Dolmage found free silver and gold in ore from all levels. It is occasionally visible to the unaided eye. Some precious metal values, given as per one percent of copper are listed below;

Ore	Oz Au/1%Cu	Oz Ag/1%Cu	%Cu
460-560 st., coarse	.053	.56	7.4
560-660 coarse	.071	.50	9.3
fine	.047	.44	2.7
Ninth Level C	.046	.52	11.3
F	.026	.31	4.1
1908-9-10	.05	.50	5.0
1913-14	.051	.40	4.5
1917-18	.06	.42	4.0

Dolmage lists calcite as the most abundant gangue mineral. Smelter analyses indicate about 30 percent $CaCO_3$. Most of this is simply recrystallized limestone. Some of it has migrated and deposited in fractures.

Grossularite, the calcium aluminium garnet, forms large masses of small crystals with closely associated diopside. Dolmage noted that this type of gangue seldom made ore. This fact is apparent from the mine plans, which indiatte that the skarn pattern and the ore pattern are associated but not identical.

Wollastonite peculiarly was not noted by McConnell. He may have mistaken it for tremolite. It is abundant on the lower levels, often intimately associated with bornite.

The diopside is a low iron variety. It is usually associated closely with garnet as noted.

Quartz is rare, occurring only as scattered grains in chalcopyrite ore. There is no extensive silicification of the limestone.

Serpentine is rather common according to Dolmage. It is secondary and unconnected with the primary ore, but holds secondary chalcocite and silver in places.

Cornell Mine

Ore and gangue minerals are very similar to those of the Marble Bay Mine. Bornite and chalcopyrite are closely comingled. Pyrite andmagnetite occur in small quantity. Molybdenite is conspicuous and is found in skarn rock which is only sparingly mineralized with copper. Tetrahedrite and native silver have been reported. Serpentine is common along shears and on the borders of replaced diorite. A shipment of seven percent ore carried 0.41 oz/ton in silver and 0.077 oz/ton in gold per percent of copper.

Copper Queen Mine.

The metallic minerals are practically the same as in the Marble Bay Mine.

Huestis detected scheelite in the ore on the dump. It occurs in large glassy crystals in otherwise normal copper ore. Some of the unmineralized skarn had small grains of scheelite in it.

Copper Queen ores were generally regarded as the richest of the district, particularly in precious metal tenor. Some records are given below.

Ore	Oz Au/1%Cu	Oz Ag/1%Cu	%Cu
1897	.06	1.0	6.2
1903-760 tons	.055	0.51	6.6
-43 tons	.089	0.43	11.2
1904-2785 tons	.091	0.60	4.5
-74 tons	.119	0.56	9.39

The gangue minerals show a greater silicification of the limestone than was the case in the Marble Bay ore. The skarn masses frequently grade into a light colored felsitic rock which in turn grades sharply into limestone. This felsitic rock is similar to if not identical with the 'A' class dykes, which are very common in the vicinity, though removed from the mine, and which do show small amounts of garnet in several places.

Little Billie

The Little Billie ores contain more molybdenite, pyrite and magnetite than the others, the last being relatively abundant. Also the different orebodies show great variation and are variable within themselves. The gangue has more amphibole.

Molybdenite occurs in bunches rich enough to be small orebodies. It is also found disseminated in quartz-diorite and in skarn to the extent of 1 - 2 % over attractive widths.

Huestis detected a small amount of scheelite in the ore.

The grade of ore shipped was lower than the other mines, and the precious metal value seldom exceeded three dollars per ton. The ratio of precious metal to copper was about the same.

Charles Dickens Shaft.

This shaft was reported to have a lens of chalcocite, below which was a sphalerite, chalcopyrite and pyrite mineralization. The chalcocite was assumed to be of secondary origin. No skarn was seen around this shaft, though it lies on the disturbed belt from Security to Marble Bay.

Security Ground.

Here a large imposing area of replaced rock, originally limestone, diorite, and possibly rock of the Porphyrite Group, carries a scattered mineralization of several types. Much of the skarn carries chalcopyrite alone. Other workings show pyrite and magnetite in addition. A little scheelite was detected here also.

Florence Shafts.

Three shafts here show different types of mineralization. The northerly shaft is in a large mass of garnetite along a shear. The garnetite is veined by fine grained quartz and mineralized with chalcopyrite and magnetite. There is a lens of fine grained magnetite interlayered with chalcopyrite.

The middle shaft shows fine garnetite replacing a dark chloritic rock, probably altered diorite. This carried considerable chalcopyrite and a little pyrite.

The southerly shaft has no garnetite but an iron cap formed from coarse pyrite in a quartz gangue. There is a little sphalerite and chalcopyrite as well. Another small shaft near the north end of Emily Lake, a few hundred feet southeast, has a similar mineralization along a shear in limestone.

Loyal Lease Mine

This property, though five miles from the Vananda Mines, is similar in being a pyrometasomatic deposit in proximity to diorite stocks. The ore on the dump (sorted) showed rich chalcopyrite with abundant sphalerite in a quartz, garnet, and limestone gangue. Bornite, magnetite, and galena were also common but of minor importance. The gangue differs from the Marble Bay ore in having a considerable percentage of quartz, and less of the fine garnet-diopside mixture. Much of the calcite has formed as a vein mineral, being banded in with quartz and oré. The ore is conspicuously banded, appearing like a vein deposit. The silver values are notably high.

Several other pyrometasomatic masses near the Loyal contain notable amounts of sphalerite, often to the exclusion of other metallic minerals.

Lead-Zinc Showing.

A small working near the Copper Queen exposed fine pyrite, sphalerite and galena replacing limestone in a shear zone. There is no skarn present, so the deposit represents an entirely different type of mineralization.

Production

Marble Bay Mine

The mine produced almost continuously from 1898 until 1919. Omitting the first three years, the yearly output has been approximately 10,000 tons of ore containing 5 percent copper, 2.5 Oz/ton silver and 0.25 Oz/ton gold. The value would be about 20 dollars per ton at present prices, so that the total production has been about 4 million dollars.

Details of production are given on an appended page. The records are not always complete and occasionly conflict. The data supplied by Tacoma Smelter represents values paid for, so that copper assays are dry assays ($1^{1/2}$ Percent low), and precious metal values may likewise be low.

Copper Queen etc.

Copper queen made shipments from 1896 to 1916. They were evidently erratic, and the records given are not complete. The maximum appears to have been about 4000 tons in a year. Individual shipments of a few tons, as recorded in the Tyee Smelter Journal were often of exceptionly high grade, but in general the ores were only slightly better than the Marble Bay ores. No estimate of total production can be given.

Cornell shipments were likewise erratic and the ore was very variable in grade. No complete record could be obtained.

The Little Billie was the smallest producer of any of the group, but the records given are not at all complete, and no estimate of total production can be given.

Sequence of Events

1. Deposition of Marble Bay limestone. In this area a pure chemical sediment, with more or less organic matter, but no variations evident from outward appearance that might control ore deposition.

2. Volcanic activity resulting in the Porphyrite Group. Intrusive dykes or small masses. Thick flows forming a massive block in this locality. Some of the dykes mapped as C type may have formed at this time.

3. Deformation. Small folds in the limestone. Limestone flows around the porphyrite block. Gneissic structure developed in the porphyrite and adjacent limestone. Some crystallization of the limestone.

4. Igneous Intrusion of main batholith. Closely following or contemporaneous with the deformation. Recrystallization and purification of much of the limestone. Locally, if not in most cases, two phases are indicated.

A. Differentatiation of the original magma. This forms a basic magma in certain localities. The basic magma invades the limestone before the main mass, in the form of stocks and dykes, which probably developed by replacement rather than injection. Some accompanying movement may be the cause of dyke like off shoots and the very angular contacts of the basic bodies.

Where most complete, differentiation carries off much iron as silicate and sulphide, and very little copper.

B. Intrusion of quartz-diorite; Acid differentiate or original undifferentiated magma. Contains copper in both cases, but more iron in the latter case.

5. Evolution of the contact-metamorphic fluid. This contains

silica, alumina, copper sulphides, and more or less iron. The iron-poor variety as at Marble Bay, probably comes from well-differentiated source magma. The iron-rich variety as at the iron mines, from an undifferentiated source magma.

The course of this fluid is governed by:-

<u>Cupola Effect</u> - Some hypothetical characteristic of the source-magma which allows the fluid to collect and stream off at certain points.

<u>Pre-mineral faults</u> - 1313 Orebody. General form of the Marble Bay shoots suggests some control by vertical or steep plane structures.

<u>Composition of beds</u>. No information.

Stocks and dykes - There is evident relation at Copper Queen and Cornell but little at Marble Bay. They may function as mechanical guides to the fluids. Also both the stock intrusion and the contact metamorphic evolution may be governed by the same 'cupola effect'.

The fluids first deposited their silicates. Then as composition changed, the metals deposited. These therefore segregate within the altered zone, favouring the borders and replacing off into pure limestone. Contemporaneous movement could conceivably localize ore without having any noticeable effect in the alteration pattern.

6. (Dolmage, Marble Bay) - Strong shearing. Zeolite and vein calcite.

7. (Dolmage, Marble Bay) - Secondary minerals deposited.

Exploration

The best place to look for new ore is around the Marble Bay Mine itself. All segments of the suggested bell shape have not yet been explored. Also the ground lying 400 ft. west of the shaft, which contains a large amount of replacement.

The Security Ground contains a large amount of replacement which is extensively mineralized. Shafts on it have not gone very deep. The diamond drill holes were made northeast of the main alteration. This ground then would certainly merit more extensive drilling.

The zone between Marble Bay and Security had been considered for prospecting from the 15th level of the former. This would explore the Security Ground also. This would have been good policy when the Marble Bay was an operating mine.

The area for 12 to 15 hundred feet northwest of the Copper Queen contains large numbers of siliceous replacements (A type dykes) with which are associated small amounts of garnetite. These are interpreted as being closely related to the contact metamorphic replacements. A few drill holes in this area might well disclose such a replacement.

Report by Charley Nag(?) or Heg(?)
1942