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MISIMA ISLAND - GEOLOGY AND GOLD MINERALIZATION.

by

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TABLE OF CONTENTS

TABLES

TEXT FIGURES

PHOTOGRAPHS

PLATES

SUMMARY

Misima is a small island in the Louisiade Archipelago, 150 miles east-south-east of the south-eastern tip of Papua. The island was visited in 1959 for a period of four months by a Bureau field party in order to establish the regional geological setting of the gold mineralization.

Misima is composed mainly of folded and faulted metamorphic rocks of unknown age, covered in the north-east by some 1,300 feet of Tertiary beds, and surrounded in the south and east by a rim of raised Quaternary coral reefs.

The metamorphic rocks are divided in a higher-grade metamorphic series in the west and a lower-grade metamorphic series in the east. They are separated by a metamorphic unconformity but other than that the character of the boundary is still problematic.

The higher-grade metamorphics are composed of amphibolites (Lalama Amphibolite) overlain by gneisses and schists (Oiatau Gneiss), and belong to the almandine amphibolite facies of metamorphism. The amphibolites were probably igneous and tuffaceous deposits; the gneiss probably originated from normal clayey and silty sediments. Parts of the higher-grade metamorphics are migmatized.

The lower-grade metamorphics consist of a volcanic formation (Ara Greenschist) overlain by a succession of intergrading dark graphitic and micaceous phyllites and schists, quartzose schists, and banded schists (Umuna Schist). A marble and limestone horizon (St. Patrick Limestone) separates the Umuna Schist from the Ara Greenschist. The lower-grade metamorphics occur in the greenschist facies.

The Tertiary deposits include rocks of three different but penecontemporaneous facies types: a volcanic facies in the east (Kobel Volcanics), a conglomeratic facies in the west (Liak Conglomerate), and an intermediate clastic facies (Gulewa Formation).

Quaternary sediments are represented by coral reefs which were raised above sea level in several stages. The maximum elevation is about 1400 feet. Alluvium is rarely present because of the rugged, rejuvenated topography.

Pre-Tertiary igneous rocks include hornblendite (probably pre-metamorphic) and trondhjemite (syn-kinematic) in the west, and dacitic and andesitic porphyries in the east. Post-metamorphic basic and acid dykes cut across the higher-grade metamorphics.

Gold, first found in 1888, is restricted in its occurrence to the eastern part of the island. Total production from both alluvial and lode sources has been of the order of 240,000 ounces of fine gold. Lode gold was successfully mined just before World War II. The mineralization is epithermal and connected with the intrusive porphyry. Native gold is the only ore mineral mined, accompanied by small quantities of the base-metal sulphides pyrite, galena, sphalerite, and some chalcopyrite.

Lode production was practically restricted to the Umuna lode, although other lodes are known. The reserves in the oxidized portion of the Umuna lode are not large enough to warrant re-opening of the mine, but it is possible that an ore body of sufficient volume and grade may be present in the primary zone, which has never been explored.

The only production in 1959 came from the Double Chance, a postwar discovery which is basically an open-cut on a seriesof thin leaders which are spaced close enough to allow profitable mining as a one-man enterprise.

There is evidence that further lodes may be concealed underneath overburden on eastern Misima. Surface exploration by panning alone is probably not enough, and it is suggested that geophysical and drilling methods be tested and, when practicable, applied.

The most favourable areas to explore for gold are areas where porphyry crops out abundantly and where the greenschist boundary is nearby.

INTRODUCTION

General - Misima is a mountainous island in the Louisiade Archipelago, 150 miles from Samarai at the south-east tip of Papua. It has a length of 25 miles, east to west, a maximum width of 6 miles, and covers about 90 square miles. The average annual rainfall at Bwagaoia is 123.4 inch (Davies, 1958) but is much higher inland. The rainfall is fairly evenly spread out over the year. During the south-east monsoon, when heavy seas are common, the only refuge for ships is in Bwagaoia harbour, which can accommodate ships of up to 1,000 tons.

The native population, estimated at roughly 4,000, is spread out over a number of coastal villages. Because the island is mountainous, native gardens are small and few, and the supply of fruit and vegetables is limited. The small European population live mainly in Bwagaoia, the Government Station.

Contact with the outside world is maintained by radio communication and by an irregular shipping service.

Field work.

A geological field party of the Bureau, consisting of two geologists (F. de Keyser and D.S. Trail), a survey hand, and fifteen carriers, mapped the island from May to October, 1959, with the object of establishing the regional geological setting of the gold mineralization.

The field work consisted mainly in compass and clinometer traverses along the numerous creeks, where good outcrop is abundant in contrast with the slopes and ridges, where a thick mantle of decomposed rocks and dense vegetation hides the lithology and structure and slows down the rate of progress. The rugged and trackless south-western part of the island was visited by chartered ship. Vertical aerial photographs on a scale of 1:40,000 approximately taken by the U.S. Air Force in 1947, and a base map compiled from the photographs, were used by the party. Structural and lithological photo interpretation was virtually impossible.
Barometric height readings indicate that the altitudes of spot-elevations given on Admiralty Chart No.1477 are generally exaggerated by one hundred to two hundred feet.

Previous investigations.

Apart from scattered observations made by occasional visitors, most of our knowledge of the geology of Misima was due to E.R. Stanley (1915), who made the only systematic study of the island, including a comprehensive report on the gold deposits, and the compilation of a geological map. Later reports on gold on Misima include those of King, Moodie & Thomas (1949), Palmer (1957, 1959), and Davies (1959). Davies also summarised the mining history of the island.

PHYSIOGRAPHY

In its long and narrow western portion, Misima is very steep and mountainous, and has a single, sharp divide 2,000 to 3,000 feet high. The highest top is Mount Oiatau (3,900 feet). Where the island broadens to the east the precipitous character decreases, and the eastern hills are not more than a few hundred feet high. This difference is probably mainly due to differential uplift as evidenced by the great variation in altitude of the elevated Quaternary reef limestones, but is accentuated by the lithological differences between the higher-grade metamorphics of western Misima and the lower-grade phyllites and schists of the eastern part.

Topography and drainage are youthful: the creeks have cut deep, narrow, v-shaped valleys, and abound in waterfalls and rapids; alluvial deposits are non-existent on western Misima and are only small in the eastern portion; and convex mountain slopes are common in the western part (Fig.1). The island is drained by numerous creeks with a considerable run-off. On eastern Misima the main watershed runs from Mt. Sisa to near Bwagaoia, and most of the main creeks originate on the slopes of Mt. Sisa.

The Quaternary uplift which raised Misima many hundreds of feet above sea-level took place in several stages. This is most clearly illustrated in the raised coral reefs along the eastern and southern coasts. The greatest number of terrace remnants is found at Ebora, in the west, where at least five, and possibly seven, benches may be counted. Stanley (1915) estimated the maximum height of the limestone to be 700 or 800 feet, but 1,000 feet is probably more correct. Still higher elevations are noted west of Eiaus, where the Admiralty Chart shows altitudes of 1390 to 1,400 feet on a ridge covered by these reefs. This illustrates the magnitude of the post-Tertiary uplifts.
East of Eiaus, altitudes of raised reefs decrease rapidly, and at Bwagaoia Point the reef is only 20 feet above sea level; nevertheless, a somewhat higher uplift has probably taken place also in this region, as is evidenced by what seem to be the morphological remnants of an old erosion platform at 200 to 300 feet above sea level, north of Bwagaoia.

STRATIGRAPHY

The geological units recognised in the field are placed in the following succession:

C. Quaternary - alluvium and swamp deposits;
raised coral reefs;

B. Tertiary (Miocene) - 3. Liak Conglomerate: conglomerate;
2. Gulewa Formation: lutites, arenites, limestone;
1. Kobel Volcanics: agglomerate, flows, tuffs, ash beds;

A. Palaeozoic or Mesozoic(?)

b. lower-grade metamorphics
(3. Umuna Schist - phyllites, mica schists;
(2. St. Patrick Limestone: marble;
(1. Ara Greenschist;

a. higher-grade metamorphics
(2. Oiatau Gneiss;
(1. Lalama Amphibolite

A. <u>Palaeozoic or Mesozoic</u>(?)

Metamorphic rocks form most of the island Their age is unknown, but they may be the equivalent of the Owen Stanley Metamorphics on the mainland of Papua which are probably Palaeozoic or Mesozoic.

The metamorphics on Misima are divided into two distinct groups of different metamorphic grade: higher-grade amphibolites and gneiss, forming the narrow and elongated western portion of the island, are placed in the amphibolite facies; lower-grade phyllites and schists, forming the eastern part of Misima, are placed in the greenschist facies. Their interrelation is not precisely known.

a. The higher-grade metamorphics

In the field, the various amphibolites, gneisses and schists that are metamorphosed in the higher metamorphic facies, were grouped into two formations for which the names Lalama Amphibolite and Oiatau Gneiss are here introduced. The Oiatau Gneiss is the younger formation.

1. L a l a m a A m p h i b o l i t e -

The name is derived from the village of Lalama on the north coast of western Misima, where the formation is well exposed. Outcrops occur along the north coast and lower mountain slopes between Ewena and Liak; along the south coast and southern slopes from about 3 miles west of Bwagabwaga to near Awaibi; and on the west coast north of Ebora. Between Awaibi and Liak these rocks are generally strongly injected by a gneissic quartz-diorite, and from Liak to west of Lalama exposures show strong migmatisation and injection by intrusive gneiss. (See page 14). The thickness of the formation is unknown as the base is not exposed, but it is at least 1,000 feet.

The main lithological types in the Lalama Amphibolite are: massive, coarse-grained to medium-grained plagioclase amphibolite; finer-grained, foliated amphibolite; banded amphibolite or quartz-plagioclase-hornblende gneiss; hornblende-biotite gneiss with varying amounts of hornblende and biotite.

All these rocks are garnetiferous in places. The common rock-forming minerals in the formation are:

plagioclase (generally oligoclase-andesine), green hornblende, quartz, brown biotite, commonly also garnet and an epidote mineral: accessories are sphene, apatite, magnetite, and pyrite. Chorite is generally present as a secondary mineral.

The coarse massive plagioclase amphibolite occupies practically the whole area of Lalama Amphibolite outcropping west of Bwagabwaga. It also occurs extensively in the creeks along the north coast, but is here associated with other rock types of the formation. Schistosity and foliation are typically absent or very coarse and weak. Plagioclase and hornblende are the dominant constituents, generally in crystals a few mm. across; sphene, apatite, pyrite, magnetite, and possibly some quartz, are the common accessory minerals. The massive amphibolite commonly contains remnants of finer-grained foliated amphibolite.

The finer-grained foliated amphibolite has a good schistosity and foliation, and possibly a lower feldspar content than the coarse massive type described above. Small quantities of biotite and quartz occur in some exposures. Typical outcrops were seen in the environs of Ebora, and transitions into the banded amphibolite or quartz-feldspar-hornblende gneiss are common.

These banded amphibolites or gneisses are well exposed along the coast just west of Lalama and are characterised by a regular alternation of light and dark bands, which vary from two to ten millimeters in thickness and are generally constant within one outcrop. (Photos 3 & 4). The light bands consist of quartz and plagioclase, the dark bands predominantly of hornblende and an epidote mineral.

Quartz-rich hornblende-biotite gneiss forms subordinate intercalations within the amphibolites. The ratio of hornblende to biotite varies greatly, often to the exclusion of hornblende, and in places the amphibolites and hornblende-biotite gneisses appear to grade into each other, as on the southern mountain slopes north of Bwagabwaga.

2. Oiatau Gneiss-

The formation is named after Mount Oiatau, and occupies the higher part of the mountainous watershed of western Misima, descending to sea level west of Ewena and along most of the south coast between Ebora and Bwagabwaga. It rises eastwards and finally disappears above the erosion surface north of Bwagabwaga, but may crop out again in the area between Awaibi and Liak.

The thickness of the preserved part of the Oiatau Gneiss is probably about 2,500 feet.

The formation is little known because it occupies the most rugged part of Misima, where tracks do not exist and access is very difficult. The gneisses and schists are composed of quartz, plagioclase (ranging from oligoclase to andesine), and varying amounts of muscovite, biotite, garnet (up to 6 mm. across) and epidote. Hornblende may be present in some beds, and in one thin section staurolite and kyanite were recognised. Apatite, sphene, and iron ore are the common accessory minerals. Some of the gneisses are highly quartzose and granular; others are rich in muscovite and garnet. Gneissic textures are well expressed, but where an abundance of micas imparts a strong schistosity the rock is better called a schist.

Foliated amphibolite occurs within the Oiatau Gneiss as a few subordinate intercalations and lenses, particularly near the base of the formation.

The Oiatau Gneiss clearly overlies the Lalama Amphibolite, and between Ewena and Lalama the boundary between the two formations is sharp and unambiguous. South of Mount Oiatau however the distinction is not so obvious; massive plagioclase amphibolite is followed, to the north, by foliated and bedded finer-grained amphibolite which gradually passes into biotite-hornblende-quartz-plagioclase gneiss and garnet-muscovite-quartz-plagioclase gneiss still containing some thin bands of amphibolite. The upper limit of the coarse plagioclase amphibolite is well defined in this area and is therefore chosen as the boundary between the two formations, although the actual boundary may lie in the transitional zone to the north-west.

b. The lower-grade metamorphics

Lower-grade metamorphic phyllites and schists occupy most of eastern Misima, and are the host rocks of the gold mineralisation. Broadly, the stratigraphical succession may be given as follows:

- e- (upper?) dark schist, phyllite, mica schist, banded schist, quartz schist;
- d- dark calcareous schist;
- c- marble;
- b- greenschist;
- ?a- (lower?) dark schist, phyllite, mica schist.

For (e) the name Umuna Schist is introduced. (d) and (c) are contained in the St. Patrick Limestone, and (b) forms the Ara Creek Greenschist. The existence of (a) is not really proved in the field but only inferred, and as horizons (a) and (e) are undistinguishable in the field, they are both placed in the Umuna Schist on the geological map.
The complete sequence is not necessarily found everywhere; the marble and dark calcareous schist appear to be missing in many places, and the greenschist, on the other hand, may occur in more than one horizon, or

may alternate with dark schists at its upper boundary.

1. The Ara Greenschist.

Ara Creek is the type locality of this formation, which is there very well exposed. The greenschist covers wide areas, mainly in a belt extending from the north coast, between Siagara and Rokia Point, southwards along Ara Creek to Mount Sisa and further to the upper reaches of the creeks west of Kaubwaga. A second, narrower belt runs from north of Eiaus over the Quartz Mountain area to Ingubinaina Creek. Both belts probably represent the same horizon. Smaller outcrops are either structural repetitions or are thin intercalations of minor importance within the Umuna Schist. A minimum thickness of 300 to 500 ft. is estimated for the formation.

The greenschists are typically fine-grained, massive and structureless . In outcrop they partly correspond to the "basic schists" of Davies (1958). Schistosity is generally weak or absent. No traces of stratification were found. Colours of fresh rock range from light greyish-green to dark green and nearly black; on weathering the greenschists become yellow brown. A variety of greenschist is a spotted schist in which the white spots are micro-aggregates of albite. Where schistosity is present, elongated spots and lenticles are aligned with it. Magnetite is in places recognisable as small octahedra in hand specimen, and pyrite is also common.

Thin sections reveal a mineralogical composition of albite, chlorite, epidote, actinolite, magnetite, and pyrite, with locally some sphene, muscovite, and calcite. Quartz is rarely present. The albite is generally untwinned, and in some beds encloses all the other minerals. Most thin sections reveal schistose structures to a greater or lesser degree.

The Ara Greenschist is overlain by the St. Patrick Limestone, and may be underlain by dark schists and phyllites. Where the marble is not present, the greenschist and the overlying dark graphitic schist and banded schist seem to have a transitional boundary in that they intergrade and possibly alternate.

2. St. Patrick Limestone.

The formation is named after St. Patrick Creek, an alternative name for Ara Creek, in which the marble is very well exposed in a gorge and probably attains its maximum thickness of about 100 feet. Other outcrops occur intermittently in a strip between the Quartz Mountain area and the region north of Eiaus; in Ingubinaina Creek; on the Mararoa track; and halfway between Mararoa and Siagara. The formation is absent, or at least not exposed, in many places along the greenschist - Umuna Schist boundary, and is in some localities only indicated by the presence of a few pebbles and boulders.

The limestone is generally a white to grey, massive, fine to medium-grained marble, uniformly sugary in outcrop. In some exposures the rock is nearly black. Overlying the massive marble is a zone of marble banded with sugary quartz parallel to the bedding. (Fig.2) These bands are 1"-3" thick, are irregularly spaced with an average interval of one foot, and are frequently interrupted, swelling and pinching, sometimes branching. They are held to be recrystallised chert layers.

In places the marble contains sandy inch-thick bands, lenses and tongues. Specks of galena, pyrite, and sphalerite are visible in some outcrops.

The light-coloured marble of the St. Patrick Limestone is in several areas overlain by a zone of dark impure limestone or calcareous schist which may contain thin dark marble bands, and which gradually merges into the non-calcareous dark phyllites and schists of the Umuna Schist. Pyrite is a common accessory mineral.

3. Umuna Schist.

A thick series of intergrading graphitic phyllite and schist, sericite schist, mica schist, banded schist, and micaceous quartz schist overlies the St. Patrick Limestone and is here grouped together under the name of Umuna Schist, after the mining centre of Umuna where these rock types abound. They form the bulk of the lower-grade metamorphics of eastern Misima. The thickness of the formation cannot be estimated as the rocks are folded, bedding is commonly not recognisable, and the upper boundary is not seen.

It is possible that schists and phyllites, lithologically indistinguishable from the Umuna Schist proper, underlie the Ara Greenschist.

Black to dark grey are the dominant colours, caused by a black opaque dust which is either carbonaceous material (assumed here) or finely disseminated iron ore. The "purer" mica schists are more silvery. The black graphitic schists decompose to a dark grey or, in places, brick red soil, whereas the more micaceous members give a lighter grey soil.

Most types are very fine grained, but there is a tendency for the grain size to increase with decreasing "graphite" content. The main mineral constituents are shown under the microscope to be quartz, albite, muscovite or sericite, and chlorite; minor quantities of calcite and epidote are found in some rock types. Apatite is an accessory mineral, and pyrite commonly is disseminated throughout.

Schistosity and lineation are pronounced, and in many places the rocks are strongly crumpled and crenulated, particularly in central eastern Misima.

The bulk of the Umuna Schist consists of the graphitic schists and phyllites grading into micaceous schists. They are generally very fissile and soft. The banded schists are hard, poorly fissile rocks typically consisting of alternating light and dark bands which vary greatly in thickness but are commonly 5-10 mm thick. They may be tuffaceous: in one outcrop a lens or inclusion of a much altered volcanic rock was found. They are distributed mainly in north-eastern Misima. Light coloured micaceous quartz schists are found in the Boiou area and in the south-east corner of Misima. They are thick-bedded to laminated, and are coarser-grained than the dark schists and phyllites. A thin section revealed a composition of quartz-albite-chlorite-epidote with some muscovite.

c. Boundary between the lower-grade and the higher-grade metamorphics.

The boundary between the lower-grade and the higher-grade metamorphics is largely concealed by the Liak Conglomerate and the raised Quaternary coral reefs west of Eiaus, and only part of it is exposed in the area north-west of Awaibi, where it can be seen in the Ulabwe and Awailu Creeks and in one of the branches of Weipoou Creek. The lower-grade metamorphics are here represented by dark graphitic schists, micaceous schist, and altered basic igneous rock; the higher-grade metamorphics consist of amphibolites intruded by gneissic quartz-rich granodiorite. In Weipoou Creek there seems to be a thin transition zone less than 200 ft. wide between the two metamorphic sequences: at the boundary, an amphibolite, in which the hornblende still has actinolitic affinity and the plagioclase is probably an albite-oligoclase, has a grade of metamorphism intermediate between the altered basic igneous rock of the greenschist facies and the amphibolite of the almandine amphibolite facies. In the other outcrops no such transition could be traced, and the boundary line is generally marked by the contrast in appearance between the dark, fine-grained, lower-grade phyllites and the underlying coarser-grained rocks with their gneissic texture and higher degree of metamorphism.

Unfortunately no actual contact was found. The attitudes of schistosity and foliation on either side, however, and their changing trends seem to correspond closely, and an angular unconformity could not be proved. Nor is it likely that the boundary is faulted, because it seems too sinuous for this.

The seemingly rather sharp difference and sudden change in metamorphic grade at the boundary is perhaps more illusary than actual, and may be due to retardation of metamorphic reaction by the high graphite content of the lower grade schists.. If this is the case, it may well be that the lower-grade metamorphics overlie the higher-grade metamorphics in a normal manner, and the graphitic mica schists are presumably the lateral equivalents of the Mt. Oiatau Gneiss, as both overlie the Lalama Amphibolite. Also, the Ara Creek Greenschist may then possibly be the lower-grade equivalent of the Lalama Amphibolite. However, the contrast between the Mt. Oiatau Gneiss, which is notably poor in graphite (some has been seen in thin section), and the black graphitic Umuna Schist is disturbingly great, and one has to resort to a very sudden change in sedimentary environment to explain the difference.

In conclusion it must be said that the nature of the boundary between the lower-grade and the higher-grade metamorphics is still not clear.

d. Metamorphism, migmatisation, and origin.

In the higher-grade metamorphics various combinations of the following minerals are found: quartz, plagioclase (oligoclase-andesine), green hornblende, biotite, muscovite, garnet, epidote, staurolite, and cyanite.

Rocks containing plagioclase together with epidote and hornblende, which are very common on Misima, are placed in the "amphibolite" facies by Turner & Verhoogen, whereas Ramberg groups them together with albite-epidote amphibolites in the "ipidote amphibolite" facies (Fyfe, Turner, and Verhoogen, 1958). As the optical distinction between hornblende and deeply coloured varieties of actinolite (a mineral characteristic of the greenschist facies) is difficult, and as epidote is a mineral with a wide range of stability within the limits of greenschist facies and amphibolite facies, Fyfe et al proposed to drop the "(albite-) epidote amphibolite" facies and to recognise only a greenschist facies and an "almandine amphibolite" facies. This has the advantage of easy classification under the microscope, since there is a sharply defined and readily recognisable transition between albite (greenschist facies) and oligoclase (amphibolite facies).

Following the definition of Fyfe et al, the higher-grade metamorphics of Misima occur in the almandine amphibolite facies, mainly in its staurolite-quartz subfacies. The co-existence of plagioclase (generally oligoclase-andesine) and an epidote mineral is typical of this subfacies, as is also the blue-green colour of the hornblende. Of the mineral combinations given by Fyfe, the following correspond with combinations found on Misima:

for pelitic rocks - quartz, plagioclase, muscovite, biotite, almandine, and epidote;

quartz, plagioclase, cyanite, staurolite, muscovite, (biotite).

for basic rocks - hornblende, plagioclase, almandine, epidote, (quartz, biotite);

hornblende, plagioclase, epidote, (quartz,biotite).

This facies indicates a medium-grade metamorphism under high pressure and stress.

The higher-grade metamorphics are, in some areas, intensively intruded and impregnated by syntectonic quartz dioritic magma, which has resulted in the forming of migmatite and hybrid rocks. Typical outcrops of these mixed rocks occur along the coast between Liak and Lalama; exposures generally consist of acid gneissic masses with numerous remnants

of amphibolite (Fig.3., Photo 6.), the outlines of which are sharp in some places, blurred and absorbed in others. Hybridization and contamination of the intrusive material is evident from the inhomogenous colouring of the gneissic masses, which show patches of different shades of grey. A thin section of one of these gneisses reveals a composition of quartz, plagioclase, hornblende, biotite, and pink garnet, with accessory apatite and magnetite. The biotite is dark greenish-brown, like the biotite of the trondhjemite intrusive mass (see page 14), and unlike the reddish-brown biotite of the uncontaminated metamorphic Mt. Oiatau para-gneiss.
It is likely that metasomatism has been active in these migmatites, but not enough laboratory work has been done to determine its nature and extent. The occurrence of large feldspar porphyroblasts in some outcrops may be an indication of such metasomatism.

Stanley (1915) considered all the higher-grade metamorphics to be of igneous origin, undoubtedly because his traverses took him mainly through the migmatised area between Liak and Ewena. However, the Oiatau Gneiss is definitely a metamorphosed sequence of pelitic and perhaps psammitic sediments, and part of the Lalama Amphibolite has at least a sedimentary component.
An igneous origin is probable for the massive plagioclase amphibolites, as their feldspars exhibit a strong rhythmic zoning and have largely retained their original crystal form; biotite and quartz are lacking, and outcrops commonly contain inclusions of other types of amphibolite.
The banded amphibolite or quartz-plagioclase-hornblende-epidote gneiss was possibly a tuffaceous deposit, an impression that is strengthened by the observation of coarse-grained hornblende inclusions in the banded gneiss (photo 4), which are regarded as possible volcanic bombs.

The lower - grade schists are generally metamorphosed in the quartz-albite-muscovite-chlorite subfacies of the greenschist facies. This implies regional metamorphism under conditions of low temperature and moderate pressure (equivalent to a depth of burial of roughly 10 kms. according to Fyfe et al.). Mineral assemblages mentioned by Fyfe et al (1958) and occurring on eastern Misima include the following:

for pelitic rocks - quartz, muscovite, chlorite, albite, (epidote);

for basic rocks - albite, epidote, chlorite, actinolite, sphene(quartz);

albite, epidote, chlorite, sphene (quartz;

albite, epidote, chlorite, calcite, sphene, (quartz (actinolite).

It is possible that the grade of metamorphism slightly increases towards the west; graphite schists west of Eiaus seem to contain biotite, though this is difficult to ascertain without the help of thin sections; and mica schists south of Gulewa contain occasional small pink garnets (spessartite?). Banded schist in the Kobel Creek area contains biotite-rich laminae.

Interesting relationships between metamorphism and deformation are shown in the thin section of a crenulated graphite schist sampled in the Ingubinaina Creek area. The schist is composed of very fine-grained muscovite, sericite, chlorite, and graphite (?) dust, arranged in very thin laminae, and has undergone crenulation and false-cleavage. This deformation is apparently post-regional metamorphism since small muscovite flakes in the crenulated folds are bent. However, occasional prisms 0.5 to 1 mm long cut across the bedding and crenulation without being disturbed, and were evidently formed after the deformation. They are composed of tiny granules of sphene (?) forming clusters in the cores of the prisms, with generally a thin outer rim of indeterminate, colourless material probably consisting of quartz or sericite. The sphene is probably a replacement of some unknown mineral. The formation of the prisms, which are very much coarser than the minerals constituting the rock, is a second stage of metamorphism, perhaps thermal (intrusive porphyry crops out nearby), but it is hard to see why, in that case, no biotite was formed.

The graphitic schists, phyllites, mica schists, quartz schists of the lower-grade metamorphics were originally fine-grained pelitic sediments and muds with a high organic content.
For the greenschists an igneous origin must be assumed, in view of their composition and appearance in the field. It seems that Stanley (1915), and perhaps others, have mistaken many greenschist outcrops for basic dykes. However, since their stratigraphical position is constant and no intrusive contacts were noticed, they undoubtedly represent metamorphosed volcanic products: lavas, ash beds, or tuffs.

B. Tertiary (Miocene).

Tertiary deposits are distributed along the north coast from Liak to Rokia Point, and reach inland for 2 to 2½ miles. A Tertiary remnant occurs between Kulumalia and Lapipai, descending from the 900 ft. contour to sea level. In all, some 10 square miles are covered by the Tertiary rocks, which have a total thickness of at least 1300 to 1500 feet.

A subdivision has been made which is based mainly on lateral facies differences, and the following stratigraphic names are introduced: Kobel Volcanics, Gulewa Formation, and Liak Conglomerate, distributed from east to west.

1. Kobel Volcanics.

The best outcrops are seen in Kobel Creek, where agglomerates or volcanic conglomerates form the walls of a deep gorge. The Kobel Volcanics occupy the eastern portion of the Tertiary outcrop, and comprise agglomerate, volcanic conglomerate, tuffs, ash beds, and flows, generally of trachytic and andesitic composition. A maximum thickness of about 1,000 feet is estimated.

In the Kobel Creek-Kalotawa area the principal rock-type is a coarse volcanic conglomerate, with sub-ordinate beds of coarse tuffs. The conglomerate is dark grey, and contains boulders with a maximum diameter of about 5 feet, mostly rounded and grading down into a poorly sorted, coarse, angular, fragmental matrix. The boulders are a grey, porphyritic andesite (field term) which contains light grey phenocrysts of feldspar, 2 to 4 mm long, and thin hornblende prisms 2 to 3 mm long. The rather high degree of rounding suggests deposition of agglomerate in an aqueous environment. Tuff bands are not common, may reach a thickness of 20 feet, and are weathered, light-grey to white, medium to coarse grained, and dominantly composed of sub-angular to sub-rounded feldspar crystals which are uniform in size in each individual horizon. Quartz may be present in small quantity. The coarse tuffs are massive, the fine-grained tuffs have well-developed lamination. All tuffs contain occasional small pebbles of lava.
The number of tuff beds increases from Kobel Creek to Kalotawa, and the volcanic rocks capping the hills behind Kalotawa are predominantly coarse crystal tuffs and flows with some beds of agglomerate, in which fragments rarely exceed 5" across.

Flows have also been reported from the Kalotawa-Guntuka shore section, and Gibb Maitland (1892) gave the following analysis of one of these lavas, which he called a trachyte:

Si	68.02%
Al	14.08%
FeO	0.29%
Fe_2O_3	5.19%
Mn	trace
Ca	5.30%
K	1.26%
Na	5.17%
loss on ignition	1.37%
	100.68%

The volcanics capping the hills around the mouth of Ara Creek are weathered red rocks, fine pebbly volcanic conglomerate, agglomerate, flows, and crystal tuffs (?). The Ara Creek agglomerate is a light green-red rock with sub-angular fragments less than 8" across, grading into a matrix of poorly sorted angular and sub-angular fragmental material. The pebbles are vesicular lavas composed of small phenocrysts of feldspar, and probably some quartz, with little matrix. The flows and crystal tuffs in this area are light greenish-grey when fresh, but weather to red and chocolate brown. They are medium grained, with feldspar and quartz phenocrysts. Drusy quartz veins and quartz-filled cavities are common in these rocks. A trachyte from Nigom shows, in thin section, phenocrysts of perthitic alkali feldspar, 1-3 mm across, set in a much altered micro-crystalline matrix in which alkali feldspar could be recognised, and a little quartz. Small phenocrysts of a mafic mineral (hornblende?) are completely altered.

The Tertiary remnants which occur on the 900 feet level near Kulumalia, and down to sea level near the Mission Station and Lapipai, consist of light-grey, soft, weathered tuffaceous sediment or tuff, and, near the Mission Station, of greenish-grey fine-grained volcanic breccia. Microscopical examination of the breccia shows rounded fragments of fine-grained trachyte with fluidal texture embedded in a fine-crystalline quartz(?)-feldspar matrix. Grains of clino-pyroxene and brown hornblende occur in the matrix as well as in the fragments. The fragments are several millimetres across. It is possible that the rock represents a vent breccia; this would also explain its occurrence at sea level while less than a mile to the north the base of the tuffs is 900 feet above sea level.

Stanley (1915) placed the source of the Tertiary volcanism 'somewhere in the deeps off the coast line between Siagara and Patlilu Point', but there is little proof for this supposition. On the contrary, some coarse cross-bedding in agglomerate or volcanic conglomerate near Gulewa indicates a provenance from a roughly south-eastern direction, and the occurrence of the vent(?) breccia near the Mission Station, as previously mentioned, also suggests a source in a south-eastern direction. The fact that no eruption centres could be recognised with certainty morphologically is perhaps due to the rapid erosion following the post-tertiary uplifts.

To the west, near Gulewa, the volcanics interfinger with, and are succeeded by, the sediments of the Gulewa Formation.

2. Gulewa Formation.

The Gulewa Formation consists of a limestone member and a great variety of clastic sediments, many of which seem to be tuffaceous. Its name is derived from Gulewa village, nearby which the clastic sediments are well exposed. The formation is about 1300 feet thick and extends from Gulewa to near Liak, where it gives way to the Liak Conglomerate.

The limestone member crops out about $\frac{3}{4}$ mile south of Gulewa. In this locality it is separated from the metamorphic basement by a thin zone of clastic sediments. The limestone is corallogene in its thickest parts, and is there practically undistinguishable from the Quaternary raised coral reefs. Outcrops in Imgamanina Creek show that the limestone is interbedded with the Tertiary sediments. It is not impossible, however, that some of the limestone outcrops mapped as Tertiary are of Quaternary age, as for instance the patch of limestone south-east of Gulewa.

Typically the limestone is white to cream, and has abundant fragments of lamellibranchs, corals, bryozoa, foraminifera, and other fossils. The corallogene types are hard, but the other organic limestones are commonly weathered to a soft and chalky substance.
In Imgamanina Creek the first signs of the approach of a reef environment, going upsteeam, are fragments and pebbles of reef limestone enclosed in bedded calcareous Tertiary sediments. These fragments give way to tongues and beds of limestone which are intercalated with weathered tuffaceous(?) and calcareous siltstone and marl. Further upstream the limestone bands

have congregated into quite massive, thick and reef-like beds, represented in the creek by huge tumbled blocks and boulders.
The maximum thickness of the limestone, south of Gulewa, is 70 to 100 feet. The limestone country is marked by numerous sink holes and by subterranean drainage, and is fairly difficult of access.

The lateral correlation of the limestone to the east is doubtful, as the Gulewa outcrop is terminated by a fault. An intermittent limestone horizon which is probably the equivalent of the limestone horizon described, exists at the base of the volcanic conglomerate in the Kobel Creek area, and directly overlies the metamorphic schists. This limestone is generally impure, and in places contains calcareous sandstone beds, and lenses of calcareous conglomerate. The calcareous sandstone is dark grey, fine to medium grained, with small silt lenses, and contains micaceous and carbonaceous material, fossil fragments and foraminifera. The conglomerate lenses consist mainly of quartz pebbles with a few flat mica schist pebbles in a calcareous matrix.

West of Gulewa the limestone thins rapidly and becomes a calcarenite, mainly composed of foraminifera and small limestone fragments, with other fragments of quartzite, gneiss, feldspar, epidote, and hornblende, as observed in thin section. Near Liak, this calcarenite is overlain by the Liak Conglomerate.

The clastic sediments of the Gulewa Formation are very varied, and include such rock types as fine-grained and coarse-grained sandstones, siltstones, mudstones, coarse greywacke, pebbly beds, conglomerates, sedimentary breccias. (Fig.4). Intercalations of agglomerate and flows are present, which are probably interfingering members of the Kobel Creek Volcanics. Some beds seem to be tuffaceous, others are calcareous. Many strata contain abundant clastic mica and carbonaceous material, shell fragments and micro-fossils. Glauconite occurs locally. The bulk of sediments is above the limestone member, but a thin zone of Gulewa sediments separates this member from the metamorphic basement in most places. Beds may be massive or thinly laminated. Conglomerates and breccias are coarse, with pebbles up to one foot across, or fine and gravelly. They range from well-sorted to poorly sorted, and pebbles are well-rounded or angular to sub-angular. In some conglomerates pebbles consist of metamorphic rocks, in others they are derived from penecontemporaneous deposits of siltstone and mudstone. The sandstones, which vary from fine to very coarse grained with angular and sub-angular grains, are commonly poorly sorted. The greywackes are coarse to very coarse grained, poorly sorted, and composed of angular rock fragments (including some volcanics), quartz and feldspar in an impure sandy matrix composed of a great variety of minerals: quartz, feldspar, augite, hornblende, chlorite, epidote, biotite, muscovite, tests of foraminifera, calcite, etc. Mudstones and siltstones are generally rather massive, but between Gulewa and Kakama they are very well-bedded, and are probably tuffaceous. A good exposure of an intercalated agglomerate horizon is found on the north coast about ½ mile west of Gulewa; its boulders and fragments range from grit size to about 3 feet across, and consist of scoria and lavas, among them a black basalt (small phenocrysts of labradorite and augite). The matrix is sandy and tuffaceous. The lower part of the agglomerate is finer and better sorted, and shows some rough cross-bedding which indicates a provenance of the material from a roughly south-eastern direction.

All these deposits are more or less grey when fresh, but become white, yellow, brown or greenish on weathering.

Bedding structures are not common. Some worm-burrows(?) and fine mud cracks occur in the mudstone, and cross-bedding is rare. A section through some load-cast structure is shown in Fig. 5.

Many beds are fossiliferous, contain lamellibranchs and other shells (Fig.6.), micro-foraminifera, and, according to Stanley (1915), remnants of carbonized plant fossils in the mudstone.

3. Liak Conglomerate

This uniform and massive conglomerate is well exposed in Gowa Creek near Liak, and in the upper reaches of Ulabwe Creek, and covers an area of approximately 3 square miles in the vicinity of Liak. Its thickness is estimated at about 700 ft. Composition and size of the mostly well-rounded pebbles and boulders vary somewhat according to locality. North of Awaibi, for instance, the boulders are an average 2-3" across, with a maximum of more than foot. They consist mainly of amphibolite, greenschist, porphyry, quartz, schists, and dolerite, with rare pebbles of Tertiary limestone. South of Liak, near the boundary with the metamorphics, the conglomerate is finer and more sandy, and the pebbles are generally coated with a film of limonite. In Gowa Creek the proportion of pebbles of Tertiary rock types is somewhat higher. In general, the content of metamorphic components increases from south to north.

Intercalated in the conglomerate are some minor lenses and tongues of moderately to poorly sorted sandstone, which is locally fossiliferous.

According to Stanley (1915), the conglomerate overlies the Tertiary sediments of the Gulewa Formation with an angular unconformity. He based this opinion on differences in attitude between the Gulewa sediments and the Liak Conglomerate. However, our field work showed that attitudes are the same for conglomerate and underlying calc-arenite, and that both appear to follow the same structural undulations. It seems, therefore, more likely that the conglomerate overlaps, and probably interfingers with, the sediments of the Gulewa Formation, and that any unconformities present are of a local character only.

The relationships of the Tertiary formations described above are tentatively shown in the diagrammatic section of plate 1. Their age was given by Stanley as late Tertiary, Micro-foraminifera sampled during our survey include the following genera and species determined by D. Belford:

> Globorotalia menardii, Globoquadrina altispira, Globigerinoides trilobus, Pulleniatina obliquiloculata, Sphaeroidinella dehiscens, Eponides umbonatus, Plectofrondicularia interrupta, Bolivinita quadrilatera, Nodosaria arundinea, Bulimina aculeata, Cassidulina cf. subglobosa, and Siphogenerina sp.

This association puts the Tertiary rocks on Misima in the upper Miocene. Stanley, who in 1915 had included the Kobel Volcanics in the Tertiary, stated in 1917 that they were "recent" but did not discuss his change of opinion. This new supposition seems illogical since he himself had written in 1915 that the volcanics just east of Gulewa were interstratified with the sedimentary rocks of proven Tertiary age.

C. Quaternary

Deposits of Quaternary age consist mainly of raised coral reefs; a few small swamps and accumulations of gravel alluvium occur on eastern Misima.

The raised coral reefs are a striking feature of the island and form terraces and benches all along the southern and eastern coasts, rising locally to a maximum altitude of 1,400 feet (see page 3)(Photo 1) Raised reefs with heights of 100 to 200 feet above sea level occur along the east coast between Rokia Point and Cape Henry (photo 2.) Along the northern shore they are notably absent.

The reefs normally have a corallogene facies and are mainly built up by foraminifera (Operculina, Cycloclypeus, and others), algae, bryozoa, and corals. Locally sub-ordinate bedded impure limestone, calcareous sandstone, gravel patches, and in one place even a conglomerate, are also exposed.

The limestone areas are characterised by their white cliffs, subterranean drainage, sinkholes, caves with stalactites, deep canyons, and the like.

On the map all raised reefs are shown as of Quaternary age. This is certain for the lower levels, but it is likely that the higher levels may be Tertiary and perhaps be the equivalent of the Tertiary coral limestone south of Gulewa. In that case the uplift of the island during Tertiary times must have been a one-sided, tilting movement: the southern end must have risen rapidly, while the northern zone was comparatively stationary so that sedimentation could take place and sands and conglomerates derived from the southern zone were deposited here.

Alluvial deposits are few, and are restricted to eastern Misima where uplifts with resulting rejuvenation of the drainage system apparently were less vigorous. They consist of sago swamps and gravel deposits, and occur at the mouths of the larger creek, such as Ingubinaina creek, Cooktown creek, Ginesia creek. The "alluvium" shown on the geological map west of Bwagaoia probably partly represents fine sandy and silty lagunal deposits raised slightly above sea level.

INTRUSIVE IGNEOUS ROCKS

These are the hornblendite, trondhjemite, post-metamorphic acid and basic dykes, and the porphyries, the Tertiary effusive rocks and the amphibolites of uncertain origin are excluded from this section.

Hornblendite

Hornblendite occurs on the divide between Liak and Bwagabwaga, and in Bwagabwaga itself. The rock is a massive, coarsely crystalline aggregate mainly of hornblende, with varying amounts of interstitial plagioclase and some scapolite and quartz. Pyroxene and epidote are occasionally seen in some sections. The hornblende is commonly 0.5 inch across, idiomorphic and short-prismatic. This habit is probably the reason that Stanley (1915) described the rock as a pure "gabbro containing many large well-formed augite crystals." The mineral shows some "schiller" structure, and is light grass green (the hornblende in the metamorphics is deep bluish green). The scapolite is clear and free from inclusions, and the plagioclase is albite twinned and rather calcic. A magmatic origin seems very likely.

The age of emplacement is open to discussion. Most probably the hornblendite is pre-metamorphic, because inclusions of the rock were found in banded amphibolite or quartz-plagioclase-hornblende gneiss near Lalama (photo 4), and remnants occur in the migmatite between Liak and Ewena. The inclusions in the banded amphibolite were perhaps deposited as volcanic bombs in tuff or ash beds. On the other hand, no sign of metamorphic effects could be recognised in thin section. Possibly the hornblendite has withstood metamorphic stresses thanks to its coarseness and massive nature. Possibly also the inclusions in the banded gneiss are not related to the hornblendite but are coarsely recrystallised amphibolite; in other words the similarity could have been caused by convergence of two different processes.

Contact relationships were unfortunately not seen, but in a few places the hornblendite seems to grade into the coarse plagioclase amphibolite.

Trondhjemite

Trondhjemites are quartz-rich tonalites, and were defined by Goldschmidt as: 'leucocratic acid plutonic rocks, whose essential constituents are soda-rich plagioclase and quartz. Potash feldspar is essentially wanting or is present only in subordinate amounts. Biotite is the most important of the mafic constituents, although it is present in small quantities. The ores are usually absent'. A rock type corresponding to this definition occupies much of the area between Liak and Awaibi and forms the main mass of Mount Apatikaiogeian. It may also be the original intruding component in the migmatites. No outcrops were seen in the lower-grade metamorphics.

In thin section the plagioclase appears to be an oligoclase or albite-oligoclase; quartz, one of the main constituents, shows strain shadows; biotite is present as small dark green-brown shreds, often accompanied by epidote. Sphene, apatite, and zircon are present as accessory minerals.

The emplacement of the trondhjemite was probably largely syntectonic, as a gneissic structure is generally apparent. Injection of smaller veins was rather forcible. This is demonstrated in an outcrop about 1.5 mile east of Ebora (Fig.7), where a trondhjemite vein shows faint flow banding strongly curving downwards due to friction against the walls, and the gneiss and amphibolite forming the wall rocks are dragged in the direction of movement. A thin section of the vein reveals pronounced granulation or protoclastic structure. The emplacement of the trondhjemite must have taken place under conditions of high temperature and pressure, to account for the smooth ruptureless plastic drag shown by the wallrock gneiss.

Post-metamorphic acid and basic dykes

Acid and basic dykes of post-metamorphic age intrude the higher-grade metamorphics in a number of places, but were not found in the lower-grade metamorphics. The dykes occur mainly in the area between Ewena and Liak, locally in swarms, and generally strike either east-north-east or west-north-west. Thicknesses range from 0.5 to 5 feet approximately.

Two thin sections were made, one of an acid, one of a basic dyke. The acid rock (Photo 7) is a mica dacite, containing phenocrysts, 0.5 to 1 mm across, mainly of feldspars with some muscovite and quartz, embedded in a fine-grained matrix of quartz, feldspar, and green-brown biotite. The feldspars are twinned plagioclase (oligoclase or andesine-oligoclase) and potash feldspar.
The crenulated margins of the phenocrysts suggest that the final stage of their growth has coincided with the crystallization of the matrix.

The basic dyke rock sectioned appears to be an hornblende-albite lamprophyre. Phenocrysts of a reddish-brown barkevikitic hornblende are embedded in a fine and even-grained, panidiomorphic network of brown hornblende and a plagioclase which is probably albite. Clusters of epidote and chlorite are probably fillings of amygdales or are pseudomorphic after some unknown basic phenocryst, perhaps olivine. Quartz is a rare constituent in the matrix, and pyrite and chlorite are accessory.

Porphyries

Under this heading are grouped a variety of generally porphyritic intermediate to acidic intrusive rocks that crop out extensively in the Lower-grade metamorphics in eastern Misima and are held to be responsible for the gold mineralization. They occur as sills, dykes, and irregular bosses of various dimensions, (Fig.8), and were probably intruded at the end of the paroxysmal phase of deformation, although they themselves are affected by continued faulting and shearing. Their emplacement took place in more than one stage, as some porphyries are seen to cut through others; felsitic varieties are generally younger than the porphyritic types. In places the country rock is hornfelsed near the intrusive contact.

The most common types are porphyries of dacitic or andesitic composition. They are light or dark grey when fresh, and contain many phenocrysts of 2 to 4 mm across in a micro-crystalline matrix. The phenocrysts are mainly white, idiomorphic feldspars, with some quartz in the more acid rocks. Plagioclase (oligoclase or oligoclase-andesine) predominates over potassium feldspar. Mafic phenocrysts are idiomorphic biotite, or green hornblende, or both.

In some localities the porphyries grade into rocks with a more plutonic, phanerocrystalline character. An extreme example is found in the intrusive mass north of Sikekeu. No matrix is present in this rock, which is a quartz diorite, made up of plagioclase, some potassium feldspar, biotite, and some quartz.

Another variety is very fine-grained, aphanitic, greenish felsitic rock in which no phenocrysts are visible. It generally occurs in dyke form, and never forms large bodies. A thin section shows a trachytic composition with strong silification in the form of impregnation and veining with quartz. Phenocrysts of potassium feldspar, though not visible in hand specimen, are present, embedded in a fine-grained quartz-feldspar matrix).

Many of the porphyry outcrops are much altered to a yellow, yellow-brown, pink, or white clayey substance, in which quartz phenocrysts, and in places white specks of kaolinised feldspar, are conspicuous. The mafic minerals are chloritized; biotite is commonly bleached to a white "mica" which could be mistaken for muscovite in hand specimen. Other decomposition products are calcite, sericite and epidote, generally in the form of saussurite.

A few outcrops of a hornblende dacite porphyry are present in the higher-grade metamorphics (Fig.7), but it is not known whether they are related to the porphyries in the lower-grade metamorphics.

Other intrusives

Dolerite dykes and veins have been reported by several authors (Stanley, 1915; Davies, 1958) from the lower-grade metamorphics, but these were not seen by members of the 1959 party. One possible example occurs at the Double Chance mine (Fig.9), but extreme decomposition and weathering have obliterated the original mineralogical composition. It is highly probable that Stanley (1915) mistook certain greenschist exposures for basic dykes.

Outcrops of what are thought to be metamorphosed basic dykes occur locally in the higher-grade metamorphics. A thin section made of one of these rocks shows a mineralogical composition of pale green hornblende and epidote enclosed in irregular porphyroblasts of albite, the main constituent. Quartz and chlorite are sparse. The hornblende is still very poor in alumina and has actinolitic affinity and the rock probably belongs to the greenschist facies. This is in strong contrast to the almandine amphibolite facies of the surrounding gneiss, and it is therefore suggested that intrusion of the dyke took place when conditions of metamorphism had become less severe.

STRUCTURE

As can be expected in areas of regional metamorphism, folding and faulting are conspicuous in the metamorphic basement; but the Tertiary and Quaternary sediments are also tectonically disturbed, though to a much lesser degree.

It is difficult to present a precise structural picture of the metamorphic formations, because airphoto interpretation is virtually impossible, outcrops are scattered and not traceable over any distance, and marker beds are absent, with the exception of the St. Patrick Limestone. Moreover, bedding is commonly not recognisable and measured dips and strikes therefore generally refer to the attitudes of schistosity and foliation, which may or may not coincide with the original bedding. The sections (Plate 1) give an interpretation rather than a true picture and demonstrate only qualitatively the regional structure.

F o l d i n g - The regional strike of fold axes on Misima is roughly east-west. Folding in the metamorphic rocks is represented in different orders of magnitude; on a small scale, schists and phyllites are plicated and crumpled, locally to such extent that rodding of the schist has taken place. This fine-scale crenulation is expressed on planes of fissility as a distinct lineation, which, where observed, is parallel to the axes of larger folds (b-lineation). It is assumed, and in some places demonstrated, that the plunge of lineation coincides with the plunge of larger structures which cannot be recognised in outcrop, and the measuring of lineation in the field may be of much value in trying to unravel the obscure major structures.

Folds of several feet or yards of amplitude are the next order of magnitude, and may be recognised in good exposures. They show steep plunges in some outcrops, but may be rather flat in other places.

With increasing dimensions structures become more difficult to interpret. The Double Chance anticline (Fig.10) for instance, could be recognised only by the presence of the boundary plane between Ara Creek Greenschist and Umuna Schist, combined with information given by the lineation.

The overall structure of eastern Misima is probably undulating with predominantly shallow to moderate dips and plunges (Sections A-B and C-D, Plate 1); the many steep dips of the planes of schistosity are attributed to secondary shear folding. It is noted that dips and strikes appear to be much more constant and regular in areas where outcrops of porphyry are small and scarce than in the densely intruded regions, where the porphyry bodies seem to have been, directly or indirectly, responsible for the confused structures. One such "quiet" area is the south-east corner of eastern Misima: here an east-plunging anticline is present.

Cross folds probably occur on eastern Misima in the region between Rokia Point and Cape Henry, where the formation boundaries indicate a general strike to the south-east, but where individual attitudes of schistosity and lineation are commonly at right angles to this direction.

In the higher-grade metamorphics dips may be gentle, as along the north coast west of Lalama and in many places along the south coast, or they may be steep, as in the region west of Bwagabwaga. It is assumed that bedding and schistosity in the Oiatau Gneiss largely coincide: planes of schistosity and bands of different composition and grain size are generally parallel. Deformation apparently occurred under conditions of high pressure and temperature, as is suggested by examples of plastic folding (Fig.11).
An interpretation of the overall structure is given in sections EF and GH (Plate 1).

Folding in the Tertiary sediments was much weaker. Dips reach 40° at the most, but are generally much less. The regional dip is towards the sea, away from the metamorphic basement.

F a u l t i n g - Faulting is common on the island and occurs in all rock units. Although definite fault planes in the metamorphics can rarely be traced in the field, sufficient evidence is shown by brecciation and shearing, in many places combined with quartz veining. The Umuna lode is the best known example. Many exposures show small-scale faulting and thrusting (Fig.12 and Photo 5).

The Tertiary sediments are also affected by faulting; small-scale faulting in exposures often show low-angle thrust movements.

Even the Quaternary coral reefs have been under tectonic stresses as can be expected in view of their considerable post-Tertiary uplift. Vertical off-sets in raised coral benches have been noticed on the south coast, and Bwagaoia harbour has probably been formed as a sunken wedge bounded by fault planes. West of Eiaus the raised coral reefs show low dips in opposite directions, perhaps owing to drag movements caused by block faulting.

Although geological and structural photo interpretation was generally not possible, a pattern of lineaments may be seen on close study of the aerial photographs (See insert on Plate). This lineament pattern, which has some influence on the drainage system, undoubtedlyincludes joint systems as well as fault planes. Bwagaoia harbour, for instance, is bounded by a set of lineaments, and probably owes its artificial-looking, canal-like appearance to differential movements along these lines: a small wedge has subsided below sea level, a western block has slightly emerged, and an eastern block has remained stationary. The coral reef west of Bwagaoia is raised about 20 feet, and its former lagoon is now just above sea level and is being filled by alluvium. The Umuna lode also seems to fit in the pattern, and the lineaments deserve close attention in the exploration for gold, as they may guide and concentrate activities along lines of structural weakness which are logical structural traps for the mineralization.

GEOLOGICAL HISTORY

Since the relationship between the higher-grade and the lower-grade metamorphics is still problematical, the two regions will be dealt with separately.

In the area now occupied by the higher-grade metamorphics, the first stages of deposition were characterized by basic volcanism and plutonism, later followed by deposition of clays and silts with occasional tuff beds and flows. These deposits were deeply buried and regionally metamorphosed; subsequently deformation took place, accompanied by local migmatization and intrusion of trodhjemite, still under deep-seated conditions. In a somewhat later stage, after the conditions for regional metamorphism had largely disappeared, lamprophyric and acidic dykes were injected.

In the eastern regions, a period of basic volcanism was succeeded, and perhaps also preceded, by a period of deposition of dark organic muds and silts, starting of with the formation of limestone banks, possibly as coral reefs or other organic structures. These volcanic and sedimentary rocks subsided and were transformed by regional metamorphism into phyllites and schists, with accompanying faulting and folding. Probably in the later stages of deformation, and after the regional metamorphism, the porphyry masses and dykes were emplaced, with accompanying gold and sulphide mineralization.

The lower-grade and the higher-grade metamorphics were then raised above sea level and eroded. In Tertiary times the outlines of the island became roughly defined, and fringing reefs formed in places. Continuing emergence seems to have been much stronger in the south than in the north, with the result that coral reefs (which continued to develop into Quaternary times) were raised, in stages, to a considerable height in the south, while Miocene shallow-water sediments and volcanics were deposited in the north. Andesitic and trachytic lavas and tuffs were laid down over the eastern part of east Misima, whereas farther west coarse clastic sediments and conglomerates were deposited. Finally, the emergence which began on the south coast extended to the north and both tertiary beds and quaternary coral reefs of the entire island were raised above sea level.

Faulting accompanied all these stages and lasted until most recent times, as is demonstrated in the formation of Bwagaoia harbour.

ECONOMIC GEOLOGY

Apart from one trial parcel of base metal sulphide ore, gold has been the only mineral mined on Misima, yielding silver as a by-product. Small quantities of lead, zinc, and copper sulphides occur but are not of economical interest.

History

Misima began its existence as a mining field in 1888, when alluvial gold was found and worked in Ginesia Creek and subsequently in other creeks. It was the first time gold was discovered in Papua.

In 1904 a prospector, R. Boyd, traced lode-quartz boulders in Cooktown Creek upstream to their origin and so located the first lode, which he called the Massive, now the central section of the Umuna lode.

A succession of syndicates and companies attempted the mining of the lode (see chart Table 2), but only a few of them were financially successful. The mine was in a state of healthy production, the monthly output was continuously increasing and record production figures were being obtained when World War II forced it to close. After the war an attempt to re-open the mine failed, and the workings have since been abandoned.

During the successful mining of this central section of the Umuna lode other companies were active on the southern and northern sections, at Kulumalia and Mount Sisa respectively, but production remained far below expectations, owing partly to operational difficulties.

Other lodes found on the island are smaller and less well-defined. The Quartz Mountain lodes are the best known among these. Production here was negligible.

After the war the only production of gold came from a few scattered localities where the metal was mined for short periods for a yield of 2,000 fine ounces at the most; these were at Mararoa, the Scottish Queen, and the Double Chance. Of these, the Double Chance is the latest find, and was still being worked in 1959 by its discoverer, Mr. H. Gladstone.

The estimated total production of gold from the lodes and alluvial deposits of Misima Island is of the order of 236,000 to 239,000 ounces (Davies, 1959), of which at least 114,000 ounces were obtained from the central section of the Umuna lode.

<u>The deposits</u>

<u>Alluvial workings</u> - Up to 1904, alluvial deposits were the only source of Misima's gold. The best known creeks were the Ginesia, Ara, Ingubinaina, Inhabit, and Maika Creeks and the two top branches of Kobel Creek, but some gold was found in nearly all creeks on eastern Misima.

The largest known, tested deposit is on Tauhik Creek, near Quartz Mountain. The allivium here was drilled and sampled in 1939, and the reserves were calculated at about 1½ million cubic yards of wash carrying 10.5 grain per cubic yard. Approximately 80% of this gold is very fine, and difficult to recover. Dredging was not considered practicable because of the scattered occurrence and the small size of the separate sections and the deepness of the ground (Donaldson, 1939).

The total production of alluvial gold on Misima is given as roughly 80,000 to 100,000 ounces, but much gold may not have been officially recorded. A few ounces of gold per year are still being won from several creeks by natives.

Potential deposits may exist at the mouths of the gold bearing Ingubinaina and Ginesia Creeks; these swampy flats have never been tested, although their areas are larger than the Tauhik area.

<u>The lodes</u> - The known areas of lode mineralization are: the Umuna line of lodes, the Quartz Mountain area, and the Ingubinaina Creek area. There is evidence that further lodes may be hidden under the decomposed rock mantle. Most of the workings are collapsed and inaccessible at present, with the exception of a few adits such as the No.7 level adit at Umuna and the Waterfall adit at Kulumalia. (Fig.13)

A. THE UMUNA LINE OF LODES

This line strikes north-north-west from Kulumalia via Umuna to Mount Sisa over a distance of about 1½ miles, and perhaps continues for another 2½ miles to the vicinity of Ara Creek. The known portion, between Kulumalia and Mount Sisa, is well-defined. Its continuation to the north-north-west is inferred only from a number of old leases situated near Ara Creek, some of which reportedly have shown good gold values in lode material similar to that of the Umuna lode sensu stricto.

The known portion of the Umuna lode follows a prominent ridge and is sub-divided into three sections: a central section at Umuna, a northern section at Mount Sisa, and a southern section at Kulumalia. The lode is best defined in the central section; in the other two the lode seems to branch and weaken. The central section has also shown the highest values and has produced the bulk of the gold.

(a) The central or Umuna section.

The lode is not well known geologically as the mining companies did not employ qualified geologists and workings have now mostly collapsed. According to Stanley (1915) the lode consists of '...two apparent walls which, in reality, represent two reversed faults, highly brecciated...'. Haddon King et al (1949) described the lode as '...a fault breccia with quartz, soft pug, and rocky gangue derived from the schists and porphyry...'. At Umuna the fault dips steeply to the west. Boulders of a sugary, vuggy, occasionally banded, white or yellow quartz mark the trend of the lode at the surface. Nevertheless the lode is not strictly a quartz reef, but is a shear zone traversed by veins and stringers of quartz.

According to Palmer (1959), the main ore body, in which gold values are erratic and very unevenly distributed, is enveloped in a halo of very low-grade mineralization with a maximum width of 250 feet.

Only the oxidised zone of the lode has been worked: this could be done cheaply because of the softness of the rock, the easy-milling character of the ore, the cheap labour, and the fact that no expensive winzing and raising was required. Access to the lode was obtained by adits driven into the hill side. Seven levels were developed, mainly by Block 10 Misima Gold Mines, N.L. (1914-1922), and by Cuthbert's Misima Gold Mine Ltd. (1935-1942), which together produced 97% of the recorded total production of about 114,000 fine ounces. (Table 2). This yield came from some 376,000 tons of ore, extracted mainly from the No.5 and No. 7 levels, and with a recovery grade averaging 6 dwts per ton (Palmer,1959). A maximum length of 4,000 feet was developed to a maximum depth of 600 feet; those portions of the load extracted averaged 15 feet in width with a maximum width of 30 feet. The part of the various companies in the production is shown on the chart, (TABLE 2).

Below the bottom level (No.7 level) the primary sulphide zone gradually makes its appearance in the form of patches of semi-oxidized sulphides of lead, zinc, and some copper. The possible value of the sulphides was realized by mine managers since 1937, but no exploration in depth was undertaken, undoubtedly because the easy gold in the oxidized zone was by no means exhausted. After the war Cuthbert's Misima Gold Mine Ltd., during an effort to re-open the mine, attempted to test the primary zone by means of three D.D. holes, but met with little success because of very poor core recovery and failure to reach targets owing to collapse of the holes in the soft country rock.

Reserves in the oxidized zone have been estimated at approximately 270,000 tons by King et al (1949) and at 400,000 tons by Palmer (1957). These estimates include the 'probable' and 'possible' reserves. Few, if any, assay and survey records exist; however, 33 samples from the No.6 and 7 levels, though not considered representative, gave an average of 2.5 dwt of gold per ton (with 0.6 oz. of silver, 0.3% of lead, and 0.4% of zinc), and King therefore feared that much of the ore reserves may have a lower grade than the ore previously worked. Depth and tenor of the primary zone are virtually unknown factors, and it is impossible to give even a rough estimate of any possible reserves. On production figures, gold values have not declined in depth, but it must be said that the bottom level is still mainly in the oxidized zone where secondary enrichment of the gold may have taken place, and gold values may therefore decrease to some extent in the actual sulphide zone. The only figures on the tenor of the ore in the sulphide zone may be obtained from two assays: one is a bulk assay of a 52-ton parcel of semi-oxidised ore which in 1952 was extracted from the bottom level by two prospectors and consigned overseas, and which showed the following values:

Au 18.5 dwts per ton, Ag 3.0 oz per ton, Pb 20.2%, Zn 36.1%.

The other assay was of a sample handpicked from a dump of high-grade sulphide ore near the portal of a drainage tunnel; it gave the following results:

Au 3.6 dwts per ton, Ag 3.0 oz per ton, Pb 23%, Zn 25.5%, Cu 0.56%.

(b) The northern section near Mount Sisa.

The lode here is not so clearly expressed as at Umuna, and cross lodes are probably present, as for instance at Mararoa. There is even some doubt whether the lode worked by Goldmines of Papua Ltd. was the main branch of the Umuna lode. After a five year period of testing and development work, the production of 8,500 ounces of fine gold and 24,000 ounces of silver, obtained from about 40,000 tons of ore in 1938-1939, remained below expectation, notwithstanding the fact that the mine was modern and well equipped, and assay results appeared to be satisfactory. .. strong discrepancy between assay values and recovery grade has never been fully explained (tailing assays showed that most of the gold should have been recovered), but mining Warden's reports suggest that theft may have been one of the reasons. The mine was closed in 1940.

A smaller lode, developed west of the main lode, differed in that it had a high proportion of calcite.

The only other production in the northern sector came from Mararoa, where Mararoa Goldmines N.L. extracted some 150 oz in the post-war period of 1947-1948; and from the Scottish Queen nearby, where H. Gladstone, its discoverer (1953), drained a small lake to expose the lode and produced about 1,225 fine ounces from 1,200 tons of ore within 22 months. Good values occurred in this deposit: the warden's reports mention monthly returns of, for example, 95 ounces from 60 tons of ore, and 40 ounces from another 60 tons of ore. Gladstone abandoned the mine when the gold values dropped below 5 dwts per ton (Palmer, 1957). The Scottish Queen is now completely overgrown, but Davies (1959) states that the gold occurred in a shallow-dipping band of grey pug probably representing a fault zone. Palmer (1957) suggests that the orebody may have a pipe form, presumably at the intersection of two planes of weakness.

Good values were reported elsewhere in the northern section of the Umuna lode and its possible north-western extension. A very rich find was made by A. Alexander in 1941 on leases abandoned by Goldmines of Papua Ltd. One parcel was said to assay 44 ounces per ton, and a check sample confirmed 5 ounces per ton (Warden's Reports). Apparently the find was a small, rich pocket only, and nothing more has been heard of it.

Farther north, near Ara Creek, and more or less on the projected strike of the Umuna lode, some good gold values were obtained in 1939 from costeans and adits on leases held by Misima North Gold Mines. Donaldson reported 24 dwts over a width of 18 feet, and 12.9 dwts over a width of 23 feet, in two lodes 12 feet apart, and estimated that 75,000 tons with an average grade of 6 dwts per ton were present to a depth of 80 feet below the surface (King et al, 1949). However, no attempts were made to develop and produce this ore.

c) The southern or Kulumalia section.

The two mining companies active in this area were the Misima Gold Reefs (New Guinea) N.L. under management of Major Stuart Love, and Gordon's Misima Company, which took over in 1940. Three main lodes and at least five other lodes were reported from the area (Palmer, 1957). The main lode is a branch of the Umuna lode.

From the available reports no reliable estimate can be made of the value of the lodes. In 1934 the average value was "established" at about 9 dwts per ton; in 1936 the ore reserves were estimated to be some 52,000 tons with an average grade of 4.8 dwts per ton (Stuart Love, 1936); and in 1938 these estimates were reduced to about 40,000 tons of "payable ore" - a discouraging conclusion after the years of extensive development work. Nevertheless the company was ready to start production when war intervened in 1942. After the war, H. Gladstone milled about 150 tons of the better ore from the area (Davies, 1959), but when production did not confirm the reported assays he abandoned the project.

B. THE QUARTZ MOUNTAIN AREA

The Quartz Mountain area is situated about 5 miles west of Bwagaoia and 1½ mile south-west of Umuna. Robert Boyd was again the first to take out leases here in 1904, the year in which he discovered the Umuna lode.

According to Donaldson (1939) the mineralization follows subordinate tectonic lines but its pattern has been obscured by slip and creep of the ore down the steep hill sides. Six or more lodes have been found within an area of about ¾ square mile. They are similar to those at Umuna, and are characterised by drusy, banded quartz, with much earthy manganiferous material in places. Some lodes are in leached, honey-combed and partly silicified limestone. Pyrite, galena, sphalerite and some chalcopyrite are disseminated throughout the quartz matrix and occur locally in the limestone. There was little or no production, owing to the generally low values encountered. In 1934 Quartz Mountain (Papua) Ltd., a New Zealand company, took over the leases, and started to build roads, bring in machinery, and to construct a mill, all before any values were ascertained or an estimate of reserves was made. Not surprisingly the only production (in 1937) was 55 ounces of gold from 1,000 tons of ore, which corresponded to a recovery grade of about 1.1 dwt per ton, against an assay value of about 6 dwts per ton.

In 1938 C.H. Donaldson was employed as manager. He carried out a sampling and assaying programme, but was disappointed with the results, as he found that good ore values were very patchy and rapidly petered out with depth (Donaldson, 1939). Low values were present over large areas.

At present the only possibilities appear to be in the former Quartz Mountain lease, containing the "Open Cut" and the No.4 or Waipuna lode, and in the Quartz Mountain Extended (see plan in Davies, 1959). Values here in places exceed 10 dwts per ton over short stretches.

The "Open Cut" is an area of quartz boulders set in clay, the boulders assaying about 5.2 dwts per ton over a length of 300 feet, the clay matrix averaging about 1 dwt per ton.

In the No.2 cross-cut, 300 feet to the south-west of the Open Cut, 19 feet of material reportedly assaying 12.6 dwts per ton were intersected.

A low cliff of vuggy quartz to the west of the cross-cut, representing a fault zone 6 feet wide, was reported to contain a stretch of 40 feet averaging 15.6 dwts per ton. Check samples taken from this cliff in 1958 gave an average of 8.1 dwts per ton (Davies, 1959).

After the war, Quartz Investment Ltd. attempted to start production from the Open Cut, but before the mill was in full production a cyclone, in 1951, badly damaged the plant, and the project was abandoned for lack of capital.

C. THE INGUBINAINA CREEK AREA

Several small prospects and leases were located along Ingubinaina Creek or in its vicinity, among which were Grant's Claim, Well's Tunnel, and Mount Sisa West. A new find in this region is the Double Chance, discovered by H. Gladstone in 1957 and still being worked in 1959.

The Grant's Claimlode consists of quartzose ironstone containing pyrite, magnetite, and probably gold (Stanley, 1915). Boulders of ironstone are also concentrated in the upper reaches of Ingubinaina Creek and Cooktown Creek (Fig.14); some are stained with green and bluish green secondary copper minerals such as malachite and probably chrysocolla. It is possible that the ironstone lode is responsible for the magnetic anomalies in this area, mentioned by Stanley (1915).

Well's Tunnel was driven for roughly 70 feet through strongly quartz-veined dark phyllite and micaceous schist intruded by feldspar porphyry.

The Mount Sisa West lease is situated along the Gubinaina Creek, a tributary of Ingubinaina Creek. It has a few small, irregular lode outcrops which consist mainly of a fine, black, gritty quartz.

Production figures for these old prospects and workings are not known but are probably very small.

The Double Chance was the only gold producer in 1959, and is fully described by Davies (1959). It is an open cut situated on a hill side above Ingubinaina Creek, on the northern limb of an east-plunging anticline (Fig.10). The open cut trends parallel to the strike of the surrounding schists in an east-north-east direction, is 12 to 15 feet wide, and at least 120 feet long. It is located approximately at the boundary of underlying greenschist and overlying phyllite and micaceous schist; the walls are defined by vertical shears, and the entrance to the cut is marked by a fault striking 135° magnetic (Fig.9). The gold is irregularly concentrated, partly as wire gold, in steep north-west trending fractures or leaders which are quartz-filled or coated with iron and manganese oxides. The high gold values occur in the portion contained between the two vertical shears; beyond these the grade is reported as uneconomic. The material mined is a weathered feldspathic schist, possibly a sheared greenschist. The values in the intervals between the fractures are very low-grade. To the north-east the number and gold content of the fractures appear to decline rapidly. Gladstone sank a prospecting shaft here in 1959, but the higher values were not picked up again, perhaps because of a possible pitch of the ore-shoot to the east.

Production in a twelve month period (1957-1958) was about 230 fine ounces from some 2,400 tons of ore, corresponding to a recovery grade of almost 2 dwts per ton. It is not certain whether values improve with depth: Palmer reported a gradual increase from 2 to 7 dwts per ton, but according to Gladstone the values vary irregularly. In September, 1959, Gladstone produced roughly 6 to 8 ounces per week by deepening the open cut and treating the ore in a small three-head stamp battery. The gold is recovered by amalgamation.

Mineralization

The mineralogy of the deposits is fairly simple: gold occurs only in its native form, generally very fine-grained with local development of wire gold. The sulphides are mainly pyrite, galena, sphalerite, and some chalcopyrite. Secondary ore minerals observed or reported are: malachite and chrysocolla, pyromorphite, cerussite, and chromate of lead. Microscopical examination by Stillwell (1936) revealed some tetrahedrite, covellite, and chalcocite, the last two replacing galena and sphalerite. The gangue is, as a rule, composed of quartz together with altered and brecciated rock fragments; in the Mount Sisa sector calcite is present, and barytes occurs between Umuna and Mount Sisa. Manganese staining and iron compounds are common.

It is evident from the reports that the gold is very unevenly and erractically distributed throughout the orebodies, and that many rich patches are scattered within a wide zone of low-grade mineralization. Stanley (1915) noted that the best values at Umuna were found '...on the footwall side in the brecciated porphyry portions, in which much well-crystalline pyromorphite is found occurring in vugs with a little chromate of lead...'. At Kulumalia, Major Stuart Love (1936) reported that the best and most consistent values occur where the lode has been most heavily leached and altered.

The sulphides occur as scattered crystals and grains disseminated throughout the quartz lodes. In the Quartz Mountain area they are found at the surface as a sprinkling of pyrite, galena, sphalerite, and more rarely chalcopyrite, in the quartz veins and altered limestone. In the Umuna lode they are rarely visible at the surface, where they have been oxidized, but occur more in depth. The ore becomes richer with increasing depth, and locally in the bottom level galena and sphalerite may each constitute more than 20% of the ore, though restricted to small bodies only. The parcel of 52 tons of sulphide ore taken from the bottom level in 1952 (see page 21) was obtained from a lens tapering from 2 to 3 feet in the middle to 2 to 3 inches at the ends.
Loose boulders of base metal ore are known from the north-eastern slopes of Mount Sisa.

The lodes are epithermal, as is indicated by the presence of barytes, the very light honey colour of the sphalerite (pointing to low temperatures during crystallisation), and the boulders of saccharoidal, drusy, and vuggy, banded quartz.

No specific host rocks are known: gold occurs in brecciated porphyry as well as in sheared greenschist and graphitic phyllites and micaceous schists. It is striking, though, that all lode gold occurrences roughly follow the greenschist boundary. The Double Chance is right on the boundary (Fig.10), and the other prospects in the Ingubinaina Creek area are also very near the boundary. Greenschist outcrops are not far from the Quartz Mountain lodes. The Waterfall adit at Kulumalia passes through greenschist, and greenschist is known by drilling to underlie the Umuna workings at no great depth. Ara Creek and Ginesia Creek, where alluvial gold was abundant, both run through a greenschist region.

The lodes are all situated in a region where porphyry outcrops are large and abundant, probably the roof area of a large complex of intrusives with numerous roof pendants and dykes and irregular masses of porphyry. This is a common environment for gold deposits.

The common opinion of previous workers is that the feldspar porphyry has introduced the gold into the greenschist and sediments. However, the possibility of the greenschists being source beds at depth should not be excluded. Such an origin is proposed by Boyle (1959) for the Yellowknife gold deposit in Canada, where greenstone is overlain by sediments and is intruded by quartz-feldspar porphyry. Boyle calculated that the gold and other elements in the lode could have been derived from the sheared greenstone and that there is no need to call upon magmatic solutions from the outside. The intrusive porphyries merely served to induce a steep thermal gradient from which the elements migrated upwards by diffusion, to be precipitated in zones of dilatation such as shear zones. No chemical analyses have been made of Misima greenschists, but the concentration of the gold on or above the greenschist boundary in areas of intense porphyry intrusion could suggest that a process similar to that described by Boyle may have been active on Misima.

No gold has ever been found in the higher-grade metamorphics of western Misima, although prospectors were active along the north coast, and it appears that the gold is restricted to the lower-grade metamorphics of eastern Misima.

The question of secondary enrichment has received some attention, and all previous investigators agree that such enrichment of gold has probably taken place. They generally have in mind secondary solution enrichment, but residual surface enrichment must also be considered probable, particularly in the Quartz Mountain area.

The supposition of secondary solution enrichment is based on the observation that economic orebodies were rarely indicated by good values at the surface. Experiments have shown that gold is soluble in surface waters only in the presence of free chlorine, which can be produced by the interaction of sulphuric acid, sodium chloride, and manganese dioxide. On Misima, sulphuric acid is generated by the oxidation of pyrite, sodium chloride may have blown in from the sea, and manganese oxides are present. The chemical reactions involved are as follows:

$$MnO_2 + 2NaCl + 3H_2SO_4 \rightarrow MnSO_4 + 2NaHSO_4 + 2H_2O + 2\,Cl\ ;$$

$$3Cl + Au \rightarrow AuCl_3\ \text{(soluble)}.$$

The gold and manganese solutions will trickle downwards until a reducing environment is met, where excess acid is removed, such as would exist in the presence of carbonates, sulphides, or organic matter. Gold and manganese will then be reprecipitated. The acidity may also be reduced by kaolinisation of feldspars: this could serve as an explanation for the fact that the best gold values at Kulumalia were reported to occur there where the lode is most thoroughly leached and altered.

In the Quartz Mountain area the rare good values appear to peter out rapidly in depth, and quartz boulders are commonly richer in gold on the outside than in their centres (Donaldson, 1939) indicating residual enrichment. McKinstry (1955) mentions that enriched gold in an oxidized zone generally owes its value to the removal of other elements (residual enrichment), whereas secondary solution enrichment is usually a local process only and produces small rich seams and pockets rather than a well-defined zone of enrichment. In outcrops of the oxidized zone it is usually very difficult if not impossible to distinguish between residual or secondary solution enrichment and hypogenetic gold, since the metal everywhere occurs in its native form and other criteria are generally lacking.

Discussion

The only reason production on Misima terminated in 1942 was the intervention of war; the production curve in the years before shows a steady rise, with ever increasing monthly output, and it is evident that there was no question of exhaustion of the ore. (Fig.15).

A different matter is the grade of the ore. At Umuna, Block 10 Misima Gold Mines N.L. (1914-1922) worked ore with an average grade of 8 dwts per ton, whereas Cuthbert's Misima Company, which produced just before the war, averaged a recovery of 5.2 dwts per ton, and the tenor was slowly but steadily decreasing (Fig.15). According to Palmer (personal communication) this was caused by decreasing values in the lateral direction then followed by development work; values should remain constant vertically. However, vertical development would be accompanied by an increase in mining and treatment costs brought upon by more expensive development and the complexity of treatment of sulphide ore, and the cut-off grade for the primary zone would therefore be higher than for the oxidized zone.

That the grade of ore has always been dangerously low and near cut-off level is illustrated by the fact that most companies worked at a loss. Even the Block 10 Misima group, which, notwithstanding its comparatively high recovery grade of 8 dwts per ton, had to spend too much capital on the construction of a tramway and other non-productive development work. New Misima Goldmines Ltd. was the first company to make a profit, thanks mainly to a splendid team of men engaged, all at moderate wages (Warden's Report). Cuthbert's Misima was successful , mainly because it took over a going concern in which all non-productive development work had already been carried out. King et al (1949) point out that to start afresh now would involve the expenditure of much capital, more than is warranted in view of the low grade and the limited reserves.

Nevertheless, Palmer (1959) takes the view that modern techniques and machinery would largely off-set these difficulties, and that the increasing sulphide content in depth may make the base metals attractive as a by-product. Sufficiently large reserves in the primary zone and satisfactory tenor are required to counter-balance the high initial and mining costs.

The best site for test drilling of the primary zone would be the area where Cooktown Creek crosses the lode, as it is here that the highest consistent values have been found and the vertical distance to the primary sulphide zone is shortest, probably within 150 feet. To give an idea of the costs involved when serious attempts at exploration and development are made, it may be cited that after the war Cuthbert's Misima spent about £120,000 during its efforts to re-open the mine; included in this amount were £12,000 on the three D.D. holes (which had a total length of 1,883 feet), some £11,000 on the reconditioning of the mill, and £36,000 on new buildings, equipment, and power plant (King et al, 1949).

The question of secondary enrichment gold is of importance since much depends on it. If large scale enrichment has taken place in the Umuna lode, then the primary zone has not much chance as a gold prospect, as a decrease in average grade can be expected. And although no indication of a decline in gold values has been found in the bottom level of the mine, it must be noted that this level is still mainly in the oxidized zone. However, if base metal sulphides increase sufficiently in depth to make them a worthwhile by-product, the possibility of an economic prospect in depth at Umuna cannot be excluded. In the Quartz Mountain area residual enrichment seems to have predominated, and there is not much hope for a successful future of this region. Nor can it be expected that the base metals will increase in depth, as they occur here in their sulphide form at the surface and not much evidence of leaching can be seen.

The prospect that other lodes are hidden on the island is good. Evidence is furnished by the concentration of large boulders of yellow, Umuna-type lode quartz in the upper reaches of many creeks, most of which have yielded alluvial gold. In most of these creeks it is improbable, geographically, that the boulders were derived from the Umuna lode. One lode may be present just east of Ingubinaina Creek and stretch from near Bwagaoia in a north-westerly direction approximately parallel to the Umuna lode.* Stanley mentions the winning of gold from a deposit of quartz boulders in Gera Gera Creek, about 1 mile above Bwagaoia, which could be in line with this lode. The Double Chance might be an off-shoot deposit of the lode, and the alignment of Grant's Claim, Double Chance and various other smaller claims led Palmer also to the conclusion that a lode parallel to the Umuna lode might exist in this general area.

Another possible lode, crossing the Umuna lode at Mararoa in an east-north-easterly direction, can be traced at the surface by slipped pyritiferous rubble and boulders of quartz and ironstone, with copper staining in places.

Large concentrations of lode quartz boulders are also found in Ara Creek, where they may have been derived from a north-western extension of the Umuna lode. Ara Ck.

Many more creeks carry gold, but where accumulations of lode quartz are absent the gold is believed to be derived from a stockwork of thin leaders which do not attain lode proportions. This applies, for instance, to the small creeks west of the Quartz Mountain area.

One of the reasons why only the Umuna lode has been discovered so far may be that the lode is deeply cut by Cooktown Creek, and that such favourable circumstances do not seem to occur in the other possible lode areas.

* Since this report was written, Pacific Island Mines Ltd. reported that costeaning approximately along this line, north-north-west of the Double Chance has revealed manganese mineralization with gold values.

As enrichment has probably taken place on Misima, surface exploration by soil panning alone is not sufficient to locate these concealed lodes, because values encountered at the surface commonly bear no relationship to those found in depth. Other, more expensive means of detection will have to be employed eventually, such as geophysical and drilling methods.

A geophysical survey might be carried out, for instance, to determine location, extent, depth, and inclination of the lode which is thought to be present east of Ingubinaina Creek. It would first be necessary to test the practicability and suitability of the various methods, as there are some difficulties to cope with, such as the dense vegetation, the topographic relief, and the presence of graphitic schists which might interfere with the interpretations. Testing could well be done at the site of the known Umuna lode; if successful, the first target should be the hypothetical Ingubinaina lode, which has road access in its vicinity, is not far from Bwagaoia, and may be the mother lode of the Double Chance. If the presence of such a lode could be shown, it would then be necessary to ascertain its gold values, either by drilling or by tunnelling.

Conclusion and recommendations

The Quartz Mountain area is not considered a valuable gold or base metal prospect.

In the Umuna lode, the primary sulphide zone is unknown and it is not excluded that reserves are present of sufficient grade and volume to warrant mining in depth. The most favourable site for test drilling would be the area where Cooktown Creek crosses the lode.

The most favourable areas to prospect for gold are the areas bordering zones of greenschist in regions where porphyry outcrops are large and abundant.

It is recommended that geophysical methods should be tested and, if shown practicable, be employed in an attempt to locate other lodes which are thought to be concealed by overburden. The first target should be a north-west striking strip stretching from Bwagaoia just east of Ingubinaina Creek.

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TABLE 1

TABLE 1 : SUMMARY OF STRATIGRAPHY

AGE	FORMATION	MAP SYMBOL	THICKNESS	DESCRIPTION	DISTRIBUTION	REMARKS
QUATERNARY	Alluvium	Qa	-	Gravel deposits, sago swamps, thick soil cover	Locally on eastern Misima	Rare
	Raised coral reefs	Q1	-	Organic reefs (corals, algae, bryozoa), with locally impure bedded limestone, sandy limestone, and gravel patches.	Benches along the southern and eastern coasts.	Raised to a maximum height of 1400 feet above sea level.
TERTIARY (MIOCENE)	LIAK CONGLOMERATE	Tml	700 ft +	Coarse pebble conglomerate, with pebbles of metamorphic basement.	Area of 3 square miles south-east of Liak.	Three pene-contemporaneous facies.
	GULEWA FORMATION	Tmg	1300 to 1500 ft	Conglomerate, sandstone, greywacke, siltstone, mudstone, pebbly sandstone, intra-formational breccia, tuffaceous and calcareous beds, and a limestone member. (100 feet thick).	Between Guntuka and Liak to a depth of about 2 miles inland.	
	KOBEL CREEK VOLCANICS	Tmk	1000 feet	Agglomerate, volcanic conglomerate, flows, tuffs, ash beds. Composition andesitic and trachytic; some basalt.	Several isolated areas of outcrop: south of Guntuka-Kalotawa, on either side of lower Ara Creek, and between Kulumalia and Lapipai.	
ANGULAR UNCONFORMITY						
Intrusion of dacitic and andesitic porphyries						
PALAEOZOIC OR MESOZOIC ? (? May be pene-contemporaneous)	UMUNA SCHIST	M/Pzu	?	Dark graphitic and micaceous schists and phyllites, banded schist, quartzose schist. Intergrading.	Main rock type on eastern Misima	Overlying St. Patrick Limestone. (Lower-grade metamorphics)
	ST. PATRICK LIMESTONE	M/Pzs	0 - 100 feet	White and dark marly and impure limestone, in places with silica bands (recrystallized chert?) and lenses and bands of sandy limestone.	Sporadic. Main outcrop in Ara Creek.	Overlying Ara Creek Greenschist (Lower-grade metamorphics)
	ARA CREEK GREENSCHIST	M/Pzg	at least 300 to 500 ft	Massive green rocks composed of albite, chlorite, epidote, and actinolite. Volcanic origin.	Main outcrop along Ara Creek and region east of Umuna.	Schistosity not pronounced. Possibly underlain by schists of Umuna type. (Lower-grade metamorphics)
-?-?-?- possible unconformity -?-?-?-						
Intrusion of Trodhjemite, followed by basic and acid dykes						
	OLATAU GNEISS	M/Pzo	at least 2500 feet	Various gneisses and schists composed of quartz, plagioclase, muscovite, biotite, hornblende, garnet, some staurolite and cyanite.	Main part of the mountain range of western Misima.	Overlying the Lalama Amphibolite. (Higher-grade metamorphics)
	LALAMA AMPHIBOLITE	M/Pzl	?	Massive plagioclase amphibolite, schistose and foliated amphibolite, and banded amphibolite or quartz-plagioclase-hornblende-epidote gneiss. Locally migmatitic. Predominantly igneous and tuffaceous origin.	Mainly along north coast between Liak and Ewena, and around Bwagabwaga.	(Higher-grade metamorphics)
Intrusion of hornblendite???						

TABLE 2.

TABLE 2 : CHART - THE UMUNA LODE : MINING COMPANIES AND PRODUCTION FIGURES

Period	Mining Company	Tons of ore	Fine ounces of gold	Average grade in cwts/ton	NORTHERN SECTION AT MT. SISA	SOUTHERN SECTION AT KULUMALIA
	CENTRAL SECTION AT UMUNA					
	TOTAL:	378,395	114,297	6.0		
1949	Attempt to re-open the mine.	2,117	351	3.3		
1942					1940	Gordon's Misima Company.
					1940	
	Cuthbert's Misima Goldmine Ltd.	199,474	52,346	5.2	1940 Gold Mines of Papua Ltd.	Misima Gold Reefs (N.G.) N.L.
1935					1933	1935
	New Misima Goldmines Ltd.	75,167	20,900	5.5	8,500 fine ounces of gold from 40,000 tons of ore.	
1928	Misima Goldmining Company, and various other syndicates.	?	13,000 ?	?		
1922	Block 10 Misima Gold Mines, N.L.	101,637	40,700	8.0		
1914	St. Aignan Mining Company.	?	?	?		

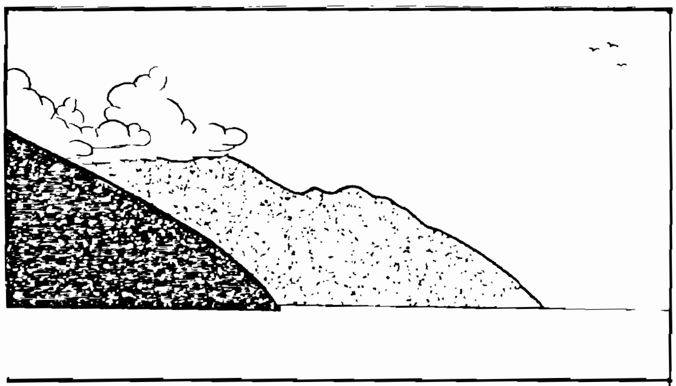

FIGURE 1 : CONVEX PROFILE OF NORTH-WEST MISIMA LOOKING WEST.

Figure 2 : Quartz bands (? recrystallised chert) in metamorphic limestone ; 1 mile north of Eiaus

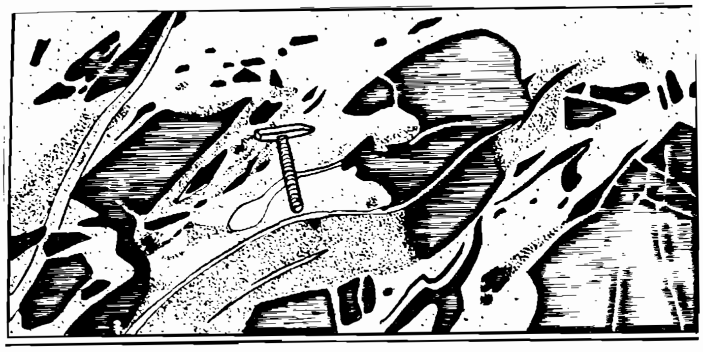

FIGURE 3 : MIGMATITE ; REMNANTS OF AMPHIBOLITE IN INTRUSIVE HYBRID GNEISS.

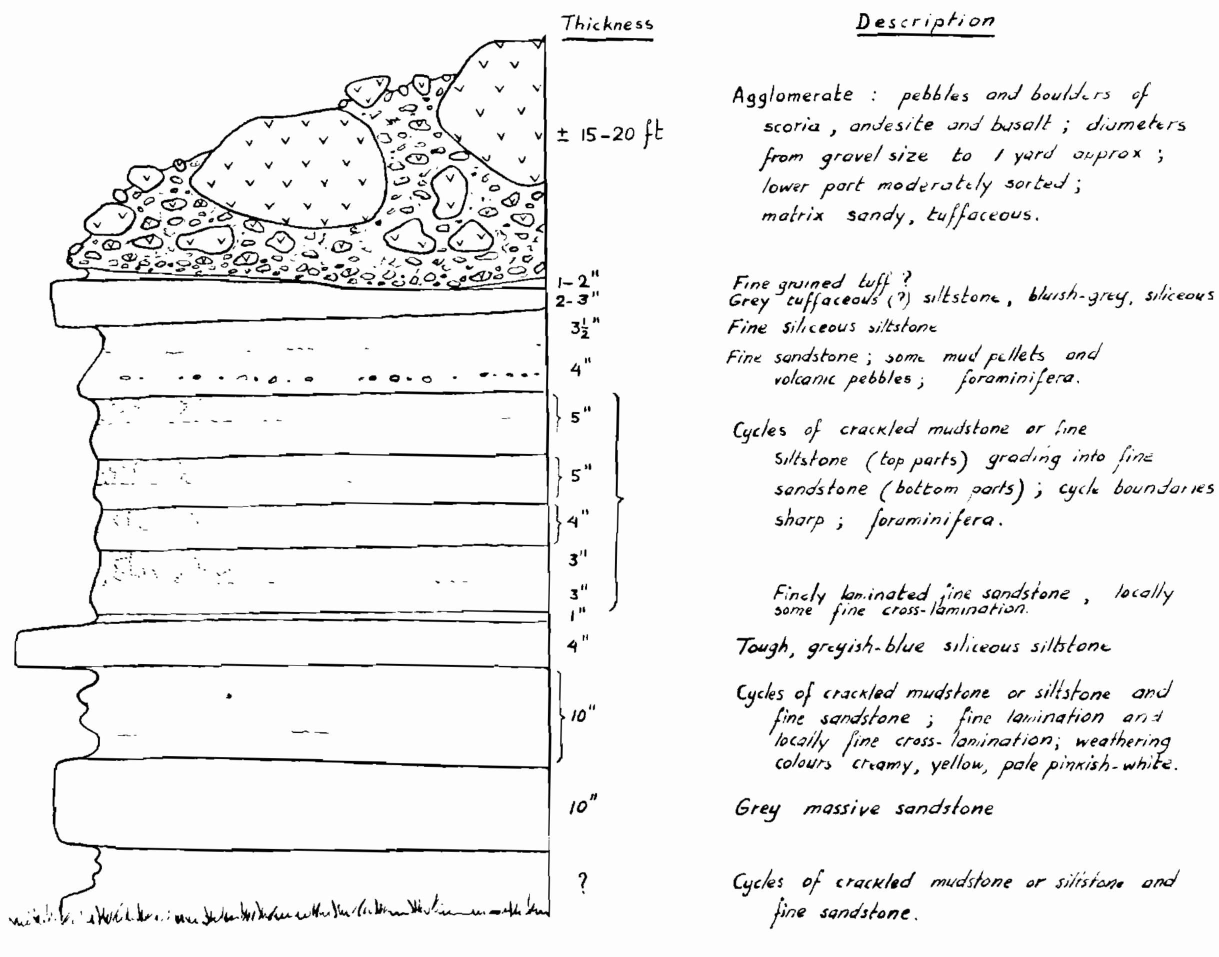

Figure 4 : Typical section of well-bedded Tertiary sediments along the shore 500 yards west of Gulewa.

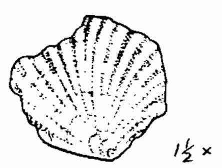

Figure 6 : External cast of Tertiary Pelecypod ; approx. 1 mile south of Gulewa

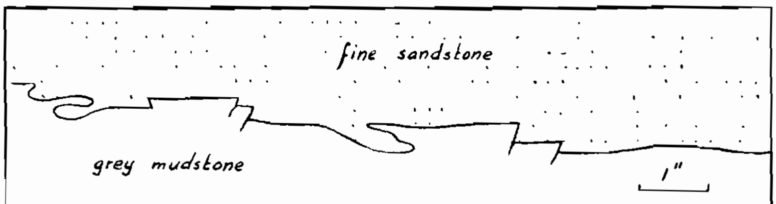

Figure 5 : Bedding structure in Tertiary sediments : section through load cast structure.

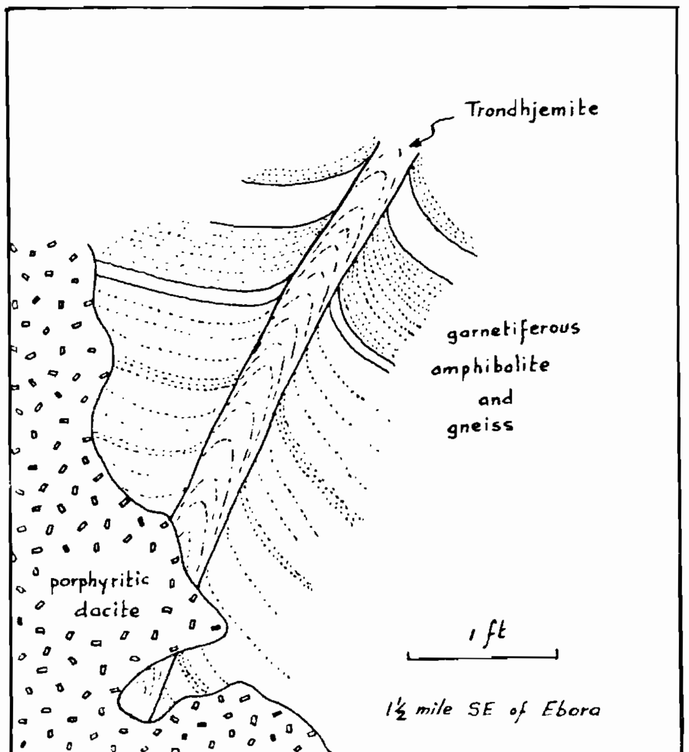

FIGURE 7. OUTCROP SHOWING AGE RELATIONSHIPS BETWEEN AMPHIBOLITE & GNEISS, TRONDHJEMITE, AND PORPHYRITIC DACITE

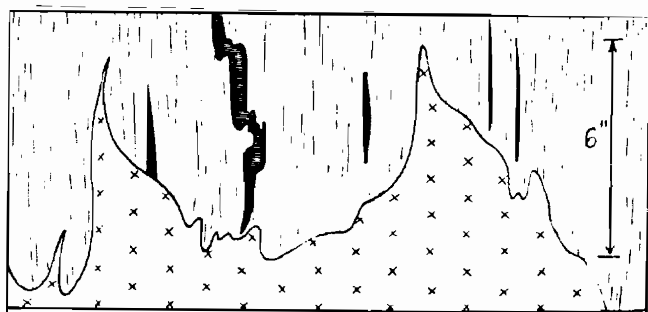

Figure 8: Feldspar porphyry intruding quartz veined phyllite, bridge in Cuthbert's Creek

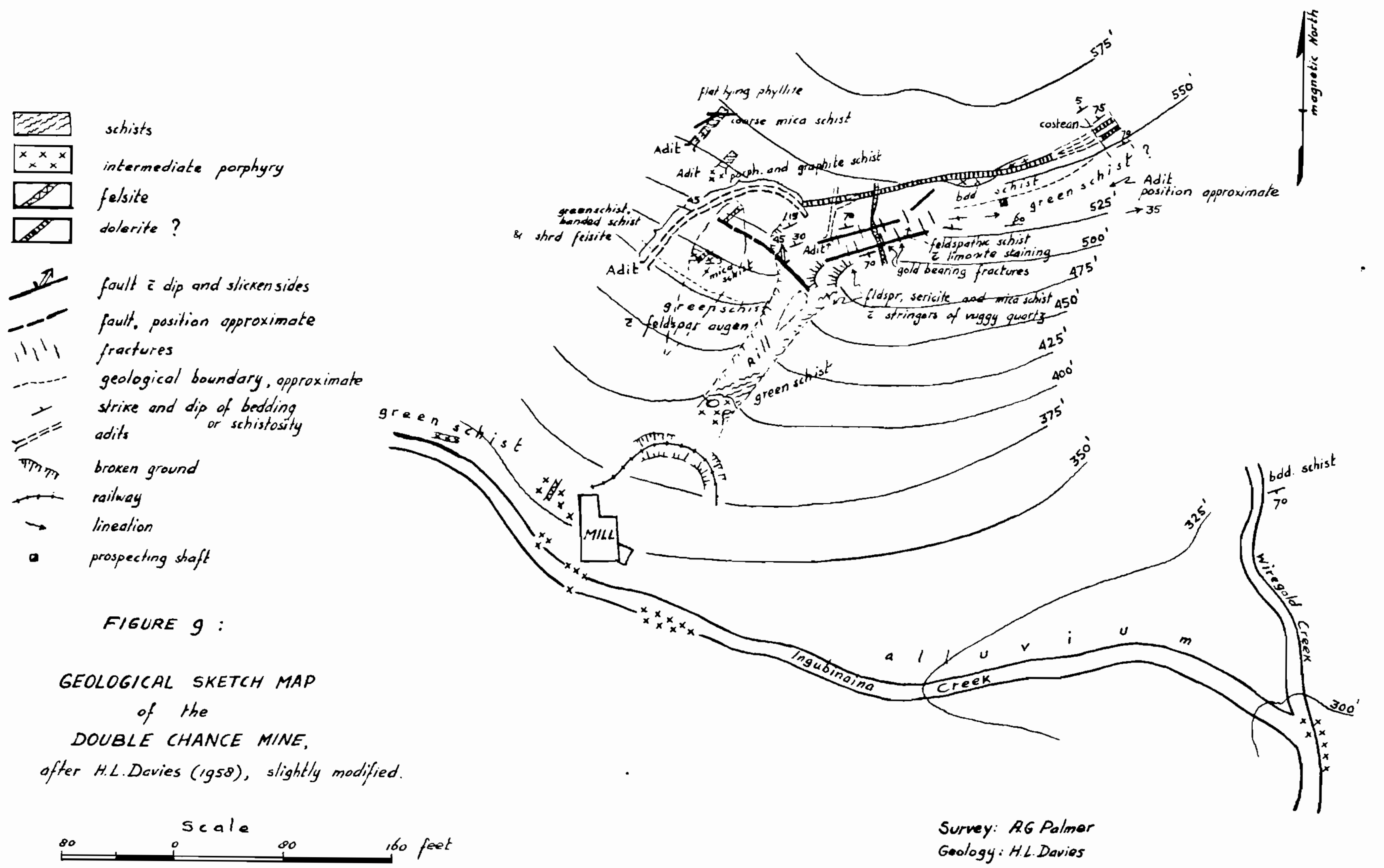

FIGURE 9:

GEOLOGICAL SKETCH MAP of the DOUBLE CHANCE MINE, after H.L. Davies (1958), slightly modified.

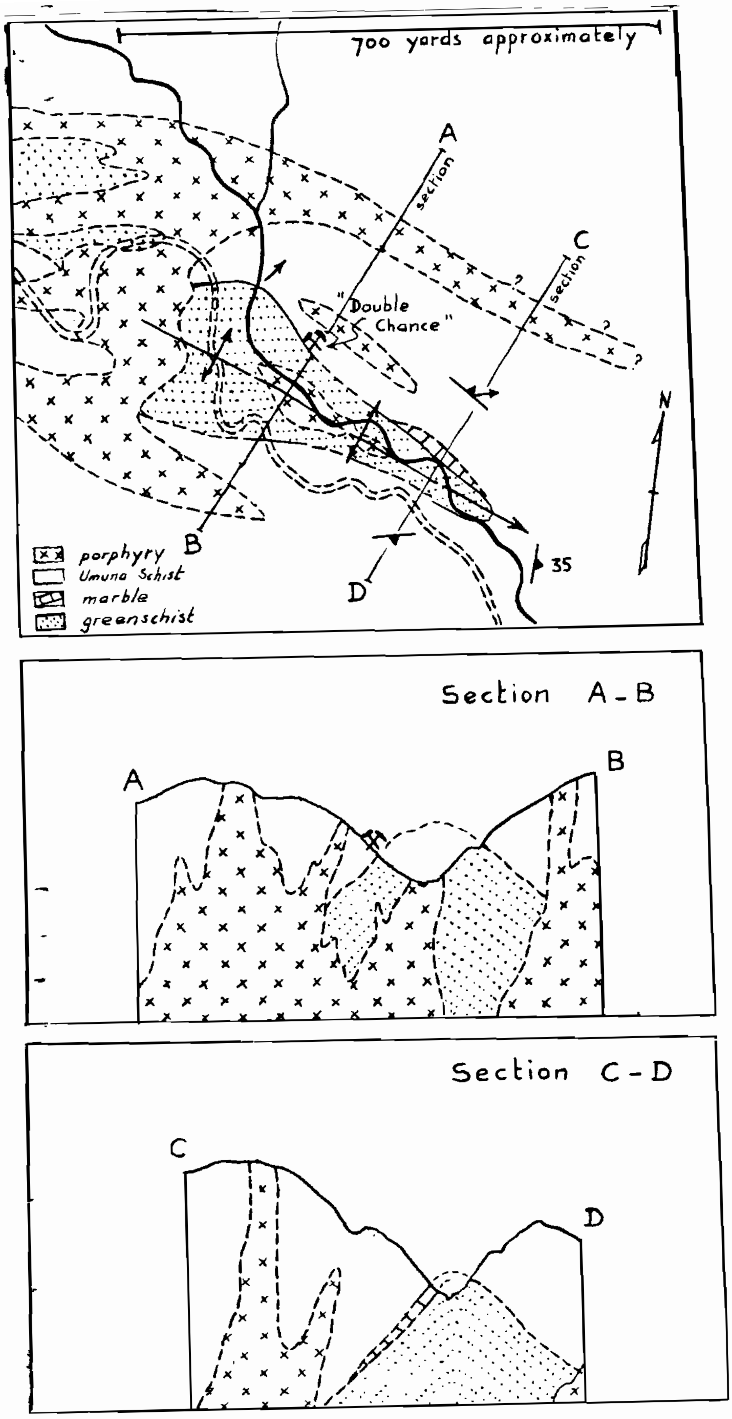

FIGURE 10 : THE DOUBLE CHANCE ANTICLINE
(geology simplified)
vertical scale = horizontal scale

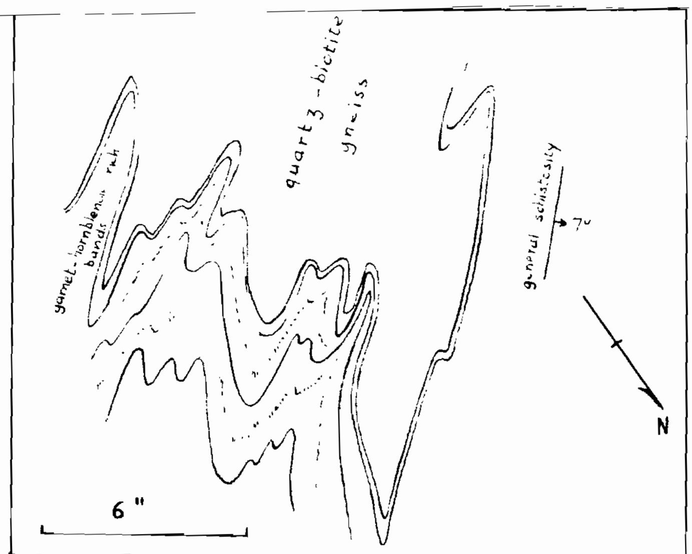

Figure 11 – Plastic minor folding in gneiss; 2 miles south-west of Lalama

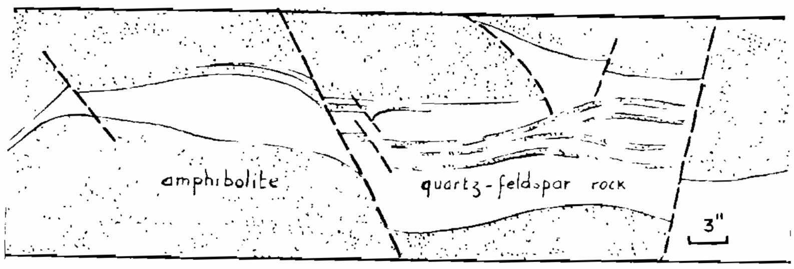

Figure 12: Small-scale faulting in amphibolite; Ebora

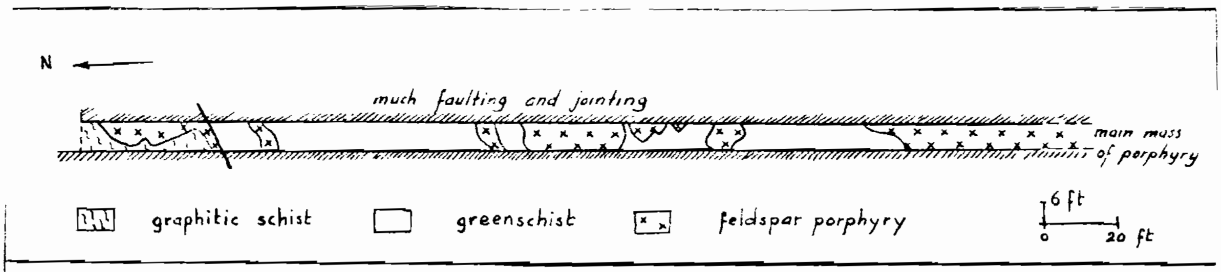

Figure 13. Section of eastwall of Waterfall Adit, Kulumalia.

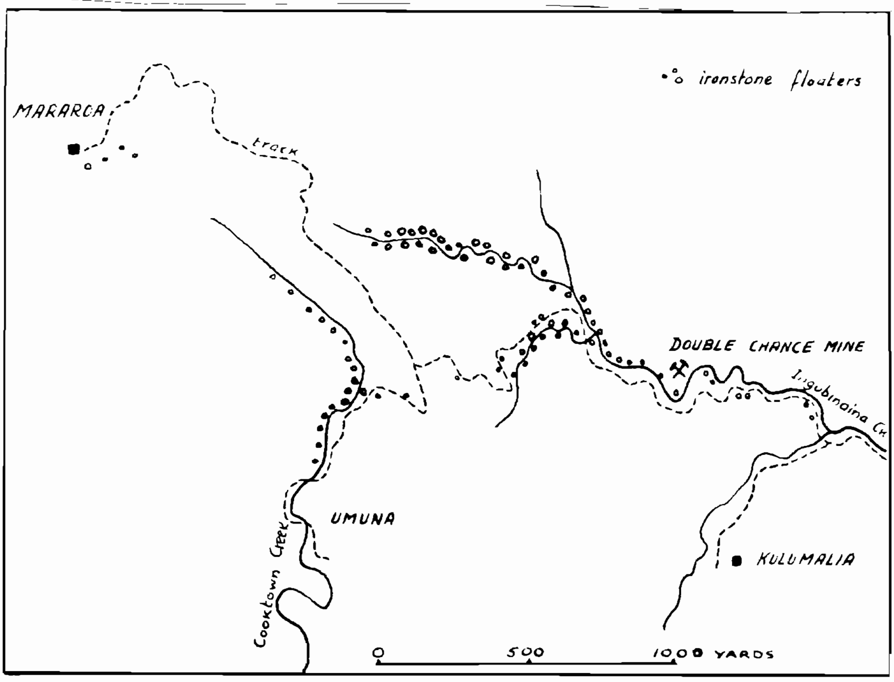

FIGURE 14 : CONCENTRATION OF MAGNETIC IRONSTONE FLOATERS AND BOULDERS in the Mararoa - Kulumalia area.

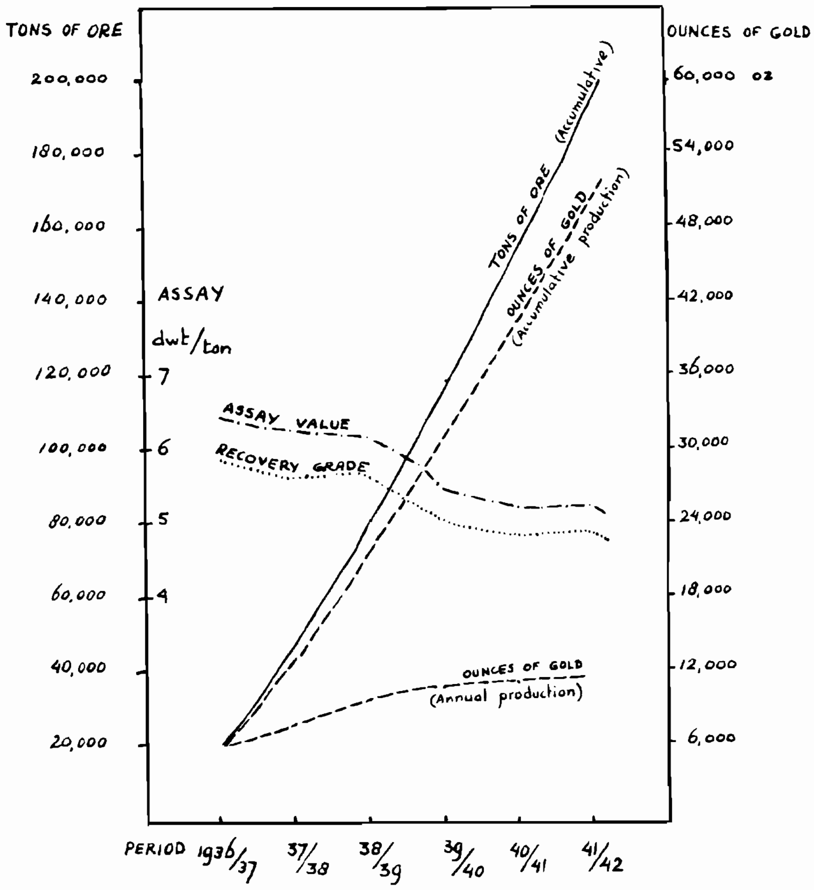

FIGURE 15 - PRODUCTION AND AVERAGE ASSAY VALUES, CUTHBERT'S MISIMA GOLDMINE LTD.

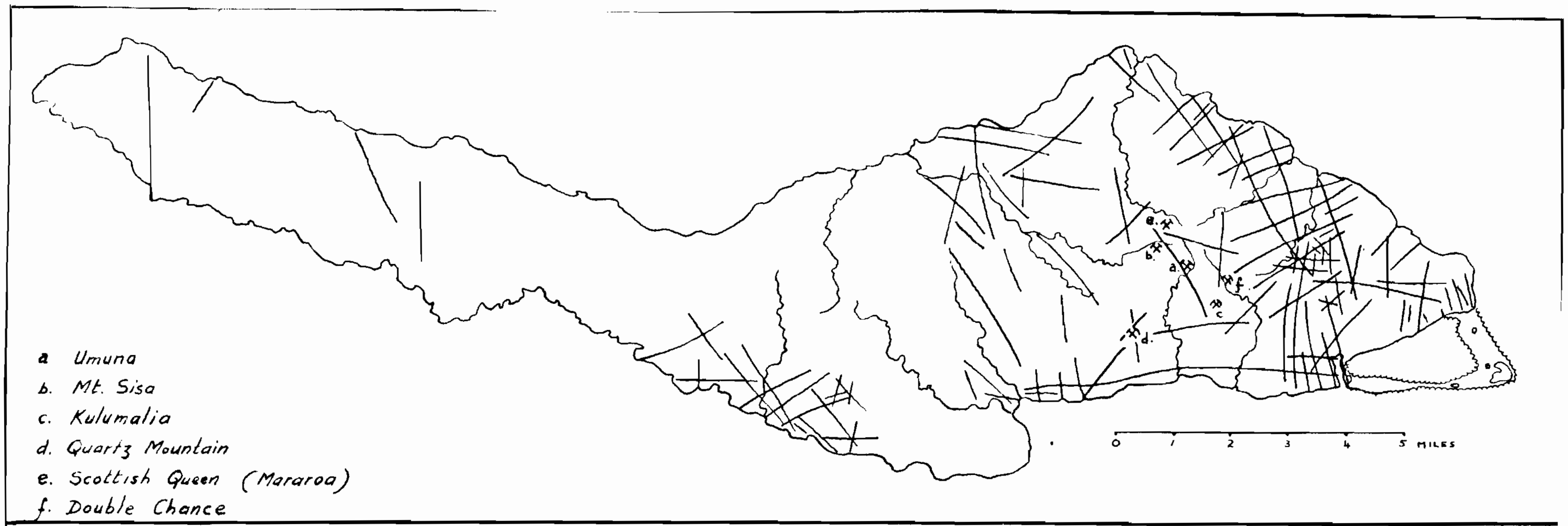

FIGURE 16 : LINEAMENT PATTERN DERIVED FROM AIR PHOTO INTERPRETATION ; and LOCATION OF MINING CENTRES.

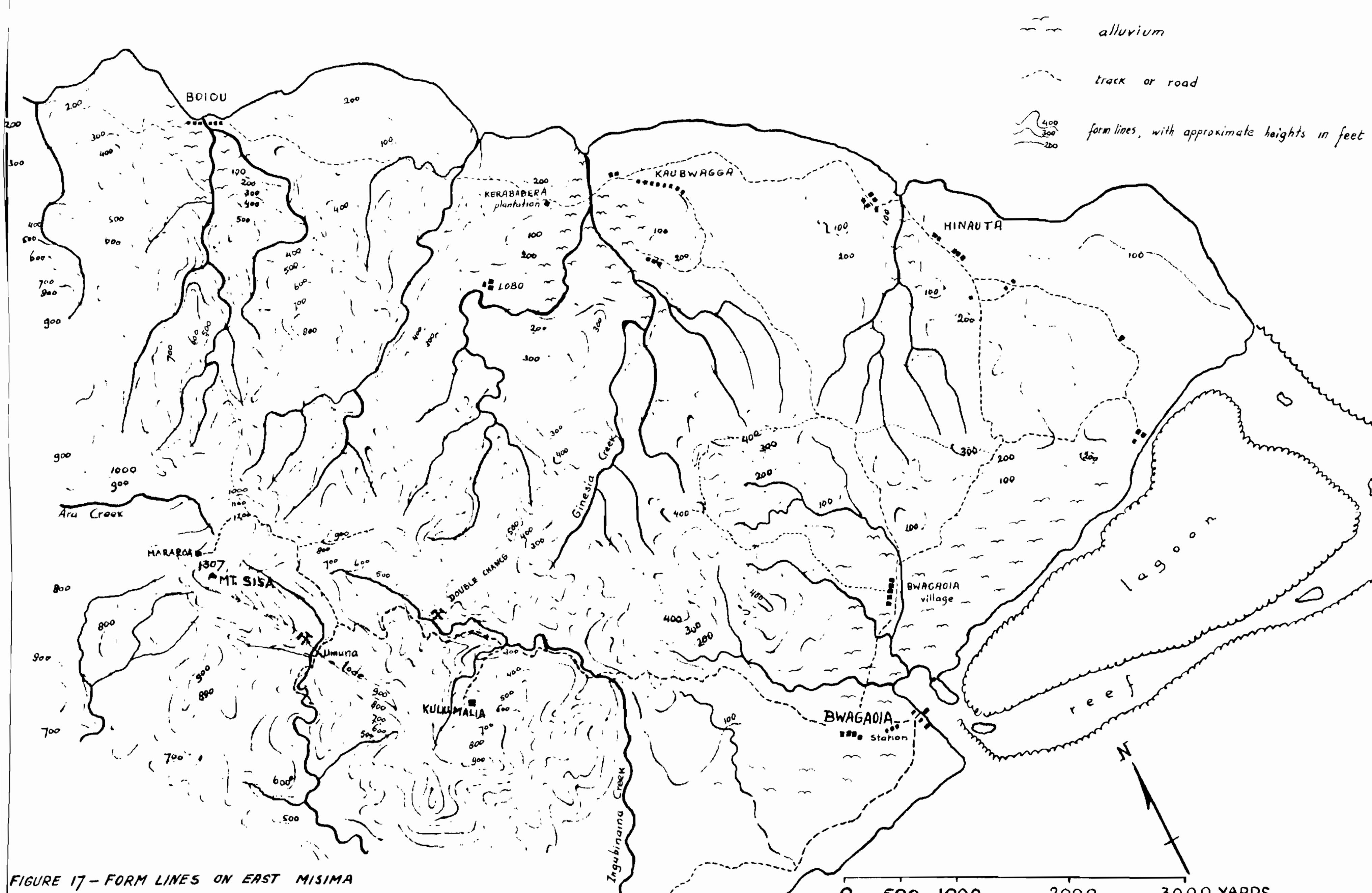

FIGURE 17 – FORM LINES ON EAST MISIMA

PHOTO No.1 - Part of the south coast, looking west. Rugged topography and benches of raised coral reef (a to f). Village in foreground is Patnai.

PHOTO No.2 - Rokia Point, consisting of raised Quaternary coral reef. Height roughly 300 feet above sea level.

PHOTO No.3 - Banded amphibolite or quartz-plagioclase-hornblende-epidote gneiss, dipping 25 - 30 north. Outcrop 200 feet west of Lalama, north coast.

PHOTO No.4 - Banded amphibolite or quartz-plagioclase-hornblende-epidote gneiss, with two inclusions of coarse-grained hornblendite. Outcrop 200 feet west of Lalama, north coast.

PHOTO No.5 - Minor disturbances in amphibolite and gneiss.
South coast, 1½ mile south-east of Ebora.

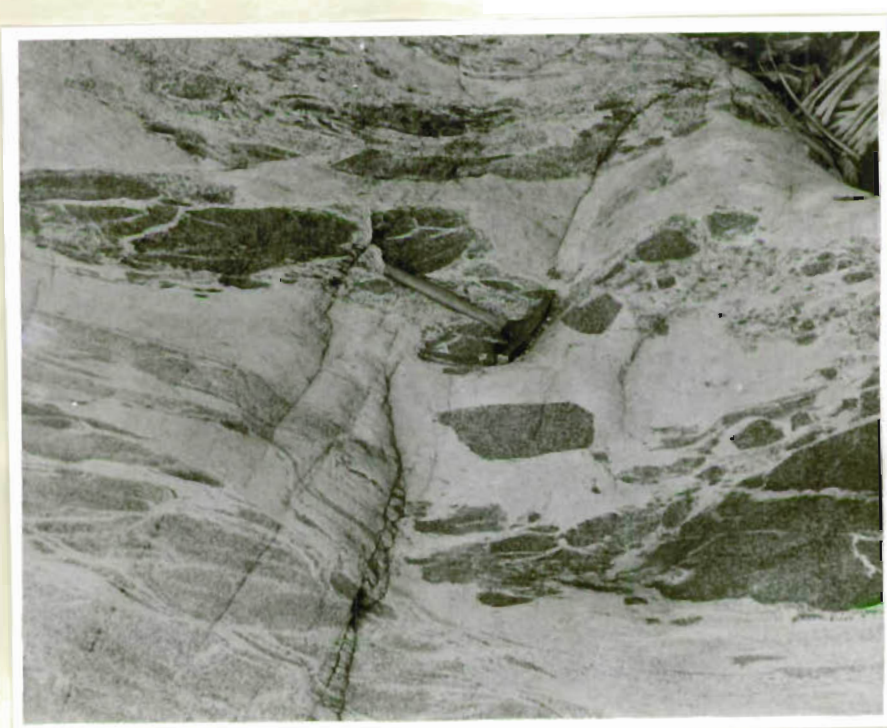

PHOTO No.6 - Migmatite: remnants of amphibolite and hybrid rocks
(dark respectively grey) in intrusive gneiss (light).
North coast, about 2 miles west of Lalama.

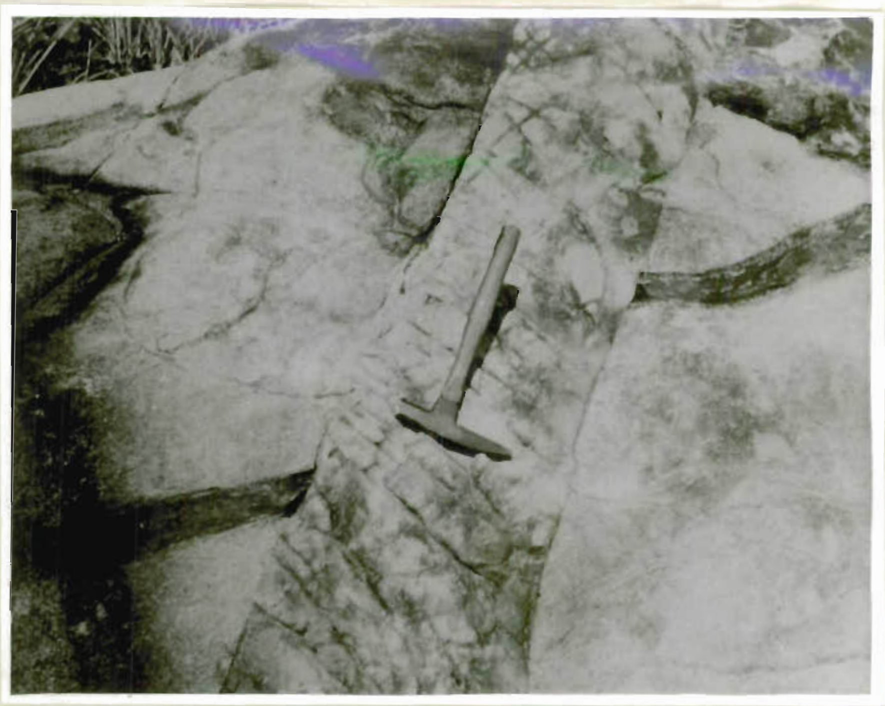

PHOTO No.7 - Dacitic dyke traversing migmatic gneiss. Shows emplacement accompanied by faulting (displacement of amphibolite band, presence of tension joints and "lineation" or flow banding).

DETAILED TAPE & COMPASS TRAVERSES ALONG TRACKS AND CREEKS

IN THE KULUMALIA - UMUNA - MARAROA - ARA CREEK AREA.

GEOLOGICAL MAP

OF

MISIMA ISLAND

PAPUA

SCALE 1 : 40,000 (APPROX)

1000 500 0 1000 2000 3000 4000 5000 METRES

1000 500 0 1000 2000 3000 4000 5000 YARDS

NOT FOR PUBLICATION - FIELD SHEET ONLY

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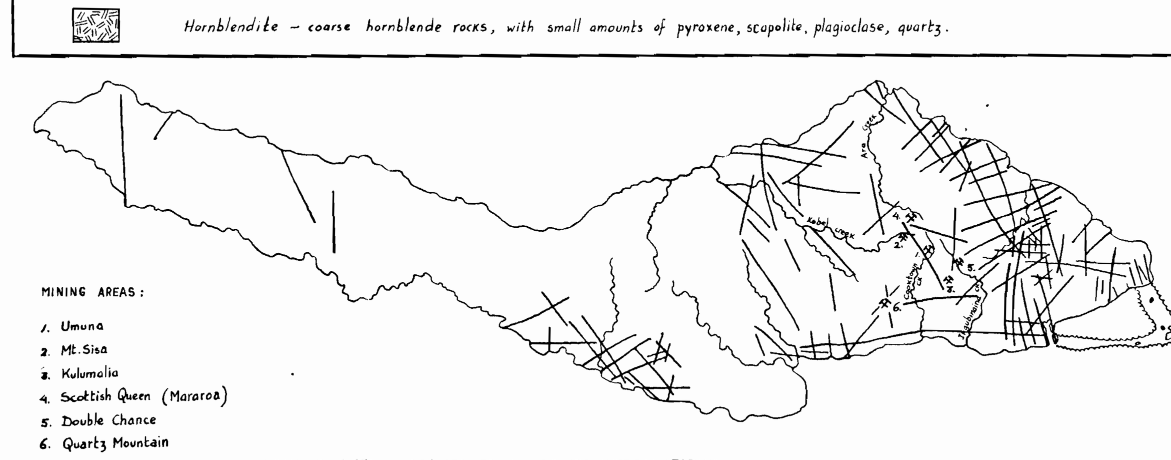
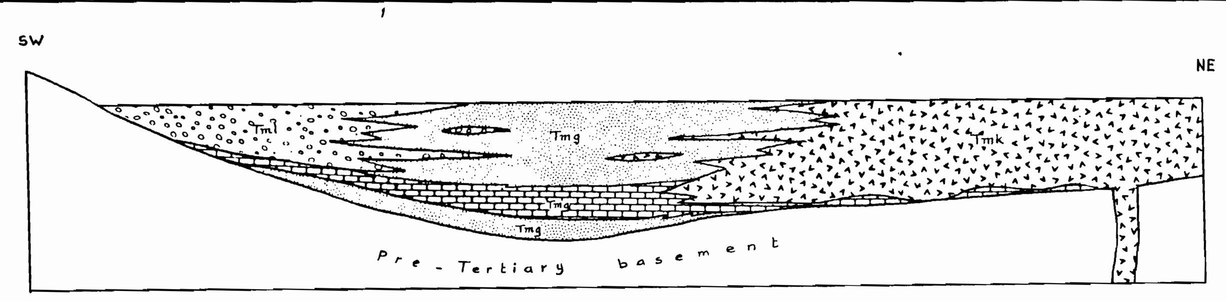
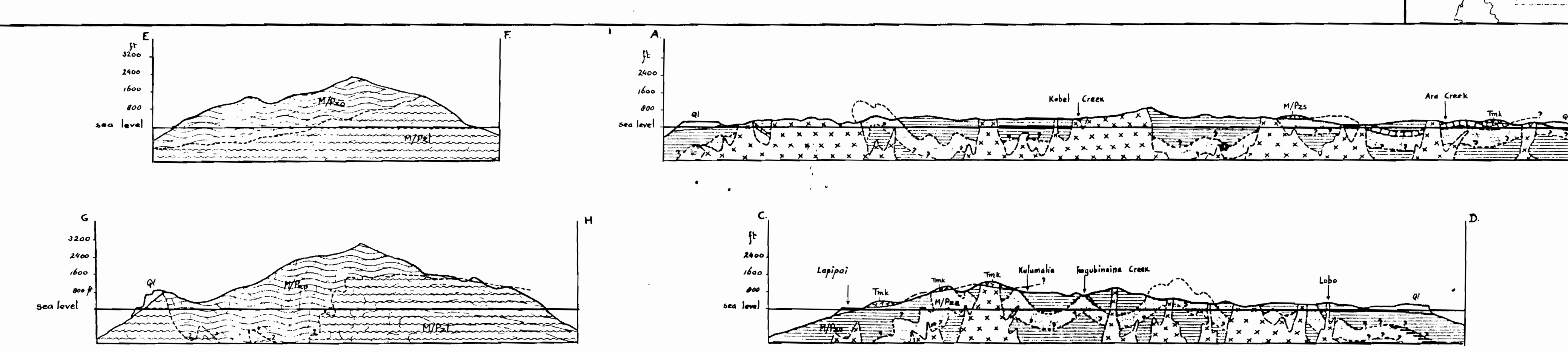


LINEAMENT PATTERN DERIVED FROM AIRPHOTO INTERPRETATION.



DIAGRAMMATIC SECTION (NOT TO SCALE) ACROSS THE TERTIARY BEDS, SHOWING PROBABLE FACIES RELATIONSHIPS



SECTIONS SHOWING INTERPRETATION OF REGIONAL GEOLOGICAL STRUCTURE ; vertical scale = horizontal scale

Geology by F. de Keyser and D.S. Trail
Compiled and drawn by F. de Keyser

January 1960