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# Geological Report on the Sapphire-Moresby King, Laloki, and other Mines, Astrolabe Mineral Field, Papua

by

by

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# GEOLOGICAL REPORT ON THE SAPPHIRE-MORESBY KING, LALOKI, AND OTHER MINES, ASTROLABE MINERAL FIELD, PAPUA.

Record 1948-9.

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# GEOLOGICAL REPORT ON THE SAPPHIRE - MORESBY KING, LALOKI, AND OTHER MINES, ASTROLABE MINERAL FIELD, PAPUA.

## LOCATION ETC.

The Sapphire - Moresby King property is situated just south of the Port Moresby - Rouna Falls Road, 17 miles east-south-east of Port Moresby, near the junction of Sapphire Creek and the Laloki River. The Laloki Mine lies about 2 miles south of the main road, to which it is connected by road, on a branch of Sapphire Creek known as Simson Creek. The position of the other orebodies in the area, Dubuna, Mt. Diamond, Elvina, Hector etc., are shown on the general geological plan, Plate F.1.

Timber is not exceedingly plentiful and consists mainly of rather stunted eucalypts, evenly distributed, with a few larger trees of different varieties along the river. A plentiful supply of good water exists in the Laloki River. Sapphire Creek just runs in the dry season, the right hand branch carrying the greater quantity.

## GENERAL GEOLOGY

### Eriama Series.

The geology of the mineral-bearing area consists essentially of a large mass of gabbro intrusive into a calcareous, and often somewhat tuffaceous, sedimentary series. Adjacent to the Sapphire-Moresby King mine, this series consists of sheared and broken grits and calcareous shales, whose attitude is very difficult to determine owing to the shearing stresses to which they have been subjected. An orientation roughly parallel to the contact is noticeable near the boundary between the sediments and the intruding gabbro. The calcareous shale grades into impure grey and red fine-grained limestone, containing usually about 50 per cent calcium carbonate. Most of these limestones are rich in microscopic fossils, principally globigerina, with a few other small foraminifera, and radiolaria. A certain proportion of tuffaceous material is present in the gritty beds which are closely associated with the ore in parts of the Sapphire mine.

At Laloki, the slightly tuffaceous grits and shales are again in evidence, but here they are much more intensely sheared even than at Sapphire. The degree of shearing is so extreme that fragments of the rocks near the walls of the orebody can be crumbled to flaky lenticular fragments, every face of which is highly polished by slickensiding. Laminated bedded shales with alternate massive and thin bands, interbedded with grits and thick beds of unsorted conglomerates containing an occasional boulder of slate or shale as much as 9 inches in diameter, are exposed immediately to the northwest of the orebody. The dip of the beds is generally to the north, but their attitude varies rapidly owing to small folds and ormulations.

Elsewhere in the district, the Eriama series, a name given to it by Gibb Maitland[1] and recently revived - consists of calcareous shales, grey and pink limestones, tuffs and grits. The grey limestone at 9 miles on the Rouna road, which is being extensively quarried for road metal, and at 11 miles, where the flux for the Sapphire Smelter is obtained, almost certainly belongs to the same series. These outcrops contain from 60 to 70 per cent Calcium carbonate.

Dips and strikes in the area examined were seldom easy to determine. Much of the work was concerned with sections close to the gabbro contact so that it was difficult to tell in many cases whether the apparent attitude of the beds was original or induced by shearing. Faulting and fracturing introduce further difficulties.

(1. A.Gibb Maitland F.G.S. Geological Observations in British New Guinea in 1891. Appendix M. Annual report B.N.G. 1891-92.

A general parallelism to the plane of contact of the gabbro with the sediments is often noticeable. At Sapphire dips are gentle to moderate, nearly always less than 45°, and either roughly to the south or to the north. At Laloki most of the dips are to the north or north north west, varying from 10° up to 70°, and crumpling and folding are in evidence. In the Dubuna locality dips are moderate to steep, mainly to the southwest, though south and south east dips were observed, and at Dubuna mine, close folding along a north south axis. The general impression is that the series is moderately folded, much disturbed by fracturing and shearing, and that it conforms more or less to the shape of the roof of the gabbro intrusive mass.

The age of the Eriama series is considered by Mr. H. Glaessner[2], Palaeontologist to the Australasian Petroleum Company in Port Moresby, to be Palaeogene, probably early Eocene, and earlier than the nearby siliceous Port Moresby series, with its intercalated lenses of nummulitic Eocene limestones. It is, however, not impossible that it may be later.

Other sedimentary series represented in the neighbourhood of the mines (refer to Plate F.1.) include the limestones, limestone grits and finegrained tuffs of the Bootless Inlet region. These rocks, which are often steeply dipping, are Oligocene in age. Also prominent in the Laloki-Sapphire area are the massive flat lying agglomerates of the Astrolabe Range, which form a capping to the ranges in the district, their upper surface probably representing the remnant of an earlier peneplain. While erosion has been carving out the present valleys, huge blocks of the solid agglomerates have settled down slowly, and these, combined with slides from the steep sides of such ridges as Hombron Bluff, often form a surface cover sufficient to mask the underlying rock. At the base of Hombron Bluff are exposed sandstones, silts and conglomerates which dip 35-40° to the northeast, and which must lie unconformably under the Astrolabe agglomerate, which is considered to be Miocene in age. For detailed descriptions of the various rocks in the Port Moresby district, reference should be made to J. H. Montgomery's "Contribution to the Tertiary Geology of Papua", in the Report of the Anglo Persian Oil Company to the Commonwealth Government, Volume IV.

THE GABBRO INTRUSION.

The intrusive gabbro comprises a large igneous mass which underlies much of the district, and considerable sections of the Eriama Series, particularly in the neighbourhood of the Sapphire-Moresby King mine, form roof pendants resting on top of it. The general colour of the unweathered rock is dark green to white, often mottled in appearance. In composition it is a normal gabbro composed of pyroxene and limesoda felspar, with some magnetite, chlorite etc. The felspar is mostly altered to saussurite, the pyroxene partly to chlorite. Both monoclinic and orthorhombic forms, diallage and bastite, are represented in the pyroxenes, which often occur in aggregates, sometimes with a roughly radiating structure.

Towards the margin the gabbro becomes much finer-grained and more uniform in appearance, though the composition remains the same, while in the central portion the grain is coarser and the crystals better developed, so that it is often possible to tell by the nature of the rock whether the contact is close or some distance away. Apophyses and dykes given off from the main mass are similar to the finegrained marginal phase, which approximates to dolerite in character. This marginal phase of the gabbro is usually hard, and near the contacts assimilation of the intruded rock has taken place to some extent, the contact not being always clearly defined. The degree of metamorphism induced in the sedimentaries is remarkably small for such a massive intrusive body, but this is probably partly due to the comparative absence of the silica-bearing solutions which are the agents of so much of the meta-

(2. Personal communication)

...sm associated with more acidic intrusions. So... as noticeable near the contacts, very little silicification, ... although contact minerals, garnets and wollastonite, are developed in places in the Eriama limestones, the total amount of alteration is not great, and quite well-preserved fossils are found adjacent to the contact minerals. Mechanical effects of the intrusion are more in evidence, shearing, faulting and fracturing are common, and a secondary orientation is induced in the sedimentaries roughly parallel to the plane of contact, which may or may not coincide with the original structure of the series. The gabbro contact on the surface can nearly always be traced with some accuracy, owing to the abundance of outcrops and the thin soil covering, the nature of which changes perceptibly according to the underlying formation.

On the gabbro it is greyish brown in colour, but acquires a more reddish tinge on the sedimentaries, particularly when the impure red limestones are present.

The age of the intrusion is probably Miocene. It is later than the Oligocene Bootless Inlet series, and earlier than the Miocene Astrolabe agglomerates. It may be casually connected with the latter but is more likely older.

## ECONOMIC GEOLOGY

### General Features.

The orebodies of the Astrolabe mineral field are very similar in their composition and general character, and possess many distinctive peculiarities which are no doubt to be correlated with the nature of the gabbro intrusion from which they were obviously originally derived. Particularly characteristic are the intensity of the pyritic mineralisation, the comparative absence of quartz and the lenticular habit of the lodes. They [illegible] occur within a short distance, less than half a mile, of the margin of the gabbro, and in many cases are actually closer than this to the igneous rock, which in all observed contacts dips under the sedimentaries at a moderate angle. The mineralisation consists essentially of massive iron pyrites, mostly finegrained, though coarser grains up to ¼ inch diameter may be present, particularly near the margins of the orebodies. Sulphur content is high, in most cases being about equal to that of the iron, though variations do occur in different parts of the field, and within the same orebody as will be pointed out later in reference to Laloki. Allowing for copper as chalcopyrite, and making the necessary deductions for the sulphur content for zinc, lead etc., the proportion of the total iron sulphide which must occur as pyrrhotite has been calculated for the different mines. On this basis the ratio $\frac{\text{Pyrrhotite}}{\text{pyrites + pyrrhotite}}$ at Laloki and Sapphire King is about 20 per cent or less, at Elvina between 30 and 40, at Bubuna over 50, and even higher at Mt. Diamond. Some doubt is cast upon the validity of the last figures, however, owing to uncertainty whether the iron in the assays available was recorded as Fe or FeO.

Marcasite and magnetite are recorded by Dr. F. L. Stillwell from the Laloki ore.

Copper, which is presumably mainly in the form of chalcopyrites, the only copper sulphide mineral which can be seen in the hand specimen, constitutes 3 or 4 per cent of the sulphide ore, sometimes more. 2 or 3 per cent of zinc is often present, also small quantities of lead, less than ½ per cent, and one or two analyses record ¼ per cent of arsenic. The gold content is seldom more than 4 dwts per ton and the silver 4 or 5 times the gold. The lodes consis of remarkably pure sulphide, with a sharp demarkation from the country rock, and their silica and general impurity content are very low. They constitute a most interesting example of mineralisation by ore bearing solutions given off by a basic magma. The formation of all observed ore bodies was accompanied by intense shearing, giving the impression that the strength of the mineralisation has been so great

as to be able to force the country rock sufficiently aside to build up large lenses of ore, mainly by actual displacement. Evidences of replacement are seen only near the walls of the lodes, as at Laloki Hangingwall, where siliceous country rock interspersed through the ore introduces smelting difficulties, and in places in the Sapphire mine where mineralisation is poor. At Sapphire the result of this method of mineralisation has been a bellying out of the lode at intervals to form lenses which reach as much as 30 feet in thickness, these lenses being connected by comparatively narrow mineralisation, sometimes carrying good values, sometimes, on the other hand, playing out to a narrow mineralised ore channel or to a streak of poorly mineralised country rock. At Laloki the ore-bearing solutions were more localised and concentrated to establish one large lenticular formation, more or less conforming to the general attitude of the enclosing sedimentary rocks.

Another consistent feature on the Astrolabe field is the shallow zone of oxidation. The country rock is seldom oxidised for more than 50 feet below the surface, while in the orebodies themselves, particularly in the solid portions, the sulphide may persist to an even higher horizon. The top of the sulphide zone is marked by black powdery pyrites in the first stage of decomposition, this type of ore being common at the Sapphire - Moresby King mine where the ore-body lies mostly close to the surface. The oxidised ores consist of masses of cellular limonite, stained to a greater or less degree by secondary copper minerals, blue and green carbonates, chrysocolla, and cuprite. At Sapphire - Moresby King it was noticed that any good copper values which may be present in the oxidised ores are generally associated with the presence of cuprite. Gold content of the oxide zone is always much higher than in the sulphides.

The Sapphire - Moresby King Mine.

This property is covered by 5 leases, the Sapphire, the Moresby King, and the Moresby King Nos. 2, 3, and 4. The ore-bearing area occupies the crest and the upper slope of a ridge, 700-900 feet above sea level, immediately south of the Laloki River and west of Sapphire Creek. The lode is generally flat lying, with dips in places both to the northwest and to the southeast, the principal direction of dip being to the northwest (refer to plan of lode, Plate F2, and section, Plate E1.). On the southeastern side of the ridge, the lode often dips in that, the reverse, direction, and indeed the contour of the lode has a general tendency to be more or less conformable with that of the surface of the hill. Ore is exposed over a total length, in a northeast - southwest direction, of more than 900 feet, and over a breadth, at right angles to this direction, of more than 700 feet, with thicknesses up to 30 feet, though usually from 1 to 6 feet. It is lenticular in habit, and ore is not continuous throughout the whole area. The mineralisation has shown a tendency to develop into large bulges in certain places, with lesser ones in others, while in some sections the lode dies out altogether or is represented by minor mineralisation of the country rock, with or without a definite lode channel. The values do not seem to be consistently related to the thickness of the lode. As a rule where the lode narrows preparatory to pinching out, values decline sharply, but often where the lode stays narrow but consistent, the values are very good. The thick lenses of ore appear to carry a fairly even moderate grade of ore.

The attitude of the lode is in a general way sub-parallel with that of the country rock-calcareous shales and grits, the former grading into impure fossiliferous limestone - though often it cuts across and in many places it is impossible to tell. The sedimentaries are so badly sheared and broken that it is very difficult to determine strike and dip. The gabbro contact runs along in an east-west direction immediately north of the Moresby King workings (see Plate F2) and dips under the lode at an angle of 25-30°. Shearing of the grits and shale is prominent throughout the workings and is especially noticeable on the walls of the lode, which appears to have been formed mainly be actual displacement of the existing formations. Replacement has played a comparatively minor role. but, signs of it are apparent, particularly in the grit areas, and in

sections where the mineralisation is poor. Owing to the paucity of sulphide exposures in the mine, and to the way in which the products of oxidation are distributed about the country adjacent to the lode in the oxidised zone, few opportunities exist to study the manner in which the mineralisation originally took place. The sulphide ore consists essentially of massive finegrained pyrites, with an intermingling of coarser brassy grains up to 1/10 inch diameter and some chalcopyrite. The proportion of pyrrhotite present is apparently greater than at Laloki as it is said that its smelting properties indicate that it is less basic than the Laloki ore. A sample of sulphide was taken in the main adit and sent away to be assayed for copper, gold, iron and sulphur, but the results have not yet come to hand. (Cu. 3.5% Au 6.8 dwts. Ag. 32 dwts. Fe 28.2 % S. 25.9 %).

The oxidised ore usually forms strong masses of cellular limonite, with a not very marked degree of copper staining, except at one or two places. Where the thickness of ore is not great, it is generally finer and more friable, whereas the thick lenses of originally pyritic ore have given rise to the more massive limonite, which sometimes has a finely nodular structure. Brecciation is occasionally noticeable especially near the margin of the orebody. Iron-staining from the oxidation of the lode extends into the country rock, and, in parts where the original mineralisation was poor, limonitic material is the only remaining evidence of its presence. Leaching of the copper minerals has taken place and the country underneath the ore may contain copper carbonates disseminated through it. Leaching both of the lode and the shale beds immediately beneath it is especially noticeable in the No.3 Workings, where the footwall shale has been leached to a light mass almost like kaolin in appearance and texture. The walls generally consist of sheared shale or grit, shearing along the hanging-wall being particularly common. Values in the sulphide ore vary up to as much as 11 dwts. Au. per ton, but average round about 3 dwts Au. and 4 per cent copper or a little more. The oxidised ore has returned values up to several ounces, but averages perhaps 10 or 11 dwts Au. per ton, and 1 to 2 per cent copper. It is difficult to account for the disparity in the values between the sulphides and the oxidised ore. On oxidation the mass of solid sulphide ore during the change from pyrites to iron oxides is reduced to about two thirds, which would mean a corresponding increase in gold value, while a certain amount of iron would also be carried off into the country adjacent to the lode. This would account for a reduction in mass to perhaps half of the original, with a resulting residual enrichment of the gold values by 100 per cent. In the absence of detailed assays it is impossible to state whether such residual enrichment is entirely adequate to account for the higher values in the oxide zone. Certainly it is difficult to see how chemical secondary enrichment can have played any appreciable part in increasing the values in such on flat-lying orebody. Moreover, the presence of consistent high values in, for instance, the No.3 Workings, indicates the presence of areas of original high values.

Copper content of the oxidised ore is low, between 1 and 2 per cent, except where local concentrations of cuprite occur. The depth of oxidation is shallow, not more than 50 feet, averaging about 40 feet in the country rock, while it is often nearer to the surface in the lode, especially in the more massive portions. Secondary enrichment appears to have played no appreciable part in the arrangement of the copper values.

The mine workings are divided for the sake of convenience by the operating company into six sections, the Moresby King, and from east to west along the upper workings, No. 1, 2, 3, 4, and 5 Sapphire. The relative position of the different sections is, shown on the plan, Plate F2. Much of the more readily accessible ore has been removed in the past, and some of the principal bulges in the lode, which contained several thousand tons, have been mined or partly mined out. Principal of these are the Moresby King main orebody, the Sapphire at No.5 Workings, also known as the "Burnt Mine", and lesser ones at No.1, No.2 and No.3 Sapphire.

These areas are also shown approximately in the plan, (Plate P2) and are indicated in the sections, (Plate B1).

No continuous exposure of ore has been traced from the Moresby King to the Sapphire workings, but no reasonable doubt exists that it is the same orebody. It may, of course, vary greatly in thickness between the two sets of exposures, perhaps pinching out altogether in places, but the general relationship is probably that shown in Section B-B' (Plate B1). Along the strike, the Sapphire lode has been exposed more or less continuously, except between No.1 and 2 workings. Gaps in continuity are known to occur, as between No.3 and No.5 workings, and a good example of such a break is exposed in the main adit, block O.16, shown in Section A-A', (Plate B1).

The lode is not infrequently faulted, the faults often being associated with a steepening or narrowing of the lode, and sometimes a drop in values. Some of the faulting is later than the ore, but a considerable amount of movement had taken place before, and no doubt some faulting occurred concurrently with ore deposition. Several faults are exposed in the under-ground workings, some of them with an important bearing on the distribution of ore. The main one, more or less parallel to the main adit, shows up in the crosscut to the adit, and is probably coincident with the fault exposed in a surface shaft in Block M.17. This fault probably runs nearly the whole length of the orebody and drops the lode down to the north, as shown in R. P. Hooper's section C-D and in sections D-D', E-E' and F-F' of this report (Plate B1).

In the Moresby King workings the ore is reported to have cut out to the west on a flat fault surface which is exposed in a shallow winze in Block No.10. The lode is apparently down faulted to the west. Other faults are seen in Sapphire No.1 workings, where the ore is also downfaulted to the west, and lesser ones in other areas. It is possible that the lode in No.5 workings is bounded on the west by a fault, though a lensing out is more probable.

In the Moresby King workings the lode dips gently to the north about the mouth of No.2 Adit, and gently to the south at the inside end of the adit, where an easterly component to the dip is also on record. Farther south the dip presumably again reverses, turning up to join the Sapphire lode north of the main fault (Section B-B'). The lode in the Sapphire workings north of the main adit dips generally down to the north, but turns over to the south with the surface, and has been found in several places lying at a very shallow depth. In general the lenticularity of the ore and the presence of so many bulges introduces great local irregularity into the dips, but the sections show the ore lying nearly flat in a northeast - southwest direction (Section A-A') and at right angles to that line, dipping mainly to the northwest, but also to the southeast on that slope of the ridge.

Production and Prospects.

Official records show that up to the end of 1940 the amount of ore mined from the property was 14178 tons, with a probable average value of 7.7 dwts. Au. per ton and 1.69 per cent copper. Total production up to July 1941 is in the vicinity of 5460 ounces of gold and 240 tons of copper. The tonnage records may not be entirely accurate, but they at least offer a guide to the amount and grade of ore mined in the past. In the following table are shown the respective amounts of sulphide and oxidised ores from the Sapphire and Moresby King workings and their gold and copper values. Often in the records the gold and copper from the different sections of the mine have not been kept separate, so the grades calculated represent only a portion of the ore mined from each place.

TABLE 1.

Sapphire - Moresby King Production.

| Source of ore | Total Tonnage | Tonnage used in calculating grades. | Au. Dwts. per ton. | Cu.% |
|---|---|---|---|---|
| Moresby King - Oxides | 6334.5 | 2404 | 10.94 | 1.2 |
| " Sulphides | 1111.0 | - | No data | |
| " Total | 7445.5 | 3487 | 6.86 | .98 |
| Sapphire Oxides | 4076.5 | 3516.5 | 12.10 | 1.5 |
| " Sulphides | 2656 | 1746 | 2.88 | 4.0 |
| " Total | 6732.5 | 5262.5 | 9.0 | 2.33 |
| Total both mines. | 14178 | 13110 | 7.7 | 1.69 |

The definitely proved ore at present consists of only a few hundred tons on the margins of the present working faces, but a very rough estimate of the probable ore which can easily be extracted at each of these faces gives a figure of about 9000 tons, averaging perhaps slightly better than 10 dwts. Au. per ton. Table 2 shows the distribution of this ore, with the very generalised average grades and thicknesses upon which the compilation is based.

TABLE 2.

Probable ore Reserves at Sapphire - Moresby King Mines.

| Section of Working | Tonnage | Thickness in feet | Value in dwts. Au. per ton. |
|---|---|---|---|
| Moresby King, on road, | 50 | 4 | 10-15 |
| Moresby King | 2250 | 6 | 8-10 |
| No.1 Sapphire near new ore bin | 300 | 5 | 15 ? |
| No. 1 Sapphire | 180 | 3 | 15-20 |
| No. 2 Sapphire | 3000 | 4 | 10 |
| No.3 Sapphire North | 90 | 1 | 20 |
| No.3 Sapphire West | 330 | 2 | 10 |
| No.4 Sapphire | 1225 | 5 | 10-15 |
| No.5 Sapphire | 1770 | 6 | 10 |
| Total | 9195 | | 104 |

The above figures are intended to serve merely as a rough guide to the amount and value of the ore which may be expected from the present showings. While in some cases it is possible that these figures may not be realised, it is much more likely that extraction, will prove considerably greater quantities than are shown in the table. There are many possible extensions of the orebody, shown by a question mark ? in Plate F2, which require proving. The lode as developed so far is bounded on the north by the surface of the hillside; on the west by the Moresby King fault, and to the west of Sapphire No.5 Workings by a pinching out of the ore on the surface, which may or may not be accompanied by faulting; on the north the surface outcrop is again the boundary, while the eastern limit of the ore has not yet been exposed.

In the Moresby King workings no work was done west of the fault surface on which the lode finished. The recent exposures at a lower level down on the road are presumably west of this fault, which would make it drop the ore down to the west. South of the Moresby King the drill holes (See plan, Plate F2) exposed nothing but country rock, though the lode, if present here at all, may very well be deeper than the bottom of the holes. A test pit should be put down immediately west of the old Moresby King stope to determine exactly what has happened here on the fault. Even if ore is exposed it is probable that it would soon run into sulphides and would not be a payable proposition.

West of Sapphire No.5 further reserves are not to be expected, since the ore appears at the surface to have lensed out.

All along the southern slope of the main Sapphire ridge, the ore should finish at the surface outcrop, but the lode has been shown in several places to fold over to the south and this is one of the most promising sections in which to look for further ore, particularly as shallow pitting should be all that is necessary.

On the eastern side also the ore has a good chance of continuing and opening up uncalculated reserves. The recent exposure during excavations for a new ore bin near Sapphire No.1 has disclosed a useful body of oxidised ore, while development now in progress on the eastern side of the Moresby King should give valuable information on that section. No known reason exists why the ore should not continue at least for some distance to the east, though ultimately approach to the gabbro contact (See Plate F1) must terminate it.

To the north the ore appears to be limited by the outcrop (Section B-B', Plate B1) though even if it should dip more steeply than the surface at any place, it would soon finish against the gabbro, which lies close beneath. The nearest exposure to the gabbro is that referred to above on the road just north of the Moresby King workings.

In addition to the external boundaries of the orebody, there are certain internal limits to ore imposed by conditions within the lode. One of these, which in calculation is extremely difficult to allow for without detailed proving, is the lenticular habit of the orebody, with the possibility of the ore playing out completely in places or losing commercial grade. The other principal feature is the change to sulphide ore. The shallow depth of oxidation and the low value of the unoxidised ore have already been mentioned, and in general the sulphide at Sapphire - Moresby King is not likely to be workable except in the case of a large lens lying comparatively close to the surface, making for cheap mining conditions. Otherwise although it is said to have better smelting properties than the Laloki sulphide, it would not be economic to mine, when such great quantity of only slightly lower value is very readily accessible at Laloki. This means that even though ore may be continuous from Moresby King to Sapphire, practically all of that portion north of the main Sapphire fault will be in sulphide and will not be worth extracting. The values shown in the two drill holes which cut the ore bear this out.

The present operations should as they proceed, show up the extent of the various sections of the orebody, but additional prospecting pits would be of value in places, particularly immediately southeast of Sapphire Nos. 2, 3, and 5 workings, between Nos. 1 and 2,

and north of No.1 and east of the Moresby King Workings.

In the current method of ore extraction and treatment, oxidised ore from Sapphire - Moresby King is mixed with Laloki sulphide ore in proportions varying from 60-30 to 30-60, together with fluxes if necessary for smelting. Average monthly throughput of the smelter, even assuming continuous maintenance of coke supplies and adequate ore transport, cannot be reckoned at more than 1000 tons, though this figure may be exceeded in individual months. Consequently it may be stated with some confidence that the mine has 2 years ore in sight, with a possibility of a total life 2 or 3 times as long.

The Laloki Mine.

The Laloki Mine is nearly 2 miles by road up the valley of Sapphire Creek from its junction with the Laloki river and a little over a mile southeast of the Sapphire - Moresby King mine. The ore is at present mined by open cut, transported by lorry to the Sapphire smelter, where it is roasted in mounds, then mixed with oxidised ore from the Sapphire Moresby King mine and smelted. The most useful reports available upon the property are J. E. Carne's "Notes on the Occurrence of Coal, Petroleum and Gold in Papua", Bulletin No.1 1913, Territory of Papua, and several geological reports by Evan R. Stanley,[4] late Government Geologist of Papua. It is assumed also that anybody studying this report will have available the excellent series of plans and sections prepared by R. Pitman Hooper, who examined the area just before the writer. The accompanying plan Plate CI, which is an attempt to show as a block diagram the Laloki orebody down to 35 feet below the Main adit (137 foot) level, is based directly upon Mr. Hooper's plans and sections.

The nature of the country rock at Laloki, with its intense shearing and slickensiding, and numerous small folds and fractures, has already been mentioned. The orebody is a huge irregular lens of practically solid sulphide, with a maximum length on the main adit level, of 450 feet, maximum width 90 feet, and exposed over a total vertical depth of about 160 feet. The dip is generally to the north and north north west at varying angles mostly between 35° and 60° above the main adit, and rather flatter below, particularly on the footwall, which is folded underneath the level, narrowing the lode down considerably. The lens increases in all dimensions down as far as the main adit level, but below that pitches to the west.

The Laloki ore is a very solid pyritic body, though somewhat friable, in the upper portions at least, and it has apparently suffered a small portion of the shearing which is so pronounced in the adjacent beds, but most of which was probably induced actually during mineralisation. Faults are known to occur, usually with small displacements, but marked by a conspicuous layer of black clayey gouge. Movement during operations of part of the lode relative to the rest is reported to have occurred, but this may be due merely to the weight of the ore acting upon an inclined fault surface. The ore is basic, composed of iron pyrites, with a varying content of pyrrhotite, chalcopyrite, zinc blende, magnetite, and marcasite. A little lead sulphide and a very small amount of arsenic may also be present. Samples of the ore were sent away to Dr. F. L. Stillwell for examination in polished section and a copy of his report is included herewith as Appendix 1.

The ore becomes increasingly basic towards the margins,

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4. Evan R. Stanley. Report on the Astrolabe Mineral Field, Annual Report Papua, 1911.
" " Prospects of the Astrolabe Minerals Field, 1917, Papua. (Unpublished).
" " Probable explanation of the Behaviour of the Orebody at the Laloki Mine. 1929 Papua (unpublished)

the central portion containing a much higher proportion of pyrrhotite. On the main adit level, the average proportion of the iron sulphide which occurs as pyrrhotite, hereafter known as the pyrrhotite ratio, is 24 per cent, calculated after allowing for all copper as chalcopyrite and making allowance for the zinc sulphide content. The footwall drive, however, is practically pure pyrites with only 8 per cent pyrrhotite, while in crosscuts through the lode the pyrrhotite ratio ranges from 16 per cent near the ends to over 50 per cent in the central portion. These facts are of interest in view of the increased difficulty in smelting the more basic ore, that is, the ore with the lowest proportion of pyrrhotite. Average pyrrhotite ratio for the mine is probably about 20 per cent.

From the sampling data vailable the average value of the ore in the mine us about 4.5 per cent copper and 3 dwts of gold per ton. Values are on the whole fairly evenly distributed, but appear to increase slightly with depth, the average of the main adit level being higher than that of representative sections at higher horizons while the known assays below the main adit level are slightly higher again. Noteworthy features in the distribution of the values (refer to Assay plan, R. P. Hooper's report) are the poor copper and gold content on the main adit level at the western end, west of a line joining coordinate 100' West on the footwall with 70' west on the hangingwall; and the high gold values on the main adit level footwall drive towards the eastern end, round about coordinate 150' East. Average value of the ore on the main adit level, the only place where reasonably detailed assay results are available, is 4.52 per cent copper, and 4.88 dwts Au. This gold value reduces to 3.4 dwts if the high values just mentioned be replaced by the average value for the level with them included, and then the total average calculated. Average iron and sulphur content for the level assays are respectively 37.58 and 39.93 per cent. Several records offairly representative sections across the lode at higher horizons near coordinate 0.0 are available and range from 2.7 to 5.4 per cent copper, and 2 to 4 dwts Au. per ton, averaging very close to 4 per cent copper and 3 dwts Au. per ton.

Ore Reserves.

Production by the present company up to the end of 1940 was 84.86 tons of copper and 310.75 ounces of gold, obtained from 4394 tons of ore. Production by previous operators has not been ascertained.

A conservative estimate of the ore remaining in the Laloki mine gives 265000 tons, averaging, from all available samples, 4.57 per cent copper and 4.13 dwts Au. per ton (3.07 dwts. if high assays on main adit level be disregarded). This tonnage figure is worked out on the assumption that the ore plays out not more than 60 feet below the main adit level, that is; that the orebody shown in R. P. Hooper's sections lenses out immediately below the bottom of these sections. Actually the orebody probably continues below this horizon, at least at the western end, for it is pitching in this direction. The tonnage factor used was 8 cubic feet to the ton, worked out from the average sulphide content on the main adit level of 80 per cent with specific gravity of at least 5.0 and assuming that of the remaining 20% to be 2.5.

The ore reserves are split up for convenience above and below the main adit level, that above being further divided into the western portion, which could be mined by gloryholing or open cut, and the remainder, which would have to be mined by some system of stoping. The limit of open cut is assumed to be the line shown on R. P. Hooper's longitudinal section. Taking a steeper face angle here would give another 10000 tons or so more ore. From the western block of ore the low grade section at the west end shown by the assays on the main adit level has been omitted, some 6000 tons here being considered too poor to work. The following table gives details of the ore in the various blocks.

TABLE 3.

Laloki Ore Reserves

| Section of Mine | Tonnage | Copper per cent | Au. Dwts. per ton |
|---|---|---|---|
| Above Main Adit level; Minable by Open Cut. | 56000 | 4.83 | 2.82 |
| Remainder above main adit level. | 95000 | 4.58 | 5.37 |
| Below main adit level. | 108000 | 4.75 | 4.88 |
| Total | 259000 | 4.70 | 4.61 |

In calculating the gold values for the east block above the adit level and for the ore below the level, the high gold assays near coordinate 150' W. on the footwall drive main adit have been included. If these be disregarded the average value is reduced by rather more than 1 dwt per ton in each case, with a corresponding reduction in the grade for the total. Copper value below the main level is calculated by averaging the available samples below the level with crosscuts on the level itself. If the first crosscut with its low values be excluded from this calculation, the average rises from 4.75 to 4.94 per cent copper. The gold figure below the level is taken, in the absence of other data, direct from the average value of the level itself.

Future development.

It is unfortunate that the block of ore most readily accessible and upon which immediate operations must rely, is the portion which carries the lowest gold values. In the writer's opinion the best method of extracting this ore is by gloryholing, trucking the ore on the main adit level. At present this level is in good condition as far as the No.3 (Gloryhole) shaft, while the old hangingwall drive can be followed for about another 200 feet. It is considered that the main adit should be extended from the No.3 shaft on a bearing of 101° to the footwall at coordinate 0.0, a distance of 180 feet, and a rise put up from that point to cut the hangingwall on the 65 foot bench. Over burden could be stripped, and trucked on the main adit level and dumped, while the ore would be trucked to the bin already in existence and loaded direct into lorries for transport to Sapphire. This would eliminate the present difficult climb on the road up to the 87' and 65' benches.

Ore east of the opencut section would present much more difficulty in extracting, and some form of stoping and filling would be necessary. The high gold values in the footwall section would help to compensate for the added working cost, but it seems that close assay control would be necessary to outline the payable sections of the lode.

Below the main adit level the ore could eventually be mined by driving a lower level adit. From a point farther down Simson Creek it would be possible, with 1000 to 1100 feet of driving, to cut the orebody some 80 feet below the present main adit. This would be ~~vastly~~ preferable to shaft sinking with the attendant cost of pumping water and hauling ore to the surface.

Other Mines.

Dubuna etc.

Many other orebodies are known to exist near the

contact of the main diorite mass, and one of these, the Dubuna, was worked with a greater or less degree of success for many years. The ore was first carted by mule to the coast and then shipped to Australia, while later a railway was built from the mine to a smelter which was established near Bootless Inlet. Further plans to mine the Laloki ore and to transport it by aerial tramway and the existing railway to the smelter were later put into effect, but falling copper prices together with mine fires made these operations unprofitable before they had been long in progress. Practically no details are accessible as to the condition of the Dubuna orebodies at the cessation of activities. J. E. Carne's "Notes on the Occurrence of Coal, Petroleum and Copper in Papua," 1913, and E. R. Stanley's "Report on the Prospects of the Astrolabe Mineral Field" 1917, provide most of the available information on the Dubuna and other mines of the Astrolabe field. Those showing the most promise, apart from Laloki and Dubuna, are the Mt. Diamond, near Dubuna, where a solid pyritic lens of ore contains 4 to 5 per cent of copper and nearly 3 dwts of gold per ton, and the Elvina, where values are rather lower. Carne gives the output of Dubuna from Sept. 1910 to June 1912 as 1396 tons, most of it apparently averaging over 20 per cent copper and 4 dwts gold. Stanley records that before 1917 Dubuna was shipping 100 tons of ore each month ranging from 5 to 21 per cent copper, and that the probable ore reserves at the time of his examination were 20000 tons averaging, on mine assays, 5 per cent copper and 3 dwts Au., very close to the average value at Laloki and other mines in the district.

Sapphire King.

Formerly known as the TOBO, the Sapphire King is a lens of ore, small but fairly persistent down the dip, on the west bank of Sapphire Creek, only a few hundred yards west of Laloki. It has been worked down to a little above creek level by the present company, producing, according to official records, 1346 tons of oxidised ore averaging 2.4 per cent copper and 11.26 dwts Au., and 206 tons of sulphides averaging 4.2 per cent copper and 5.16 dwts Au. It should be mentioned, that these records are not always correct in detail and reliable local opinion maintains very strongly that much of the ore so recorded came from the Moresby King. In view of this fact, no reliance can be placed on the above production figures as a guide to values. Carne quotes a sulphide assay from the lower adit as returning 2 per cent copper 3.25 dwts Au. per ton. Sufficient time was not available to reopen the adit to obtain samples. The Sapphire King is not at present to be considered as a source of ore, but the possibility must not be overlooked that it might open out in depth to a much larger lens of sulphide ore.

Federal Flag.

This showing is referred to in earlier reports as the Astrolabe. It is situated on the side of a small gully which runs into Sapphire Creek from the east, and close to the main Rouna Falls road, about ½ mile past the Sapphire Creek - Laloki River junction. It was originally worked for alluvial copper, and later a small tonnage of fairly high grade oxidised ore was mined by means of costeans and adits. A lens of limonitic ore about 30 feet long, maximum width 10 feet, striking east - west and dipping south, is at present exposed on the surface. Its copper content is not high and the gold value is unknown. It appears certain that work in depth would expose lenses of sulphide ore in the Federal Flag area, but nothing can be said as to their probable commercial value.

Conclusions and Recommendations.

Oxidised ore at Sapphire - Moresby King contains low copper, but moderate to good gold values. The sulphide ore is not much better in grade than at Laloki. Sufficient oxidised ore is available at Sapphire - Moresby King to maintain a reasonable share in the total mine production with the smelter working normally, for probably at least 2 years.

The Laloki mine contains over 250000 tons of sulphide, more than 50000 of which is easily extracted by open cut methods, average value 4.5 per cent copper, 2.8 dwts Au., per ton.

Increased copper production depends upon increasing the proportion of Laloki ore in the smelter feed, as well as maintenance of transport facilities within the company, and of adequate coke supplies for the smelter and of development work at Laloki sufficiently ahead of production. As the Sapphire - Moresby King ore contains the high gold values, which carry most of the profit, an increase in Laloki ore reduces the value of the matte obtained. On the other hand, as the known reserves at Laloki are immensely greater, it would obviously be the best long range policy to distribute the Sapphire - Moresby King production through as long a period as possible, thus postponing the problem, which must be faced eventually, of treating the Laloki ore alone.

None of the other mines on the field appears to offer hope of immediate working, but the number of known orebodies and the general intensity of mineralisation indicates that further examination of the possibilities is definitely warranted to test whether other orebodies comparable to Laloki may yet be located. The best method of achieving this end would be a geophysical survey. The solid pyritic lenticular orebodies, surrounded by practically unmineralised sedimentaries, should constitute an ideal layout for the application of geophysical means of investigation. The ample proportion of pyrrhotite, which has magnetic properties, together with some magnetite, makes them especially suitable for magnetometric survey, while on account of the high conductivity of the metallic sulphides and their high specific gravity, about double that of the country rock, they lend themselves just as readily to electrical or gravimetric methods of determination respectively. It is suggested that any programme of geophysical work should begin with an intensive survey at Laloki, and also at Sapphire - Moresby King, where enough is known of the orebodies to enable the instrumental results to be checked to a certain extent, while at the same time further information would be gained about the unexplored portions of the orebodies. Next the Dubuna - Mt. Diamond - Elvina area should be examined in detail, then a general reconnaissance made along zones bordering the gabbro contact, which should first be accurately mapped geologically and any areas where positive indications are obtained investigated at greater length.

N. H. FISHER

Geologist and Vulcanologist. T.N.G.

APPENDIX I.

MINERAGRAPHIC INVESTIGATIONS OF THE COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH.

REPORT NO.227 — UNIVERSITY OF MELBOURNE
15th October, 1941.

AURIFEROUS ORE FROM LALOKI, NEW GUINEA.

Small specimens of auriferous ore from Laloki, New Guinea, assaying 6 dwt. Au., together with a test flotation product assaying 15.3 dwt. Au., 5.9% copper, have been submitted for mineragraphic examination by the Melbourne Ore-dressing Laboratory.

The ore samples consist of massive sulphides with a quartz gangue. The sulphide minerals are chiefly marcasite and pyrite, with a very subordinate amount of chalcopyrite, sphalerite, and galena. The marcasite and pyrite tended to form spherical growths showing concentric banding, suggesting deposition from colloidal solutions. They are much fractured, particularly near the margins of the coarse areas, and the fractures are filled with quartz. Chalcopyrite occurs as occasional patches, several millimetres across, of relatively coarse crystals, and as occasional minute inclusions in the pyrite and marcasite. It tends to be associated with the sphalerite, which in places occurs as small isolated areas, moulded on the pyrite and marcasite. The galena was observed in the polished sections only as a very occasional minute inclusion in the pyrite and marcasite.

The test product was found to consist of a concentration of chalcopyrite, sphalerite and galena. The grain size of the product was very uneven, ranging from particules 60 microns long, to the finest dust. The bulk of the particles are 30 microns in diameter, or smaller, and the bulk of the chalcopyrite, blende and galena occurs in these smaller grains. Composite grains of chalcopyrite with blende are not uncommon.

Only two particles of gold, both free and measuring 0.014 x 0.021 mm., and 0.005 x 0.005 mm., respectively, were seen in a polished section of the flotation product. The sample was then treated on the Superpanner, and yielded a minute head of free gold, associated with a distinct concentration of galena. The head, together with the galena, was collected and polished in a briquette. Six particles of free gold, measuring 0.005 x 0.005 mm., 0.015 x 0.020 mm., 0.017 x 0.020 mm., 0.023 x 0.020 mm., 0.023 x 0.037mm., and 0.023 x 0.050 mm., respectively, were seen in a polished surface. The product contained occasional grains of galena more than 60 microns in diameter, but the bulk of it was finegrained as before. Some of the galena grains were composite with chalcopyrite. The greater proportion, however, was free.

ADDENDUM TO REPORT 227. — 26th November, 1941

Specimens of ore from the Laloki mine have been forwarded for examination by N. H. Fisher, Government Geologist of New Guinea. These specimens yielded additional information to that compiled for the Melbourne Ore-dressing Laboratory on October 15th. 1941, so that this note is regarded as an addendum to Report 227.

The specimens appear to be richer in copper than those previously examined, and contain brassy yellow patches of chalcopyrite associated with the massive pyrite. An indistinct folded structure appears on some of the ground surface and is distinguished by a darker band containing magnetite. Grains of magnetite, not mentioned in Report 227, are abundant in parts of the specimen and, when embedded in pyrite, are often ragged and corroded. Magnetite is thus an earlier mineral, partly replaced by pyrite. Occasionally the incipient change from magnetite to pyrite is observed when the magnetite grain is studded and interlaced with innumerable and exceedingly minute threads of pyrite. In other

places a few minute inclusions of hematite are present in magnetite; and larger plates of hematite, bluish-white in colour, are occasionally intergrown with magnetite or isolated in pyrite.

Pyrite is the most abundant sulphide and is, in places, intergrown with marcasite. The amount of marcasite is variable as it appears less abundant in these specimens than in those previously examined.

Scattered crystals of arsenopyrite are intergrown with pyrite, and these contain occasional minute inclusion of chalcopyrite and pyrrhotite.

Chalcopyrite is the only copper mineral present. It occurs in large ragged plates and also as smaller grains between individual crystals of pyrite or grains of magnetite. To a lesser extend it is associated with sphalerite. It appears to have been deposited later than magnetite and pyrite.

(Signed) FRANK L. STILLWELL