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NOTE ON INVESTIGATION 66201, COPPER DEPOSITS IN THE UPPER WARANGOI AREA, EAST NEW BRITAIN.

by

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CONTENTS

SUMMARY

The principal geological units within the area are a dioritic plutonic mass, intruded into low-grade regionally metamorphosed rocks, both being separated by a northerly trending fault from poorly consolidated sedimentary rocks which lie to the east. Minor sulphide mineralization occurs throughout the main dioritic intrusion, both as disseminated ore and in mineralized quartz, quartz-calcite and pegmatite veins. The results of stream sediment sample analysis for copper suggest a relative copper concentration in a wide zone along the western (normal contact) margin of the diorite. Analysis of ridge and spur soil samples collected in the north of the mineralized area verify that the higher copper values come from the marginal zone of the diorite, and show that the copper is unevenly distributed in this zone, and also that copper values in any one hole can vary considerably with depth of sample.

From an economic point of view, ore of the disseminated type is of main interest, but distribution of this ore is patchy, and reserves with high copper values appear to be small. An exploration programme designed to examine the economic potential of the mineralization would need to include geological mapping and stream sediment sampling to the south of the area examined by the writer, to determine the areal extent of the mineralization; soil sampling, preferably of weathered bedrock, carried out on a grid system over the entire outcrop area of the diorite; chip sampling of continuous exposures of diorite along creek beds, and in pits and costeans; and finally drilling of selected areas to examine the mineralisation at depth and to gain precise information on the size and value of possible ore reserves.

INTRODUCTION

Late in November, 1965, a number of rock specimens, some containing evidence of copper and other associated mineralization, were received from Mr. O.I. Ashton, M.H.A. They originated in the Upper Warangoi area (Central Bainings census division) of the Kokopo Sub-district, East New Britain, and were collected in part by natives from Arumbum village (see Plate. 1), and in part by himself, when he accompanied these natives to one of several source areas.

Ore mineralization in the specimens was sufficiently interesting to warrant further investigation, and the area was visited by the writer on January 25th and 26th, 1966, with natives of the village. Selected specimens were subsequently forwarded to the Bureau of Mineral Resources in Canberra for mineragraphic examination, and the results of this, together with information gained during the short visit, showed that a closer examination of the area would be necessary. It was, therefore, recommended by the Mining Advisory Board that a geologic investigation be carried out by the Resident Geological Section to determine the nature of the mineralization and its probable extent.

On 11th May, 1966, the Administrator, under the Mining Ordinance, declared an area of 132 square miles a Reservation --"... reserved from occupation and prospecting... for the purpose of facilitating geological investigation by the Administration, and to permit the giving of instruction in prospecting methods".

The area was visited again by the writer from June 6th to 13th, 1966, in company with the senior field assistant, Mr. B.J. Humphreys, and a native assistant. A large part of the area was mapped geologically, and 75 stream sediment samples were collected. Costeaning was carried out in an effort to gain precise information on the type and mode of occurrence of mineralization. The stream sediment samples were forwarded to A.M.D.L. for analysis of copper, lead, zinc, silver and molybdenum content; and a number of ore specimens were sent for assay.

The results of the stream sediment sample analysis showed a weak copper anomaly in a zone along the western margin of the diorite.

The area was visited again by the writer, in company with Mr. B.J. Humphreys, from September 24th to October 2nd, 1966. On this occasion, a limited soil sampling programme was carried out in the north of the mineralized area, involving the sinking of 58 auger holes and the collection of 100 soil samples, and geological mapping was continued. The soil samples were forwarded to A.M.D.L. for copper, lead, zinc and molybdenum analysis.

The mineralized area lies several miles southwest of Arumbum village, access being gained through the village by foot-track from the plantations which lie between the Nengmukta and Kavavas Rivers, which in turn are linked by road to Kokopo and Rabaul. (Both the Nengmukta River and the Kavavas River, with several of its tributaries, are often referred to as the Upper Warangoi River.)

Beyond Arumbum the track passes through the mineralized area and crosses the Baining Mountains to the southeast coast. Other tracks go to the villages of Riet and Maranagi , and there are a number of lesser tracks used for hunting and to give access to gardens. In addition, a number of tracks have been cut specifically to give access to the mineralized localities.

Creeks within the area are generally shallow and fordable, although subject to rapid flooding, and afford a convenient though difficult means of access. Forest cover and under-growth is generally thick, as the area has a high and fairly constant rainfall.

To the east and northeast of a line marking the edge of the eastern fall of the Central Baining Mountains, is an undulating land surface, heavily forested, about 800 to 1000 feet above sea-level, in which the larger streams are quite deeply incised. To the west and south of the line, the land surface rises slowly at first, through a narrow zone of foothills, then quite steeply, reaching a maximum height exceeding 7000 feet in several places.

The mineralized area lies within the foothills zone of the mountain range, and has a relatively low relief in the northern part, but this gives way to steep, rugged country in the southern part, and to the south of the area examined by the writer.

The people of Arumbum, and of Riet and Maranagi are Bainings (a small group in the Central Baining Mountains, different from the larger populations in the North Baining Mountains), who retreated to the mountains with the entry of the Tolois into the north-eastern part of the Gazelle Peninsula. They are primitive people, living in a largely undeveloped area, with little agriculture and few natural resources. The system of administration of the villages is still that of tultul and luluai, and it is largely through the initiative of the tultul of Arumbum that the existence of the ore deposits has been recognised.

GEOLOGY

INTRUSIVE ROCKS

The principal intrusive rock is typically a uniform coarse-grained diorite to quartz diorite (tonalite) composed of translucent white plagioclase, often with granulated and partly resorbed grain boundaries, 15 to 30% primary ferromagnesian minerals (hornblende and biotite), and variable interstitial quartz (up to 20%). Magnetite (probably titaniferous) is a common accessory throughout, together with minor apatite and primary sphene. Minor orthoclase is sometimes present. The relative abundance of the primary ferromagnesian minerals varies, and they have often undergone a variable degree of alteration. The biotite begins to alter marginally to chlorite, with the concomitant crystallization of sphene, which, in the advanced stages, forms irregular prismatic masses in the cleavage or at grain margins. Epidote, which is strongly pleochroic from colourless or pale yellow to bright lemon yellow, is frequently associated with the alteration. The hornblende, which is often sieved or spongy, and sometimes has small biotite flakes growing in the cleavage, alters to chlorite, epidote, and an unidentified fibrous (? serpentinous) mineral. The magnetite is often associated with the ferro-magnesian minerals.

In the northern part of the main body the composition is generally that of a quartz diorite (10 to 15% quartz), while exposures in the south of the area show compositional variation from biotite granodiorite (15 to 20% quartz, 10 to 15% orthoclase), to quartz diorite (15% quartz and very minor orthoclase), and hornblende diorite (minor interstitial quartz and no orthoclase). Medium-grained leucocratic rocks of intermediate composition are quite common throughout, and some microdiorite is also present. Aplite and pegmatite veins and dykes occur throughout. At one locality, the pegmatite contains coarse, honey-brown mica.

The diorite is bounded to the east by a major fault, which has caused intense granulation and mylonitization of the igneous rock in a zone which often exceeds 50 yards in width. Evidence of the fault is often apparent several hundred yards from the contact with the sedimentary rocks. The fault dips steeply to the east, and has a large normal component of displacement, with considerable uplift of the western (mountain) block. The initial stages of the faulting post-date the consolidation of the igneous mass, and evidence suggests that the fault is still active. At several localities within the diorite there are smaller faults which have caused local granulation of the rock.

The boundary between the main igneous mass and the low-grade schists is for the most part a normal contact, but at several localities there are fault contacts with minor displacement. There is little evidence of rapid marginal cooling of the intrusion or of its having caused major thermal alteration of the country rock.

Dykes and veins of diorite, and of pink and white aplite and pegmatite, penetrate the country rock for distances of up to several hundred yards. In several exposures it was seen that relatively small, angular blocks of schist had broken away and fallen into the intrusive body which, except in one section along the Rapmetka River, is generally free of xenoliths.

In the southernmost creek examined, several small isolated bodies of diorite crop out at some distance from the main contact.

To the west of the northern limit of the main intrusive body, is a second dioritic intrusion of slightly different character, comprising dark, medium-grained hornblende diorite, strongly intruded by porphyritic microdiorite, which sometimes makes up as much as 50% by volume of the rock. The microdiorite is porphyritic mainly in plagioclase, although ferromagnesian minerals (hornblende, minor biotite and secondary chlorite) comprise 50% of the fine-grained groundmass, in which they define a poorly developed flow foliation. There has been much subsequent movement on fracture and joint planes, with the result that the two fractions are often highly mixed. The microdiorite is also intrusive as dykes and small, irregular bodies into the metamorphic country rock.

Further north, there are boulders of a similar dark, medium-grained diorite in the creek wash, and there are exposures of mixed diorite-microdiorite in the northernmost creek, where the microdiorite also occurs in separate outcrop.

It appears likely from field examination that the medium-grained diorite and the microdiorite are older than the coarser, mineralized dioritic intrusion.

METAMORPHIC ROCKS

The country rocks which are hosts to the intrusions are regionally metamorphosed, low-grade schists and "semi-schists". Stress during metamorphism was variable, resulting in a variation in texture from hornfelsic to phyllitic - both textures are observable in country rock both immediately adjacent to, and at some distance from, the intrusion so it is unlikely that the hornfelsic texture is a product of thermal metamorphism caused by the intrusion. The textural differences are also, in part, a reflection of initial textural and compositional differences in the rock.

The main rock types present are basic schists of varying schistosity, derived from fine-grained, non-calcareous sediments, and porphyritic basic volcanics. In some areas, metamorphic differentiation of the minerals is complete, giving rise to banded quartz-biotite or quartz-actinolite schists. In several areas the metamorphic rocks are highly pyritic. It is difficult to assign the mineral assemblages to any of the sub-facies of contact or regional metamorphism proposed by Turner and Verhoogen (1960).

The more schistose members of the succession are generally lineated, and are sometimes crenulated. Orientation of the linear elements varies, indicating the likelihood of several periods of deformation, either local or regional.

Strongly epidotized basic porphyritic rocks crop out in the northernmost creek examined, and occur in the wash of several other creeks, but these cannot be included with the metamorphic rocks. Their field relationships are not known, but it is probable that these rocks are part of the intrusive suite which intrudes the metamorphic rocks here and in other parts of New Britain (Noakes, 1942).

SEDIMENTARY ROCKS

These occupy the undulating, dissected area east of the major fault, and comprise poorly consolidated claystones, siltstones, sandstones and pebble, cobble and boulder conglomerates, with some agglomerates in the lower part. The base of the succession is not exposed. They are flat-lying or dip gently to the east, and are in sharp fault contact with the rocks of the mountain block. Their age is unknown, but they can probably be correlated with the Plio-Pleistocene "Lamogai Series" of L.C. Noakes (1942).

Boulders of indurated, silicified pebble conglomerates, sandstones, siltstones, and, more rarely, recrystallised and silicified limestones are present in many of the creeks draining from the main range. These are obviously older than the rocks described above, but they were not observed in situ.

ORE MINERALIZATION

Within the area examined evidence of ore mineralization is found throughout most of the area of outcrop of the main dioritic intrusion, generally as infrequent mineralized boulders in creek wash, occasionally in outcrop.

The mineralization occurs in several different forms: as disseminated sulphides in the diorite; or in quartz, quartz-calcite, or pegmatite vein material.

The principal ore minerals are the copper sulphides chalcopyrite and bornite, with lesser lead and zinc sulphide (galena and sphalerite) occurring in vein material, and molybdenite occurring infrequently in both disseminated and vein material. Tetrahedrite is a rare accessory and was identified in one sample only, a mineralized pegmatite vein. Pyrite is a comparatively rare accessory with the ore minerals, although highly limonitic quartz rubble is common in many creeks in the area, and this sometimes has minor chalcopyrite or malachite associated with it.

There is no evidence of an oxidised zone, or of a zone of secondary enrichment associated with the mineralization; probably because of the shallow weathering and limited soil development resulting from rapid erosion. Secondary ore minerals are therefore restricted to small areas of malachite staining, occasional massive malachite and sometimes azurite, with associated chalcocite, in highly weathered veins, and to the frequent rimming of primary copper sulphides by chalcocite and sometimes covellite.

DISSEMINATED SULPHIDES IN THE DIORITE

In this rock, disseminated magnetite, bornite, less frequently chalcopyrite, and occasionally molybdenite, occur in fairly close association with aggregates of altered ferromagnesian minerals.

In thin section, the plagioclase of the host rock is cloudy, with considerable growth of sericite and minor epidote, and generally has granulated and partially resorbed grain boundaries. Quartz is usually present and varies in proportion up to about 15% by volume of the rock. The primary ferromagnesian minerals, probably mainly biotite (from hand specimen examination), have been completely replaced by an aggregate of chlorite (often with opaque oxide in inherited cleavages), epidote, sphene, and minor calcite. The ore minerals which are sometimes found in intimate association with the altered ferromagnesians are often embayed and skeletal in habit, and vary in grain size up to 1 cm, although most grains are smaller than 5 mm. The usual close association of the ore minerals with altered ferromagnesian minerals suggests that the sulphide was introduced during alteration of the primary ferromagnesian minerals, the ore so produced being of a disseminated replacement type.

Ore of this type occurs at a number of localities within the area of outcrop of the diorite, but distribution of the sulphide minerals is very patchy, and high grade deposits of this type appear to be small.

Weathering of disseminated sulphide is probably the cause of most of the malachite staining which penetrates the rock or marks joint and fracture planes at many localities.

Semi-quantitative analysis by emission spectroscopy was carried out on three representative ore samples of the dissiminated type, and the results in p.p.m. are:-

	Cu	Pb	Zn	Ag	Au	Mo
(i)	10,000,	7,	$<$20,	20,	$<$3,	$<$1.
(ii)	1,000,	2,	20,	0.3,	$<$3,	$<$1.
(iii)	$>$10,000,	7,	$<$20,	30,	$<$3,	1,500.

MINERALIZED VEINS

These also are of irregular distribution throughout the diorite, the vein material being of several different types: principally quartz veining, often with related quartz-calcite and calcite veining; and some pegmatite veining.

The quartz veins are generally from half an inch to six inches in width, but occasionally form dykes up to 18 inches wide. They sometimes contain associated calcite, which varies from a minor to a major constituent, and in many places there are associated veins of dense, creamy-white calcite, up to several inches in width, which occasionally carry minor sulphide. The principal ore mineral is chalcopyrite with lesser bornite, occasional galena and sphalerite (low iron content) and rare molybdenite. Pyrite is very rarely present. Secondary minerals common in weathered veins are malachite, chalcocite, limonite and haematite.

Mineralization within the veins is generally patchy, particularly in the wider veins, in which the copper and lead-zinc sulphides tend to segregate, forming local concentrations. An 18 inch wide dyke examined by costeaning is made up of quartz with some calcite, roughly layered, containing very irregular lenticular masses of galena and minor sphalerite, several inches thick and up to 12 inches long; and patches of large chalcopyrite grains, with small chalcopyrite grains scattered throughout. Weathering has caused the formation of chalcocite, limonite, haematite and minor malachite. A narrow vein from another locality consists of a fissure lining of calcite crystals, with infilling massive calcite and minor quartz. Minor galena, translucent sphalerite and chalcopyrite occur in the vein.

Where extensive quartz and quartz-calcite veining has occurred the diorite is generally altered about the veins in a zone which may be as wide as 10 feet. The altered rock is greenish, with abundant irregular grains of quartz. In thin section it is seen that the original plagioclase has been completely replaced by sericite and minor calcite; the ferromagnesian minerals have been completely replaced by an indistinguishable colourless mass which sometimes comprises sericite, quartz, and fine sphene, with opaque dust and sometimes needles in the old cleavages; and the origional quartz, especially that close to the veins, has been augmented by introduced quartz.

The quartz vein mineralization has taken place subsequent to the consolidation of the dioritic mass, infilling fractures caused by shattering of the mass.

Mineralized pegmatite veins and dykes are considerably less common than the mineralized quartz and quartz-calcite veins. They are generally quite wide, and the ore minerals are more massive than in the quartz veins. The pegmatite is usually quartz-feldspar, and varies in grainsize from medium to quite coarse.

The most common type of ore mineralization is massive chalcopyrite, which may form a layer in the centre of the dyke. In two examples, found in creek wash, the chalcopyrite layers were respectively 2 inches and 6 inches wide. In another example, of a roughly banded quartz-feldspar pegmatite dyke about 12 inches wide, massive chalcopyrite was scattered througout, making up about 30% by volume of the rock.

At one locality a 12 inch dyke of kaolinised, comparitively fine-grained, white quartz-feldspar pegmatite contained two 1-inch veins of black ore, symetrically placed near the margins. A mineragraphic examination of the ore, carried out in Canberra, showed it to be composed of:-

tetrahedrite	55%
sphalerite	25%
galena	15%

chalcopyrite, chalcocite and covellite - accessory.

One specimen also was found of a fairly coarse, weathered feldspar pegmatite, containing plates of molybdenite (several inches in diameter) and some chalcopyrite and chalcocite.

It is possible that the mineralized pegmatite dykes are slightly older than the quartz and quartz-calcite vein mineralization.

Semi-quantitative analysis by emission spectroscopy was carried out on one sample of massive chalcopyrite from a pegmatite vein, and on two samples of quartz vein material collected from different localities. The results in p.p.m. are:-

	Cu	Pb	Zn	Ag	Au	Mo
(i)	>10,000	15,	100,	50,	<3,	30.
(ii)	5,000,	1,000,	2,000,	50,	<3,	1,000.
(iii)	10,000	10,000,	800,	150,	<3,	2.

STREAM SEDIMENT SAMPLES

The collection of stream sediment samples proved difficult in streams within the diorite, as the sediment contains very little fine material; this being a consequence of the coarseness of the diorite, rapid erosion, and high rainfall in the area. However, samples (sieved to minus 80 mesh) were obtained from all streams within the area, and these were analysed by A.M.D.L., using the atomic absorption technique, for copper, lead, zinc and silver, and for molybdenum using X-ray fluorescence.

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The results for copper are quite low (see Plate 3), rarely exceeding 250 parts per million. However the values vary considerably and a consideration of the relative values for copper over the whole area shows that the highest values lie within the dioritic intrusion, in a wide belt along the western margin. The higher copper values often, though not always, come from the streams in which the signs of copper mineralization are most plentiful.

The results in parts per million for molybdenum vary from less than 10 to 140 (see plate 4). The higher values occur within the diorite, but generally not in the marginal zone of anomalous copper values, and there appears to be no correlation between results for copper and molybdenum.

Values for lead and zinc are variable, and are generally inconsistent with the observed lead/zinc mineralization. Few conclusions can be drawn from their distribution. Values for silver are consistently low, with several minor anomalies of little apparent importance.

SOIL SAMPLES.

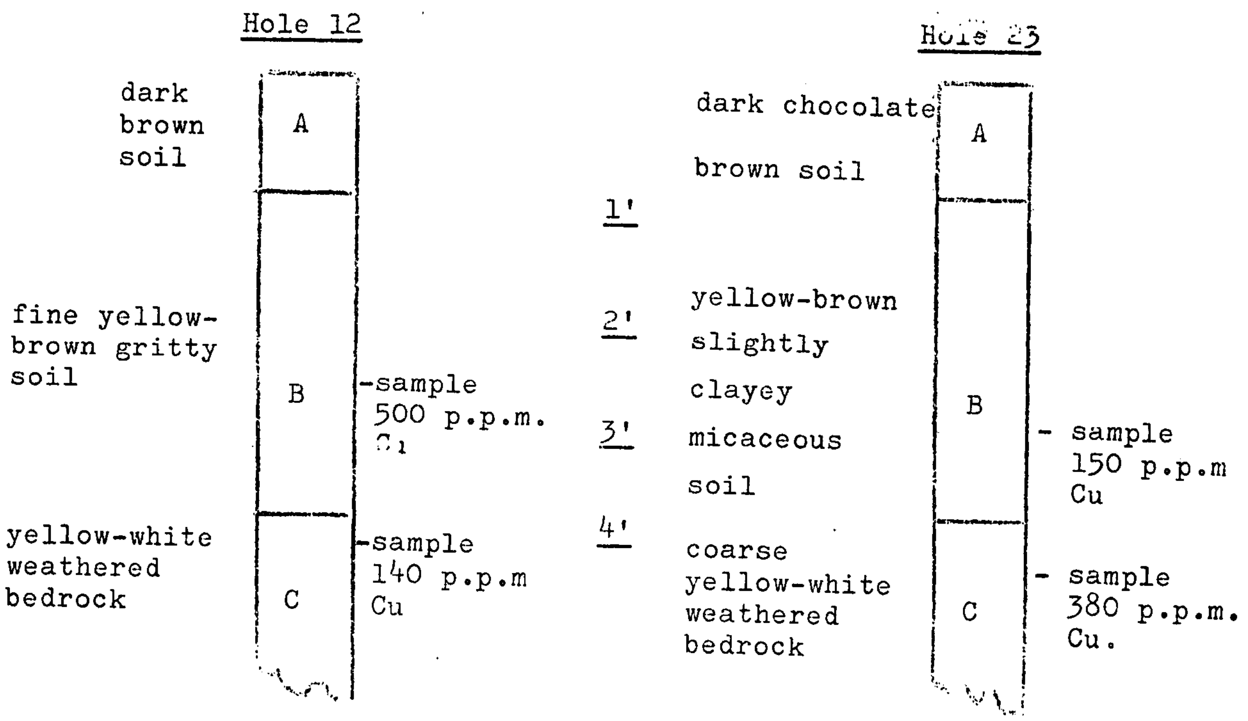
A limited soil sampling programme was carried out in the north of the anomalous copper area indicated by the stream sediment sample analyses, in order to verify the existence of the anomaly and to examine the distribution of copper within it. Traverses were made along ridges and spurs in the area, and auger samples were collected at roughly 200 to 300 feet intervals. Over most of the area the ridges and spurs are very narrow and steep sided.

The usual soil profile developed over the diorite comprises a black to dark brown humus-rich surface (A) layer, from two to twelve inches deep but generally between four and six inches deep, underlain by a yellow, yellow-brown or brown horizon (B) of variably clayey soil which is generally gritty and is sometimes micaceous, and which may contain rock fragments in the lower part. At depths varying between two and six feet, but generally about four feet, this grades, often imperceptibly, and sometimes with a gradual colour change, through a gritty basal layer into yellow-white or grey-white weathered bedrock (C), which has the texture of undisturbed diorite, but is soft and very friable. Solid bedrock is often considerably deeper. The soil profile developed over schist varies in that the B layer is generally thicker and finer textured, and varies in colour with the composition of the schist.

A total of 58 auger holes were drilled and 100 soil smaples were collected: in most holes samples were taken both at about 2ft 9 ins. and as soon as the auger penetrated weathered bedrock. The samples were forwarded to A.M.D.L., where they were sieved to minus 80 mesh and analysed for copper, lead and zinc by atomic absorption, and for molybdenum by X-ray fluorescence.

The results of analysis for copper show:

(i) There is usually a considerable difference between the values obtained for soil and weathered bedrock samples from a single hole, although one is not consistently higher than the other. There is probably also a considerable variation within both the soil and weathered bedrock, but this was not properly tested. Fairly typical soil profiles and results are as follows:-



Less typical are those for Hole 2 in which three inches of dark soil, underlain by yellowish, fine clayey soil which passes through a transition zone into weathered bedrock at depths of seven to nine feet. Samples were taken at 2 ft. 9 ins. (60 p.p.m.) and 9 ft. .. ins. (1400 p.p.m.).

(ii) The values vary considerably over the area of the survey, with the higher values (greater than 500 p.p.m.) occurring in the diorite within 300 yards of the contact with the schist. Within this zone, however, the values are not consistantly high, suggesting that the copper distribution is patchy.

The values in parts per million for lead and zinc are generally low, the distribution of values being as follows:-

Pb p.p.m.	%	Zn p.p.m.	%
C-25	85	0-50	65
26-50	10	51-100	25
>50	5	> 100	10

Anomalies occur in the holes numbered 11, 27 and 53. In Hole 11, the values for Pb are low (75 and 12 p.p.m.) but those for Zn are very high, 3000 p.p.m. in both samples. The mineralized pegmatite dyke containing tetrahedrite, sphalerite and galena crops out about 50' below the hole, in the creek to the east; the hole is located at the top of a small slide about 50' high in the steep bank of the creek to the west, and the diorite exposed by the slide is extensively malachite-stained. However the copper values in the hole, 260 and 150 p.p.m., are not particularly high. Hole 27 shows a minor anomaly, with 350 p.p.m. Zn in the weathered bedrock (sheared diorite). In Hole 53, the lower part of the B layer contains iron-stained rock chips, and the weathered bedrock, encountered at 4 feet is iron-stained; the values at 2 ft. 9 ins. for Cu, Pb and Zn are 270, 15 and 4 p.p.m., respectively and those at 4 ft 6 ins. are 4200, 390 and 190 p.p.m.

The values in parts per million for molybdenum are fairly constant over the area surveyed, and do not vary significantly in individual holes or between holes located over the schist or the diorite. Except in the first 6 holes (where the values are low) the results fall between 60 and 90 p.p.m.

CONCLUSION

Geological and geochemical investigations carried out in the Upper Warangoi area of East New Britain show the presence of copper and related ore mineralization in a coarse-grained intrusion of dioritic composition, and suggest a relative concentration of copper mineralization along the western margin of the body.

The mineralization is genetically related to the diorite, and occurs in two principal forms; as disseminated ore in the diorite, and in quartz, quartz-calcite and pegmatite veins and dykes. In the disseminated ore, the principal ore minerals are bornite, with lesser chalcopyrite and rare molybdinite and in the mineralized veins, cholcopyrite, with lesser bornite, some sphalerite and galena and rare molybdenite.

Examination of rocks in thin section suggests that hydrothermal activity was coincident with, and possibly largely responsible for, much of the ore mineralization. The close association of skeletal grains of ore with altered ferromagnesian minerals in the disseminated ore type suggests that it is a replacement ore, probably formed by hydrothermal activity in the final stages of consolidation of the igneous mass. The common alteration of country rock around mineralized quartz and quartz-calcite veins suggests that hydrothermal solutions were active during the emplacement of the veins, and that shattering of the diorite took place prior to the hydrothermal activity.

Consideration of the distribution of copper values found in stream sediment samples suggests a relative concentration of copper mineralization along the western margin of the diorite. The results of analyses of soil samples collected in a small test area verify that the higher copper values occur in the marginal zone of the diorite, and show that the distribution of copper is patchy within this zone. It is also apparent from these results that copper values vary considerably with the position of the sample in the soil profile. The most reliable results, particularly in an area of moderate to high relief, can be expected with samples obtained from undisturbed weathered bedrock: in the area examined, this is rarely deeper than 5 feet.

From an economic viewpoint, ore of the disseminated type is of main interest, as a sufficiently large reserve would constitute a low-grade copper ore body suitable for open-cast mining. The presence of mineralized veins in the disseminated ore would add to the overall value of the ore, but generally the mineralized veins are neither large enough, nor of high enough value to be worked individually, except perhaps by limited underground operations carried out on a small scale.

An exploration programme designed to examine the economic potential of the mineralization would need to include geological mapping and stream sediment sampling to the south of the area examined by the writer, to determine the areal extent of the mineralization; soil sampling, preferably of weathered bedrock, carried out on a grid system over the entire outcrop area of the diorite; chip sampling of continuous exposures of diorite along creek beds; and in pits and costeans, and finally, drilling of selected areas to examine the mineralization at depth and to gain precise information on the size and value of possible ore reserves.

REFERENCES

C.D. Branch:	Bureau of Mineral Resources Laboratory Report No. 16, April 1966 (unpublished)
L.C. Noakes, 1942	Geological Reports on New Britain. Geological Bulletin No. 3, Bureau of Mineral Resources.
I.R. Pontifax:	Bureau of Mineral Resources Ore Mineralogy Report No. 4, March, 1966 (Unpublished).

Port Moresby
January, 1967

APPENDIX I

THIN SECTION EXAMINATIONS

MAIN DIORITIC INTRUSION

P1213	Quartz diorite
P1214	Altered diorite
P1252	Biotite granodiorite
P1253	Hornblende diorite
P1255	Biotite - hornblende diorite
P1256	Quartz diorite (tonalite)
P1257	Hydrothermally altered diorite and mineralized vein.
P1254	Microdiorite
P1251	Aplite.

MIXED DIORITE-MICRODIORITE INTRUSION

P1258	Hornblende diorite
P1259	Porphyritic microdiorite

METAMORPHIC ROCKS

P1215	Quartz-plagioclase-hornblende semischist (description by C.D. Branch).
P1250	Albite-actinolite-quartz schist.

P1213 Quartz diorite

Medium to coarse-grained (grainsize generally less than 2 mm).

Subhedral, slightly sericitised or kaolinised plagioclase makes up about 45% of the rock. It is often marginally resorbed, and may be enclosed by anhedral quartz (with occasional myrmekitic intergrowths) or, less commonly, anhedral orthoclase. The quartz is strained and makes up about 25% of the rock; slightly cloudy orthoclase makes up less than 10%.

The primary ferromagnesian minerals, biotite in excess of hornblende, often occur together in small clusters and make up about 15% of the rock. The biotite is pleochroic from light to dark brown, and is partly replaced by chlorite (pleochroic from pale brown to light olive green), with the concomitant crystallization of sphene. The hornblende is light green, and is often sieved or sometimes spongy.

Magnetite is a minor constituent, and primary sphene, apatite and secondary epidote are accessories. One small grain of chalcopyrite occurs in the section.

The composition is very close to that of a granodiorite.

P1214 Altered diorite

Fairly coarse-grained (generally less than 4 mm grainsize) rock, made up of about 65% subhedral to anhedral plagioclase (possibly minor orthoclase) which is highly sericitised, about 15% ferromagnesian minerals, very minor quartz, and accessory apatite and primary sphene. Opaque minerals make up 20%.

The ferromagnesian minerals are principally chlorite (light green to pale olive green) in excess of biotite (light to dark brown), these being in intimate association, as the chlorite is replacing the biotite with the concomitant crystallisation of abundant sphene which occurs as irregular prismatic masses in the cleavage and at grain boundaries. Epidote, strongly pleochroic from colourless or pale yellow to bright lemon yellow, is less frequently associated with the alteration. It is possible that the chlorite and chlorite-biotite masses may have, in part, replaced primary hornblende, but there is no evidence to support this.

The opaque ore occurs as embayed and skeletal grains in close association with the ferromagnesian minerals, and comprises magnetite in excess of bornite, with very minor chalcopyrite enclosed by the bornite. The grains are altered marginally. This rock was submitted for mineralogical examination - see Appendix II, Number 4.

P1252 Biotite granodiorite

Medium to coarse-grained rock (1 to 2 mm, but up to 4 mm grainsize) comprising 55 to 60% plagioclase, 15 to 20% quartz, 10 to 15% orthoclase, and 10 to 15% ferromagnesian minerals.

The plagioclase (calcic oligoclase to sodic andesine) has granulated and resorbed margins, and is often rimmed by quartz (with some myrmekite) or orthoclase. The plagioclase is sometimes faintly zoned, and there is minor alteration to calcite and sericite. The quartz occurs as fairly small, irregular masses, which generally show only faint signs of straining. The orthoclase occurs principally marginal to plagioclase. Biotite is the principal ferromagnesian mineral, and occurs in sieved grains up to 3 mm long. It is generally fresh and has small amounts of spongy, pale green hornblende and apatite associated with it. Minor spongy hornblende occurs individually in aggregates up to 2 mm long, and minor brown chlorite occurs in several parts of the section.

Minor opaque oxide and very minor chalcopyrite are present, generally in association with the ferromagnesian minerals.

P1253 **Hornblende diorite**

Coarse-grained rock (up to 6 mm grainsize) comprising 75% plagioclase, 5% quartz, less than 5% orthoclase, and 15% ferromagnesian minerals. The plagioclase is generally 4 to 6 mm long, granulated and resorbed marginally, sometimes with bent twins, and is unaltered and unzoned. The quartz (slightly strained) and the orthoclase are fairly fine-grained and occur interstitially.

The ferromagnesian minerals are very largely sieved and spongy green hornblende (up to 2 mm), with occasional associated aggregates of fine-grained brown biotite. Opaque oxide is a minor constituent, and chalcopyrite a very minor constituent. Apatite is an accessory mineral.

A narrow crush-zone crosses the section and there is minor displacement accross joint planes.

P1255 **Biotite - hornblende diorite**

Coarse-grained rock (up to 5 mm) grainsize comprising 75% plagioclase, 5% quartz and 15 to 20% ferromagnesian minerals.

The plagioclase (sodic andesine) is granulated and resorbed marginally, with some bent twins, and is partly altered to sericite and minor calcite. The quartz occurs as irregular interstitial patches.

Sieved green hornblende is the principal ferromagnesian mineral (up to 1½ mm grainsize), with less common brown biotite altering to green chlorite (with the concomitant crystallization of sphene and minor epidote and calcite). Minor opaque oxide is associated with the ferromagnesian minerals.

Small crush zones and a narrow quartz-calcite vein cut across the section.

A poorly expressed flow foliation is defined in both hand specimen and thin section by the sub-parallel alignment of elongated plagioclase grains.

P1256 **Quartz diorite (tonalite)**

Marginally resorbed, subhedral grains of plagioclase (70 to 75%, up to 8 mm long), showing good albite twins (which indicate a composition of calcic oligoclase to sodic andesine) and poor zoning, with minor alteration to sericite; irregular interstitial masses of slightly strained quartz (15%); and ferromagnesian minerals (15%) with very minor orthoclase (possibly), and accessory sphene, apatite and calcite.

Green hornblende, sometimes sieved, and brown biotite (with lemon yellow stringers of epidote in the cleavage, and minor marginal alteration to green chlorite and fine sphene) occur separately in roughly equal quantities and have associated with them accessory apatite and sphene, and small grains of opaque oxide.

P1257 Hydrothermally altered diorite

The rock comprises altered diorite about vein material.

The altered diorite comprises about 40% coarse quartz grains, 50% fine sericite and quartz, and less than 10% altered ? ferromagnesian minerals.

The quartz occurs as grains up to 3 mm across, which often combine with adjacent grains to form elongate aggregates. The sericite occurs as highly birefringent flakes, which tend to form large, sieved, optically continuous plates of muscovite, enclosing less abundant fine, irregular quartz mosaics and some irregular calcite. It is probably pseudomorphing original plagioclase.

The altered ? ferromagnesian mineral is generally an indeterminate mass, masked by fine dust, sometimes with abundant clusters of fine opaque needles; occasionally it comprises sericite flakes and quartz, with fine granules of sphene, and abundant opaque dust.

It is associated occasionally with minor magnetite, ? bornite and chalcopyrite.

The vein is an open fracture, lined with sharp calcite crystals, and filled with more massive calcite and quartz. It contains minor galena, translucent sphalerite, and chalcopyrite.

P1254 Hornblende microdiorite

Irregular, marginally resorbed plagioclase (up to 1 mm grainsize), makes up about 75% of the rock. It is generally poorly twinned or untwinned, and slightly altered to sericite and minor calcite, with some marginal orthoclase.

The ferromagnesian minerals make up about 20% by volume, and are largely green hornblende (with minor small biotite flakes in the cleavage) and minor brown biotite (forming clusters of small grains).

Quartz occurs interstitially, and makes up less than 5% by volume. Minor opaque oxide is present, and apatite, sphene, epidote and calcite are accessories.

P1251 Aplite

Fairly fine-grained allotriomorphic-granular rock composed largely of irregular quartz and orthoclase, with some perthite and small plagioclase grains, and some larger, highly resorbed relict "phenocrysts" of oligoclase. Graphic and myrmekitic intergrowth is fairly common. There is accessory chloritised biotite (and hornblende) and opaque oxide.

P1258 Hornblende diorite

Medium-grained (generally less than 2 mm), highly fractured rock, comprising 75% marginally granulated and resorbed, subhedral plagioclase, showing good twinning and some alteration to sericite; 20% green hornblende with some alteration to chlorite; 5% strained interstitial quartz, and accessory sphene and opaque oxide.

A similar diorite from further north contains very minor chalcopyrite.

P1259 Porphyritic microdiorite

Occasional corroded phenocrysts of plagioclase (generally less than 1 mm long, but up to 2 mm) showing some alteration to sericite, in a fine groundmass of plagioclase, green hornblende and brown biotite, with abundant granular iron ore, minor pyrite, and very minor chalcopyrite. There is a faint flow foliation defined by the ferromagnesian minerals in the groundmass.

P1215 Quartz-plagioclase-hornblende semischist (description by C.D. Branch)

Hand specimen. Moderately dark grey fine-grained hornfels, with faint schistosity indicated by fine lenses of mafic minerals.

Thin section. The rock consists of a fine (0.02 mm), even-grained mosaic of quartz (25-30%), plagioclase (40%), and iron-ore (10-15%), surrounding lenticular patches of granular, green hornblende (20%). A few small plates of epidote, and ragged laths of biotite 0.01 mm long and pleochroic from pale yellow-brown to deep red-brown, accompany the hornblende.

This rock was probably a fine non-clacareous sediment. It has been metamorphosed to the albite-epidote-amphibolite facies mainly by thermal metamorphism, but the faint schistosity indicates a little contemporaneous shearing.

P1250 Albite - actinolite - quartz schist

Corroded relict phenocrysts of calcic plagioclase, with numerous small inclusions (often colourless amphibole) in a well foliated groundmass of plagioclase (? albite), colourless actinolite and quartz, with abundant granular iron ore, occasional brown biotite and green chlorite, and rare epidote. Occasional larger plagioclase grains have the appearance of poikiloblastic growths.

The foliation is fairly well defined by crystal orientation, and by a slight tendency for the ferromagnesian minerals to form bands.

The rock is a porphyritic basic volcanic which has suffered low-grade metamorphism under conditions of slight stress.

APPENDIX II

ORE MINERALOGY REPORT BY I. R. PONTIFEX

No. 1 (Vein material)

This specimen consists of irregular, skeletal grains of bornite and chalcopyrite, scattered through quartz. Malachite stains the rock and occurs in small patches within it. The copper minerals make up about 25% of the specimen.

In polished section the maximum dimension of the bornite grains was found to range from 0.3 mm. to 4 mm. The bornite is replaced around its grain margins, and along cracks and cavities within it, by narrow rims of chalcocite (0.01 mm. wide). It rarely contains small inclusions of chalcopyrite.

The chalcopyrite in the rock is more localised than bornite and it forms masses up to 2 cm. across. It generally contains irregular inclusions of, and is intergrown with, bornite.

Grains of chalcopyrite are replaced around their margins and along cracks by chalcocite. Some very small grains consist entirely of chalcocite.

A veneer of hydrated iron oxides commonly borders the out-side margins of chalcocite.

No. 2 (Mineralized vein in altered diorite)

This rock consists of an allotriomorphic crystalline aggregate of mainly quartz, (possibly a quartz pegmatite), which abuts against a grey, fine-grained, chloritised, biotite granite. The quartz aggregate carries skeletal grains of chalcopyrite, bornite and molybdenite. It is stained by malachite and hydrated iron oxides.

The copper sulphides make up about 10% of the quartz-rich part of the specimen, the molybdenite about 3%.

In polished section the chalcopyrite is found as fractured grains up to 3 mm. across. Generally it is replaced around grain boundaries and along internal fractures by colloform bands of hydrated iron oxides.

Bornite occurs in discrete grains, smaller than those of chalcopyrite, and less commonly as inclusions in, and intergrowths with, chalcopyrite. It is replaced around its margins by thin rims of chalcocite.

Molybdenite occurs in discrete grains up to 4 mm. across. These consist of aggregates of small micaceous clumps of this mineral.

Small cavities in the rock are lined by colloform bands of hydrated iron oxides up to 0.12 mm. wide. These probably have derived from pre-existing chalcopyrite grains.

No. 3 (Pegmatite dyke - see text page 9)

This specimen consists of discontinuous bands and elongate patches of coarse aggregates of sulphide minerals in quartz. It appears to be part of a fissure fill type of mineralised quartz vein.

In several polished sections the ore minerals and their approximate proportion were found to be:

tetrahedrite	55%
sphalerite	25%
galena	15%
chalcopyrite	accessory
chalcocite	"
covellite	"

The tetrahedrite has a distinctive cherry red streak which suggests that it has a low Fe content. It occurs in irregular masses which contain small inclusions of galena, sphalerite, and chalcopyrite; the latter two minerals frequently form composite grains. Fine stringers and patches of chalcocite, which are associated with lesser amounts of covellite, are scattered throughout the tetrahedrite. These have derived by the alteration of tetrahedrite along fractures and within small voids.

Several aggregates of short prisms of a non-opaque mineral also occur within tetrahedrite. These are possibly crystals of quartz (in drusy cavities) although their brilliantly colored internal reflections suggest that they are zircon.

The tetrahedrite is intergrown with masses of sphalerite in which it commonly intrudes cleavage planes and fractures. The sphalerite has a light brown color and an adamantine, semi-translucent lustre which indicates that it has a low Fe content. It rarely contains small inclusions of chalcopyrite and galena.

Galena most commonly fills interstices between, and cavities within, masses of tetrahedrite, sphalerite and ? drusy quartz. It frequently contains irregular inclusions of tetrahedrite and some is replaced around grain boundaries by small patches of chalcocite. The galena appears to have been introduced at a late stage in the formation of this ore mineral assemblage.

Chalcopyrite generally occurs as inclusions in the above mentioned sulphides but rarely it forms discrete grains in the quartz gangue.

The ore minerals are deficient in iron and no pyrite was found in the sections examined. On this basis it is pointed out that it is unlikely that surface weathering of the deposit which this rock represents would give rise to a gossan.

No. 4 (Disseminated ore. See also thin section P1214)

This specimen appears to be part of a water worn boulder of granite which contains patches and laths of chlorite (apparently after biotite) and skeletal grains of magnetite and bornite. It is stained with malachite and it is moderately magnetic.

The maximum dimension of the bornite and magnetite masses varies between 0.05 mm. and 5 mm.

The distribution of the ore minerals is erratic. In one section bornite forms about 7% of the rock and magnetite about 7%. In another, bornite forms about 2% and magnetite about 12%.

These minerals occur both as discrete patches and as composite grains.

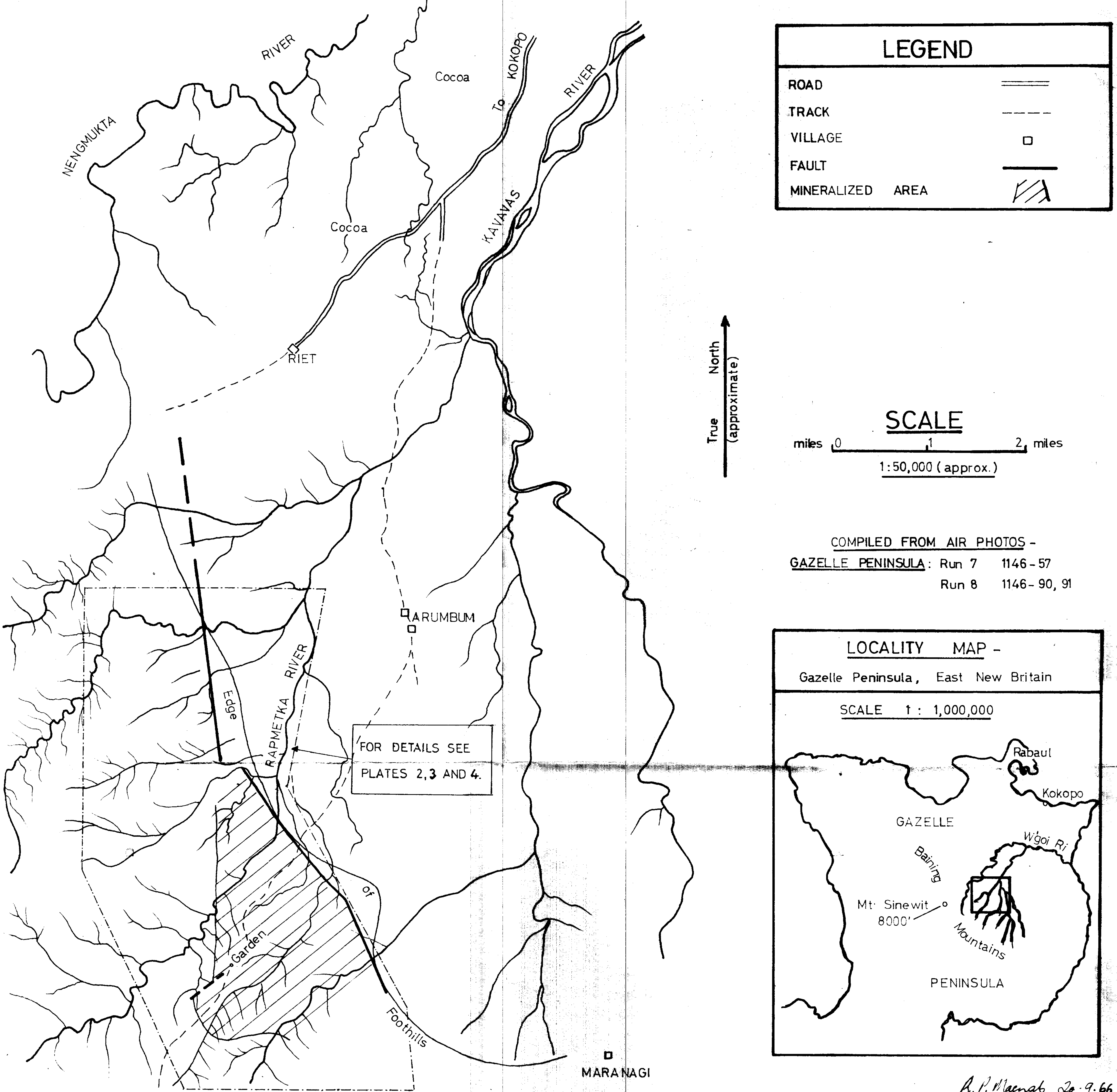
The bornite is altered around its grain margins and along fractures to chalcocite.

The magnetite, which is titaniferous, is replaced by patches and rims of hematite around part of its grain margins and along abundant internal fractures.

PLATE 1

PNGB56-2-9(amended)

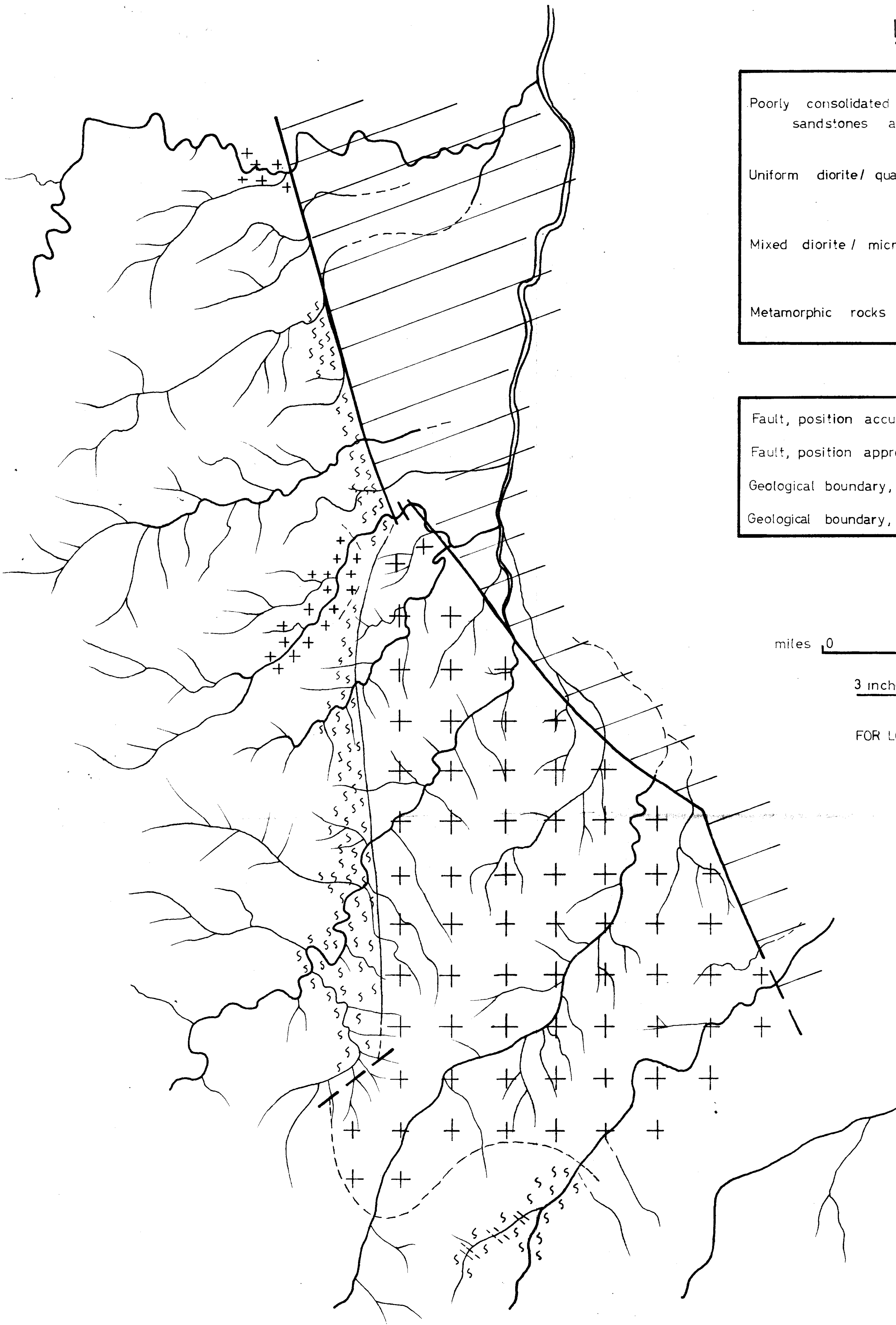
LOCALITY MAP, UPPER WARANGOI ORE MINERALIZATION



A. P. Macnab 20-9-66

PLATE 2 PNGB56-2-10

GEOLOGICAL MAP, UPPER WARANGOI AREA



LEGEND

Poorly consolidated claystones, siltstones sandstones and conglomerate	[diagonal lines]
Uniform diorite / quartz diorite	+
Mixed diorite / microdiorite	+ + +
Metamorphic rocks	s s s

Fault, position accurate	——
Fault, position approximate	— — —
Geological boundary, accurate	——
Geological boundary, approximate	- - - - -

scale

miles 0 1/2 1 miles

3 inches to 1 mile (approx.)

FOR LOCALITY SEE PLATE 1.

true north (approximate)

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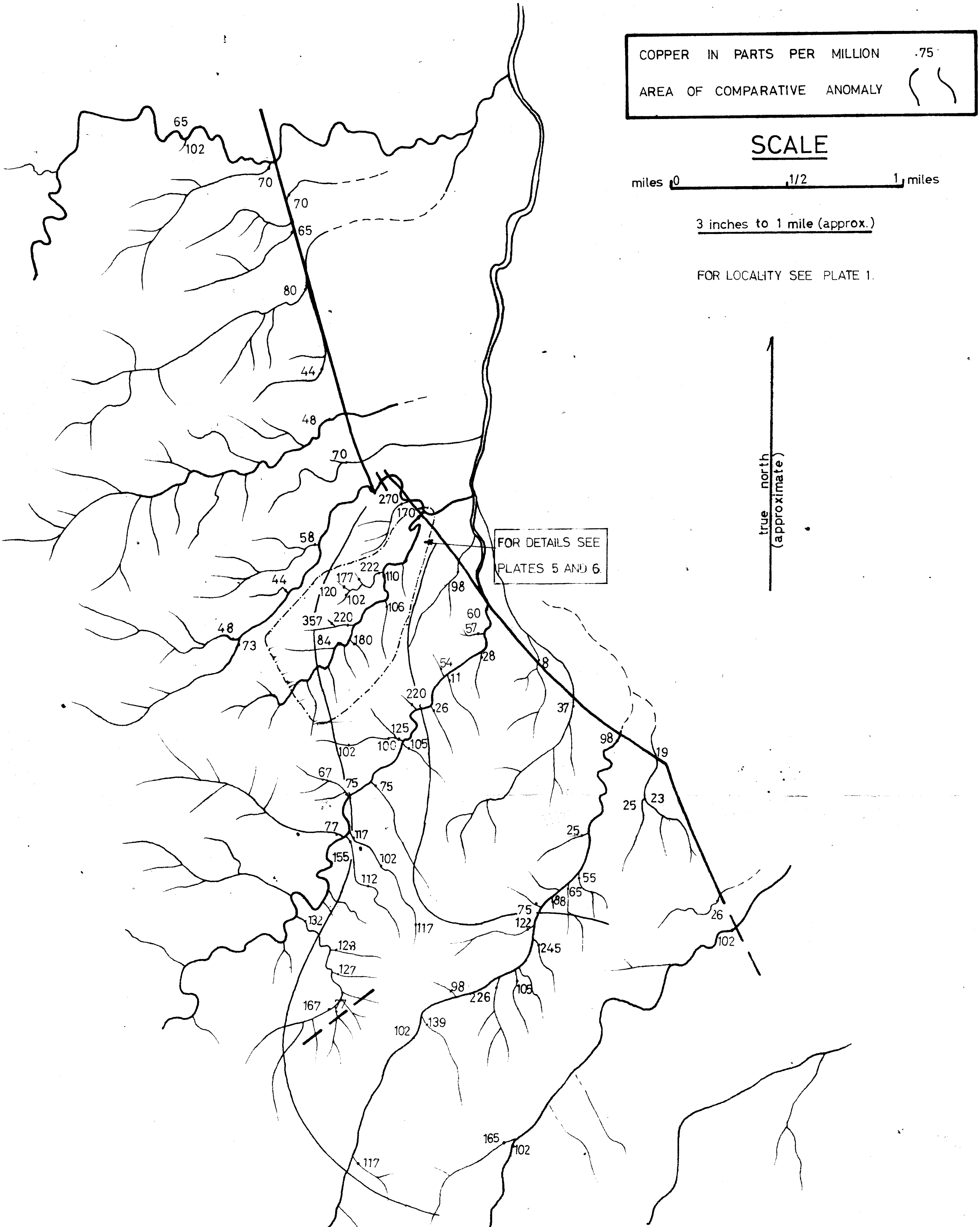
PLATE 3

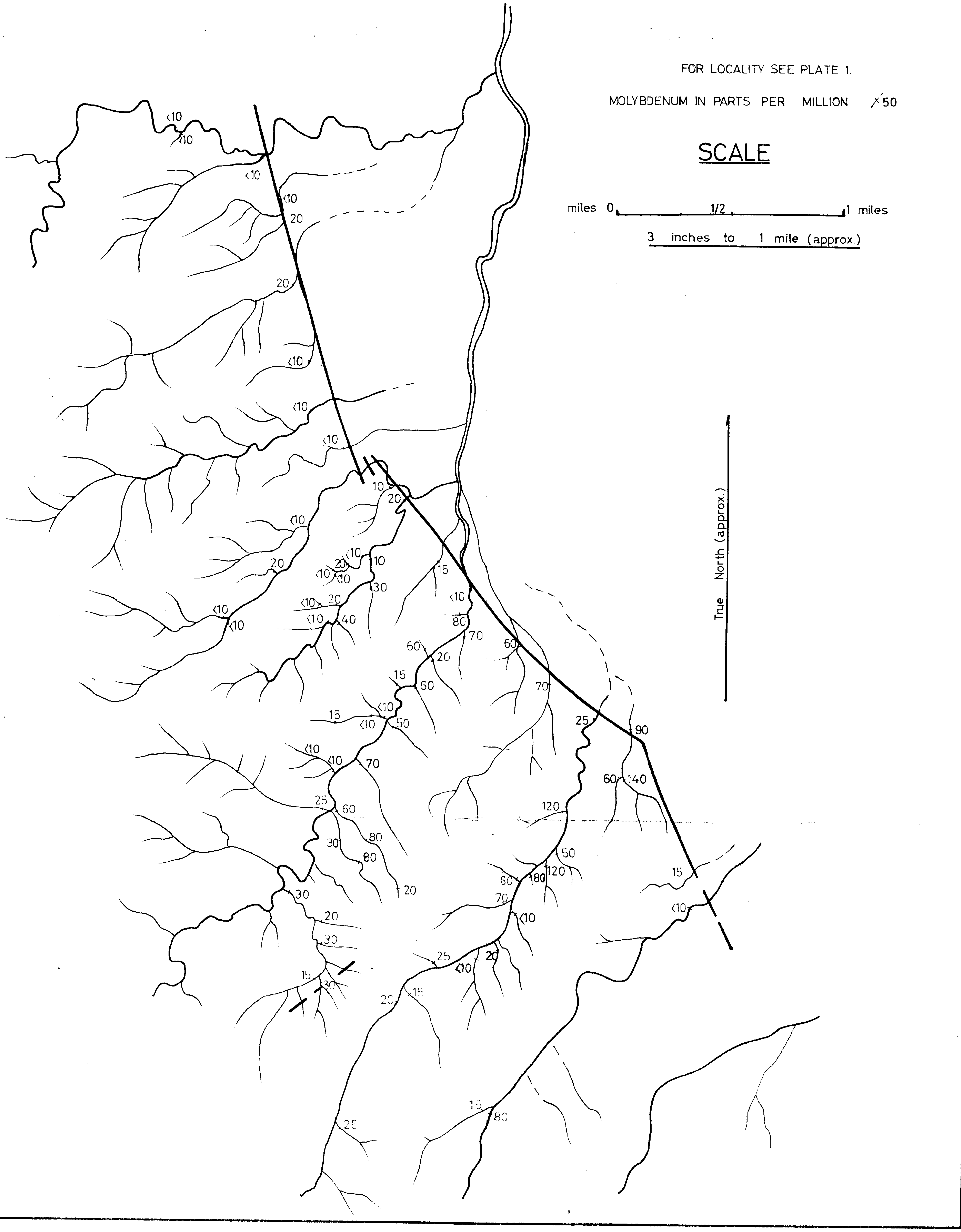
PNGB56-2-11

STREAM SEDIMENT SAMPLES - ANALYSES FOR COPPER



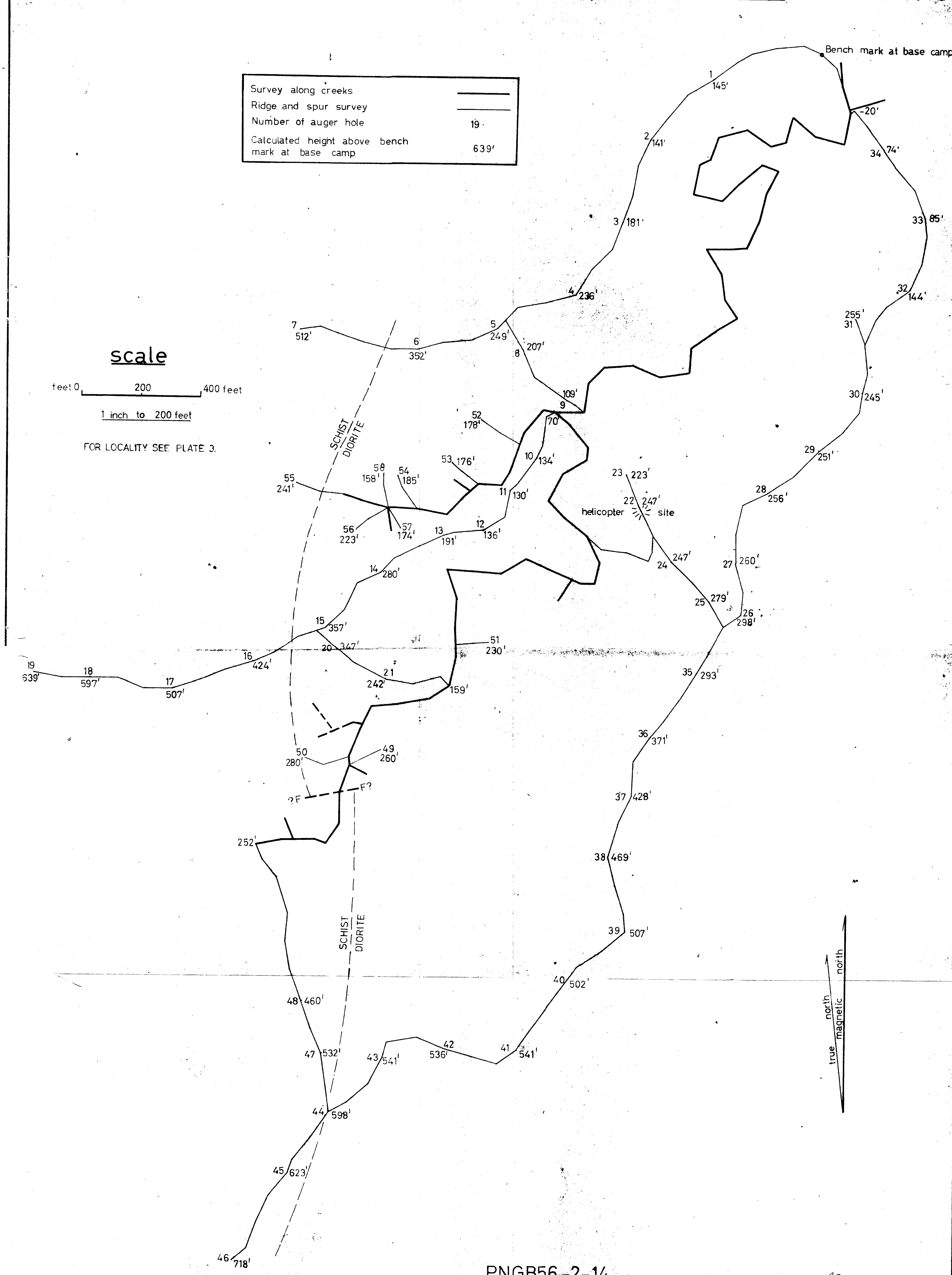
R.P. Macnab 20.9.66

STREAM SEDIMENT SAMPLES - ANALYSES FOR MOLYBDENUM



UPPER WARANGOI AREA - SOIL SAMPLE LOCALITY MAP

PLATE 5



PNGB56-2-14

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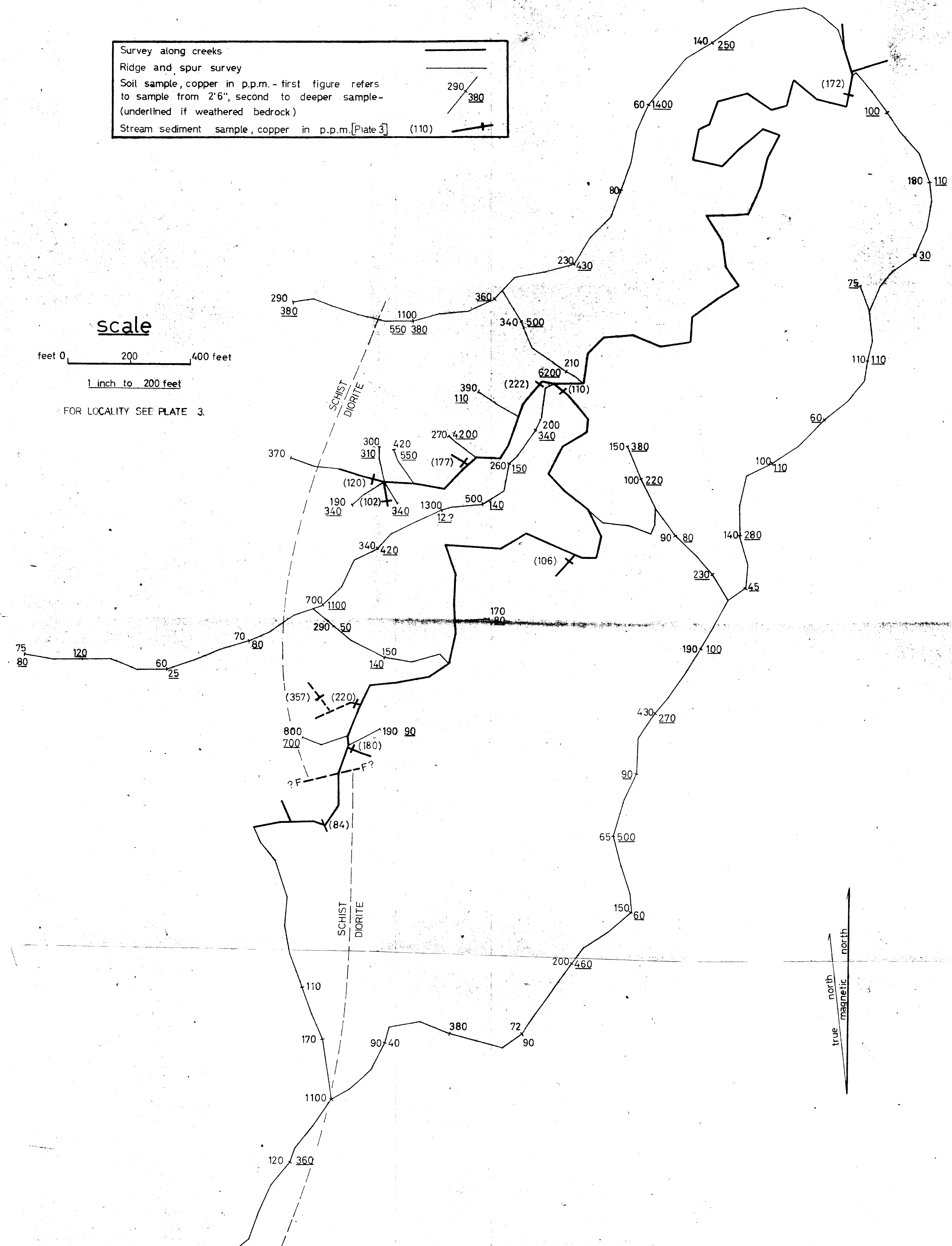
PLATE 6 SOIL SAMPLES – ANALYSES FOR COPPER



PNGB56-2-13

21.12.66