A STUDY OF THE MINERALISATION AT THE KITTICOOLA COPPER MINE, PALMER S.A.

by

R. L. Thompson

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ABSTRACT:

The Kitticoola Copper and Gold Mine near Palmer, is one of a number of such occurrences in the Mount Lofty Ranges, South Australia, but differs from the norm in that it is located within a granitic host rock, intrusive into lower Palaeozoic meta-sediments of the Kanmantoo Group.

In this study, field relationships, together with mineralogical studies of the ore and associated hydrothermal alteration are outlined and suggestions put forward as to sequences of formation.

Geochemical studies including soil sampling and rock, gossan and ore analyses are also presented together with conclusions pertaining to exploration.

I INTRODUCTION:

Location

The Kitticoola Copper and Gold Mine is situated 2 miles south of Palmer, which is 41 miles from Adelaide, on the eastern side of the Mount Lofty Ranges, South Australia (fig. 1 inset A). The area under study is shown in fig 1 (inset B).

Since 1845, the mine has been worked extensively for both copper and gold by a succession of companies and syndicates. At the present time it is owned by Kitticoola Mining Company, a joint venture between Sturts Meadows Prospecting Syndicate N.L. and John McIlwraith Industries Ltd. This study has been undertaken in conjunction with underground exploration and I.P. surveys carried out by the Company's consultants, McPhar Geophysics Pty. Ltd.

Aims of the Investigation

Essentially the study is an attempt to determine relations between the geology, geochemistry and ore distribution within the area. A discussion of observations arising from field mapping; macroscopic and microscopic petrography; ore mineralogy; soil, rock and ore chemistry, and pH data is presented in this report. The observations possible are necessarily limited, but may be important in any extension of studies in the region.

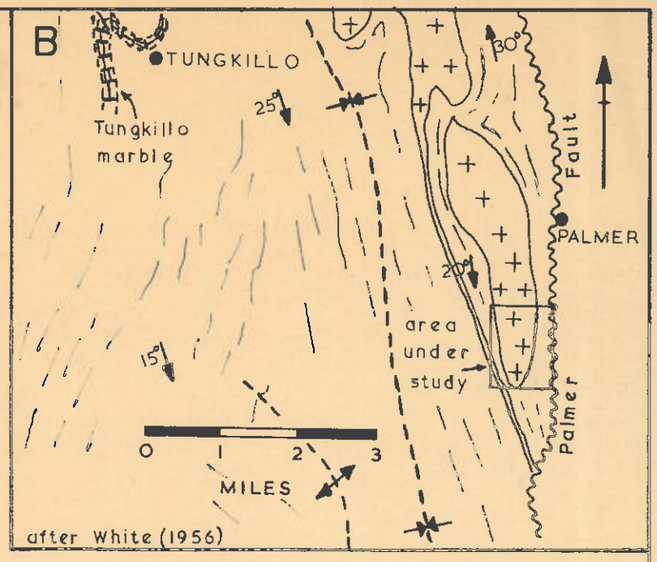
GURE I

GEOLOGICAL MAP

of the area near

THE KITTICOOLA COPPER AND GOLD MINE

PALMER S.A



ZONE

to Palmer

FAULT

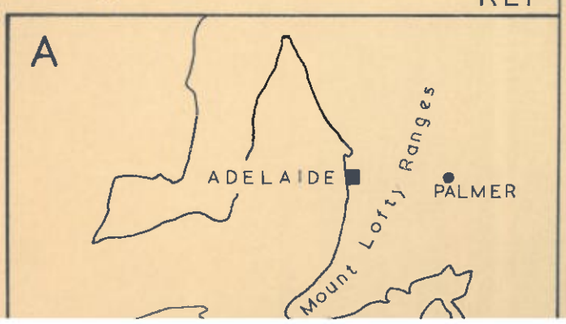
PALMER

Peedy Ck

RLT

EFERENCE

- Granite
- Migmatite
- Granitic gneiss
- Amphibolite
- Quartzo feldspathic schist and gneiss (micaceous)
- geological contact observed
- inferred
- shear zone
- compositional banding
- lineation
- strike and dip



Previous Investigations

Regional geological studies of the Palmer Granite and associated metamorphic rocks have been made by Rattigan and Wegener (1952); White (1956), (1966); and White, Compston and Kleeman (1967). Reports on the Kitticoola Mine by geologists of the S.A. Department of Mines appear in issues of Mining Review. Summaries of the mine development are presented by Brown (1908), Jack (1914), Hughes (1953) and Johnson (1965). Mines Department drilling, carried out from 1937 to 1938, failed to find significant intersections of ore at depth, in some of the lodes. Thus far, no specifically detailed surface geological work within the vicinity of the mine has been carried out up till the present time.

2. REGIONAL GEOLOGY:

The mine workings are situated within a granitic host rock: the Palmer Granite. This is a small, regionally conformable body which occurs in association with migmatites and high grade schists and gneisses in the metamorphic belt flanking the eastern Mount Lofty Ranges. Rb/Sr dating provides an age of 490 ± 15 m.y. for the granite (White 1967). The granite occurs within metasediments of the Kanmantoo Group of lower Palaeozoic age. (Johnson, 1965). Within the Palmer region the rocks of the Kanmantoo Group consist chiefly of quartzo feldspathic schists and gneisses with

marbles and calc-silicate rocks near the base and a marker horizon of pyritic schist, (Nairne Pyrite Formation), high in the sequence,

3. STRUCTURAL SETTING:

Structurally, the rocks of the Kanmantoo Group are folded into a series of open synclines and anticlines plunging gently in a S.S.E. direction, the plunge of the folds varying from 20° to 35°. The metamorphism is presumed to have taken place during an early Palaeozoic orogeny. The Palmer Granite intrudes the eastern limb of a major syncline (fig. 1 inset B); the west and east contacts between metasediments and granite dipping at 50° to 60°.

To the east of the Palmer Granite lies the Palmer Fault which has a westerly dip north of Palmer, the dip within the vicinity of the mine being unknown but presumably westerly (White, 1956). It has been suggested that the Fault follows a Palaeozoic line of weakness along which further movement has occurred in Tertiary times (Fenner, 1930).

4. LOCAL TOPOGRAPHY:

In the mineralised region in the southern section of the granite, bare rounded hills rise to a height of 200 to 400 feet around the extensive gully of Reedy Creek (Plates 1 and 2). The enclosing metasediments to the west

of the granite rise to greater heights while the eastern edge of the area is delineated by the Palmer Fault scarp.

5. LOCAL GEOLOGY:

Within the area studied the following rock types have been recognised, (figures 1 and 2).

(a) granite

(b) migmatite

(c) granitic gneiss

(d) amphibolite

(e) quartzo-feldspathic schist and gneiss - micaceous and transitional to migmatites.

Field Relationships

The granite has been intensely shattered due to the presence of the Palmer Fault, the intensity being greatest east of Reedy Creek. As well, shear zones along the E. and S.W. portions of the contact have given rise to a strongly developed foliation within the granite.

The southern extremity of the granite is more siliceous in composition and shows obvious deformation characteristics as well as being inhomogeneous. Here included lenses of the quartzo-feldspathic envelope rocks are intermingled with the granite. It seems likely that the greater silica content in this southern section is due to the later residual fluids of the crystallising granite.

It is notable that the grain size decreases and the deformation characteristics become more apparent towards the contacts, with a corresponding increase in mica content also.

The contact of the granite and metasediments would be better described as a zone, as lenses of granite and associated quartzo feldspathic appear to be intermingled, these lenses being too small to be shown in fig. 2. This is not to be confused with the minor scale veined granitic gneisses described by White (1956).

Most important however, is the development of two sets of fracture systems within the granite, one set striking NNE/W with a dip 60°W and the other set WSW with a dip 60°N. This has resulted in the structural control of mineralisation at Kitticoola.

Migmatite boulders occur within the beds of Reedy, Talbot's and Harrison's Creeks (fig.2), but these are presumed to be displaced from their place of origin (Plate 3). However mixtures of granite and migmatite occur away from the creek beds in what appear to be in situ cases. Here strikes of the foliation surfaces of the migmatites have been found to correspond with those of the enclosing quartzo feldspathics and migmatites. Generally though the extent of soil near the creeks prevents

any clear determination as to the extent of the migmatite boulders and float (as shown by the inferred limits in fig. 2).

To the west of the granite contact zone lies a thin strip of granitic gneiss approximately 200 feet in width. This is the southerly extension of the Rathgen Gneiss (White 1956 and 1966), the main body of which occurs to the north of Palmer. No investigation of it other than noting its field occurrence has been made.

Along the western and eastern contact zones of the granite lie a number of discontinuous lenses or pods of amphibolite their strike corresponding to that of the envelope rocks although there is a possible discordance in some instances. These occur either within the granite itself or within the quartzo feldspathic envelope rocks. These lenses of amphibolite show degrees of shearing or deformation varying from nil to strongly crystalloblastic textures. Usually associated with the amphibolite pods along the contact zone are occurrences of a near surface capping of "kunkar" or caliche. Where this occurs the amphibolite is also noted to have a bleached appearance presumably from the introduction of later quartz and carbonate.

The occurrence of the amphibolite lenses as shown in figures 1 and 2 is an oversimplification, as the many minor changes in size, extent and occurrence, over distances of a few feet are too small to be exhibited correctly. Because the amphibolites occur in shear zones, it is probable that the lenses are more dissected than is depicted on the map.

The positions of the amphibolite lenses on the western and eastern contacts relative to each other, and the occurrence of amphibolite as separate bodies within the granite, suggests that they may have originally been part of a whole.

Close to the contact the envelope rocks have more of the appearance of quartzo feldspathic schists and gneisses, than migmatites. In a sense these rocks are transitional to the latter, but since they exhibit differences in texture and composition, a less restrictive term than migmatite seems appropriate. For example, a thin band of feldspathic quartzite, occurs along the western and eastern contacts of the granite. This unit is not shown in fig. 2 because of its small extent. Occurrences of true migmatite and veined gneiss are best developed in the S.W. portion of the area, surrounding the thin strip of Rathgen granitic gneiss.

The extensively sheared eastern contact due to the imbricate zone associated with the Palmer Fault (White, 1956) also contains minor faults originating in the quartzo feldspathic rocks and passing into the granite. They are characterised by a high content of biotite and chlorite, and minor occurrences of mylonite.

Mineralogy.

Macroscopically the granite is massive, holocrystalline and medium to coarse grained, with a gneissic texture. Plagioclase is opaque white to green, due to sericitisation, whereas microcline has a pinkish red appearance. Both feldspars exhibit excellent cleavage and quartz has a clear vitreous lustre. The granite is penetrated by microfractures along which muscovite occurs.

Microscopically it appears that microcline (including potassic feldspar intergrowths), and plagioclase (oligoclase), are in equal abundance. Perthitic-antiperthic intergrowths are occasionally developed. Quartz shows undulose extinction and biotite is replaced by muscovite. Minor magnetite, ilmenite, rutile, zircon and traces of sphene are present. The dominant texture is allotriomorphic granular and the granite is best described as an altered adamellite.

The migmatite is fine grained and consists of plagioclase (oligoclase), potassium feldspar as microcline, biotite in prismatic laths which are well formed and show a strong preferred orientation, and quartz which shows evidence of strain.

The essential minerals of the amphibolite are hornblende and plagioclase (andesine), the latter occasionally occurring as porphyroblasts. The hornblende has a classical pleochroism (Williams et al 1954, p242) with X = light yellow green, Y = greenish brown, Z = deep blue green; and rarely is twinned. Plagioclase occasionally sericitised, exhibits twinning, the complexity of which decreases to that of simple twins in strongly sheared rocks. Biotite and quartz are minor and sphene invariably surrounds magnetite in reaction rims. The rock is fine grained and textures vary from relict ophitic and intergranular, to poikiloblastic and equigranular, according to the degree of shearing and deformation. The original rock was basic and probably doleritic.

The quartzo feldspathic schists and gneiss is fine grained, and consists of quartz, plagioclase (albite-oligoclase), microcline and biotite. The latter often shows a strong degree of orientation. Minor zircon and magnetite are also present. Along the contact zone muscovite is often intergrown with biotite in ragged laths, limonite being

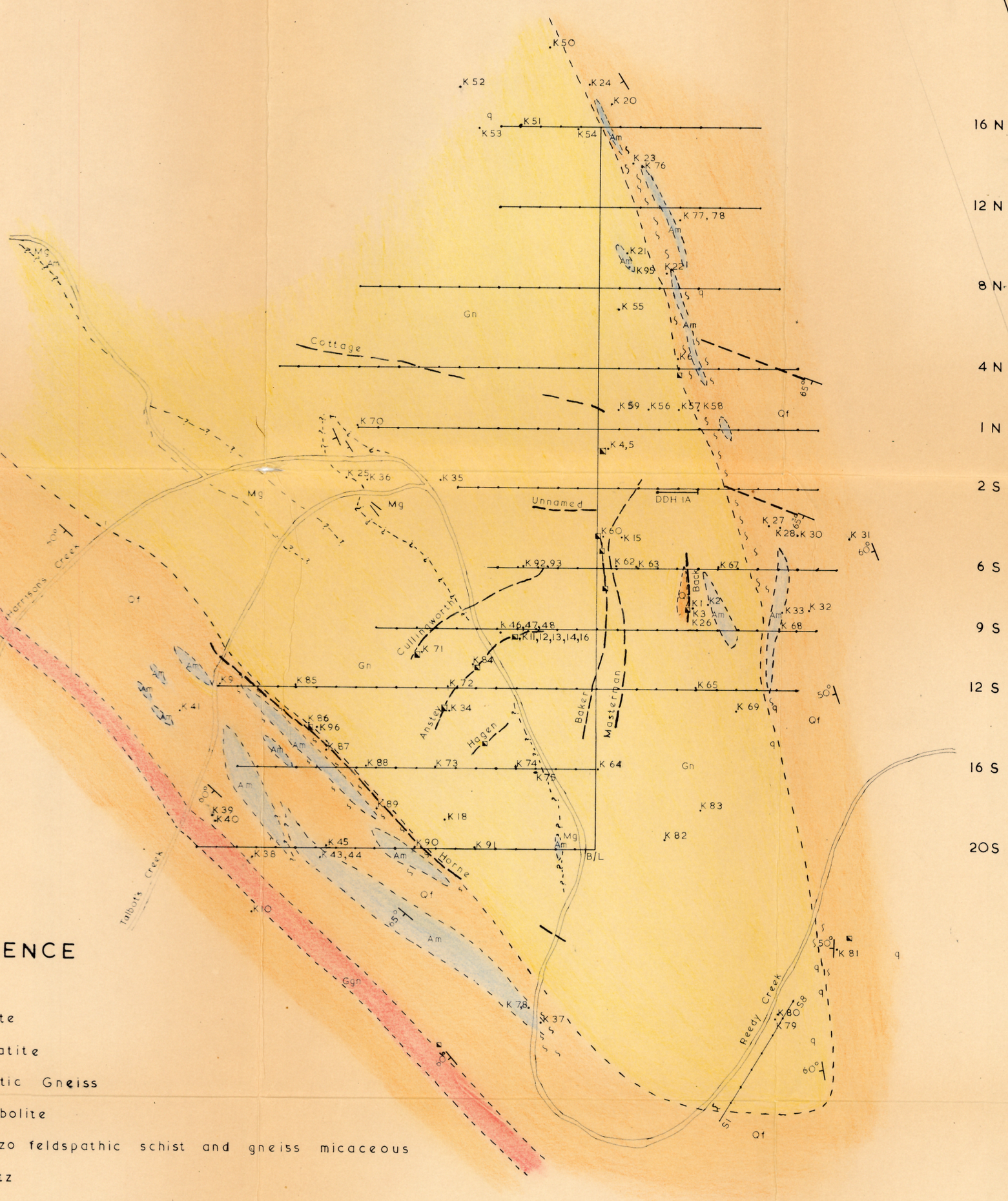
FIGURE 2

GEOLOGICAL (AND SAMPLE LOCATION) MAP

of the area surrounding the

KITTICOOLA COPPER MINE

Palmer S.A.



REFERENCE

- Gn — Granite
- Mg — Migmatite
- Ggn — Granitic Gneiss
- Am — Amphibolite
- Qf — Quartzo feldspathic schist and gneiss micaceous
- q — Quartz
- Hagen — Lode
- Geological contact
- -?-?-? — inferred limits
- Fault
- Shear zone
- Strike and dip
- Shaft
- •K 56 — Rock sample location
- 12 N — Grid line
- S1 to S8 — Soil sample traverse
- DDH 1A — Diamond drill hole

SCALE

0 500 1000 2000

feet

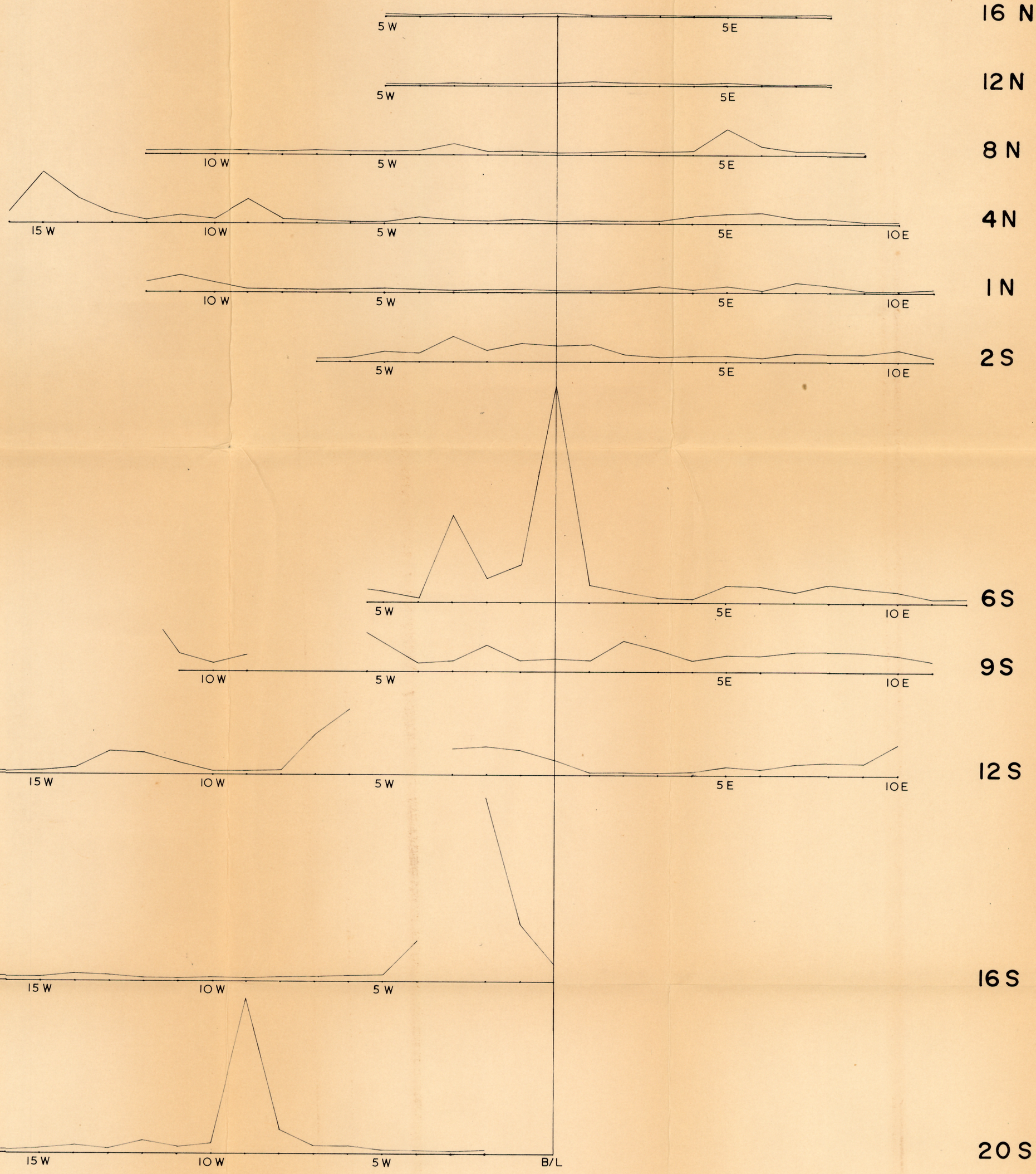
October 1970

RLT

FIGURE 3

GEOCHEMICAL PROFILES FOR COPPER

Kitticoola Copper Mine Palmer S.A.



Horizontal Scale

0 500 feet

Vertical Scale

0 500 1000 ppm

Note Profiles discontinuous across Reedy Creek

October 1970

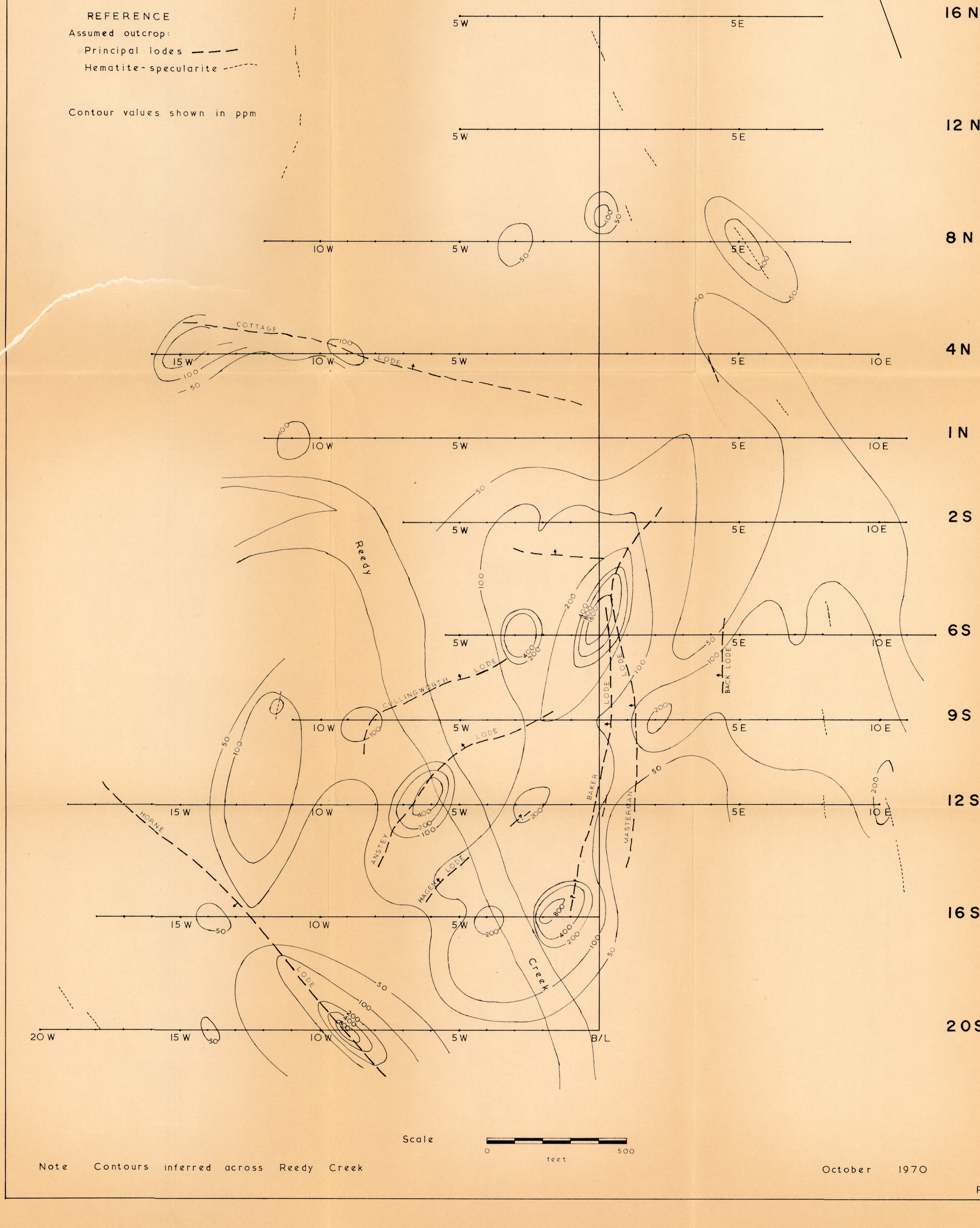
RLT

FIGURE 4

GEOCHEMICAL CONTOUR MAP FOR COPPER

KITTICOOLA COPPER MINE

Palmer S.A.



Note Contours inferred across Reedy Creek

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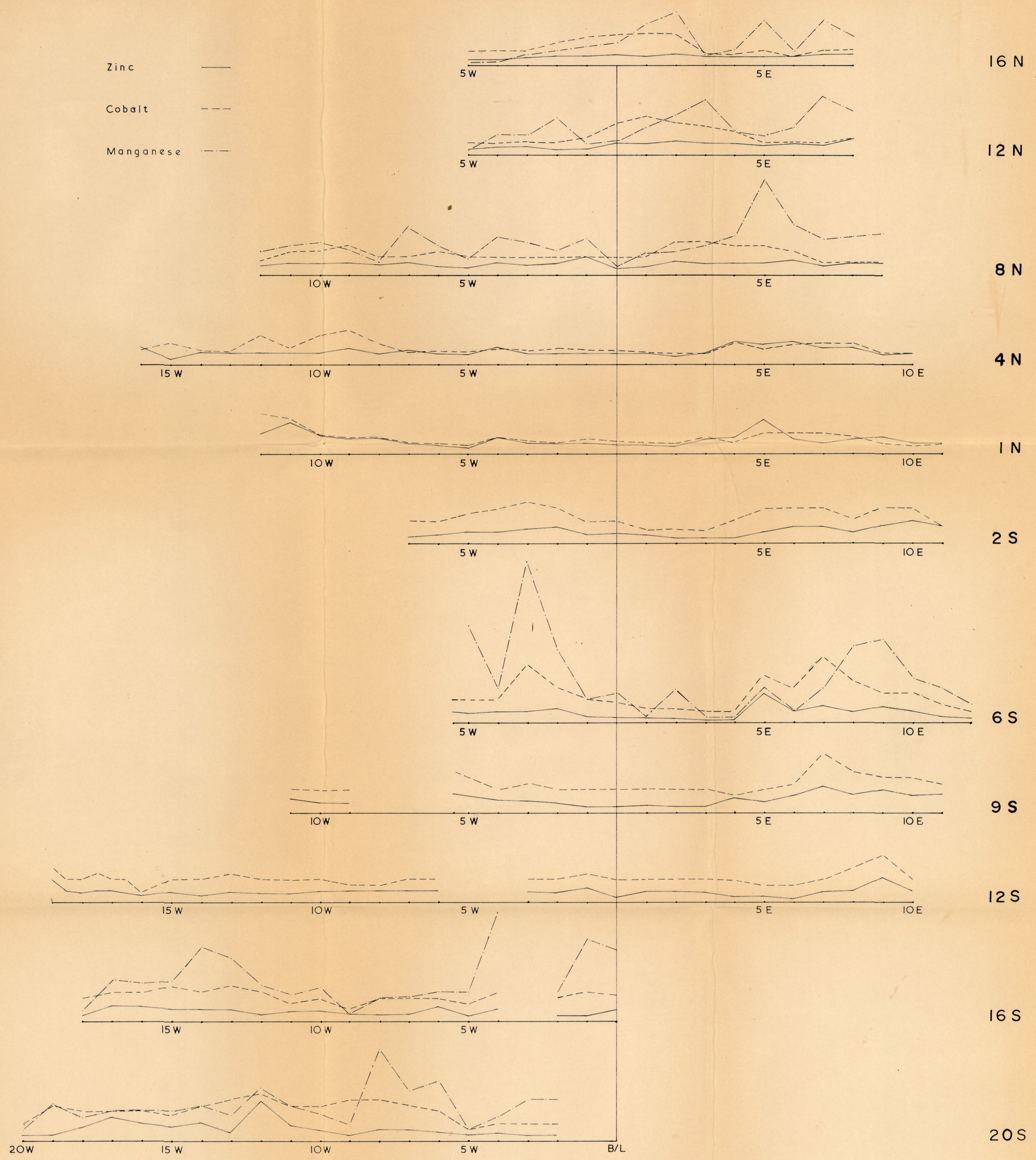
FIGURE 5

GEOCHEMICAL PROFILES FOR ZINC, COBALT, MANGANESE

Kitticoola Copper Mine

Palmer S.A.



Horizontal Scale 0 — 500 feet

Vertical Scale Zinc and Cobalt 0 — 50 — 100 ppm

Manganese 0 — 500 — 1000 ppm

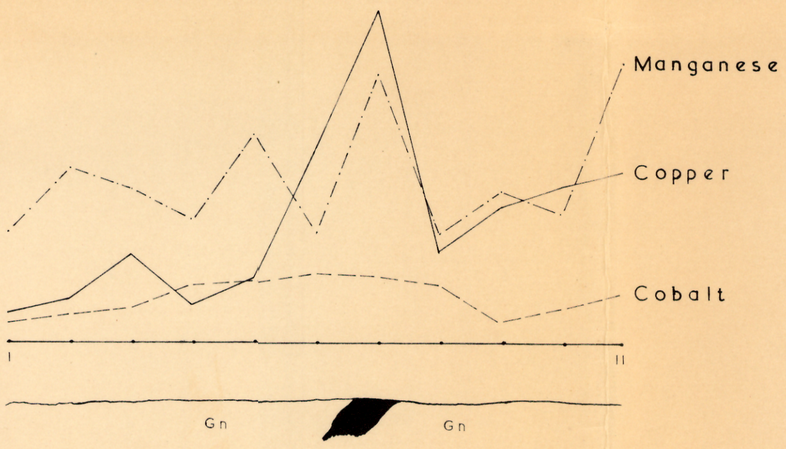
Note Profiles discontinuous across Reedy Creek

October 1970

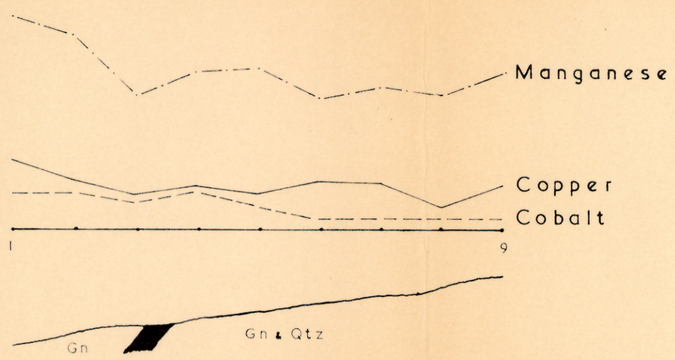
RLT

FIGURE 6

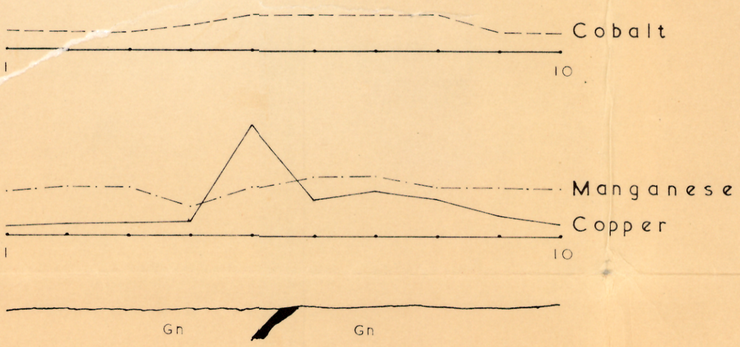
A ANSTEY LODE 9·5S 4W



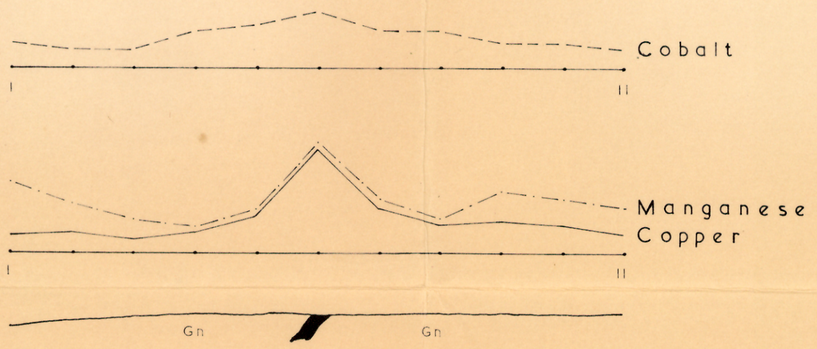
B BAKER LODE 7S 0·5E



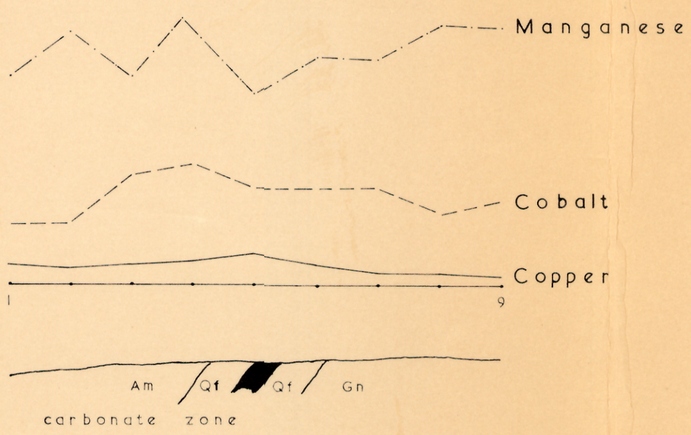
C ANSTEY LODE 14S 8W



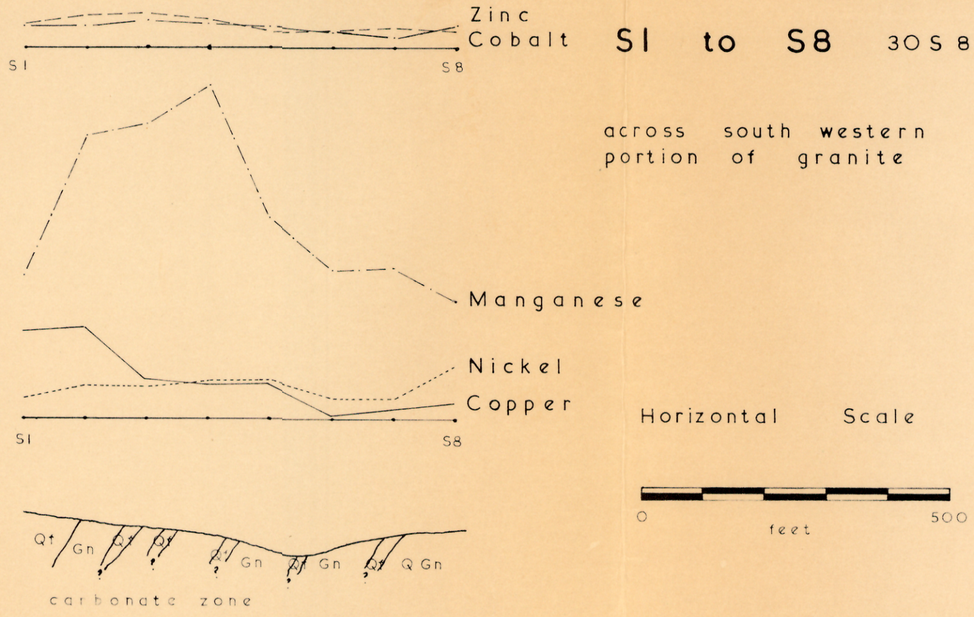
D HAGEN LODE 15S 5W



E HORNE LODE 16S 12W



F S1 - S8



GEOCHEMICAL SOIL SAMPLE TRAVERSES

INCORPORATING CORRESPONDING
GEOLOGICAL SECTIONS
(schematic only)

KITTICOOLA COPPER MINE Palmer S.A.

REFERENCE

- Gn — Granite
- Am — Amphibolite
- Qf — Quartzo feldspathic schist micaceous
- Lode

16S 12W Location of traverse shown thus

Horizontal Scale — traverses A to E only

0 5 10 20
feet

Vertical Scale — traverses A to F

Cobalt Zinc Nickel

0 50 100
ppm

Copper Manganese

0 500 1000
ppm

October 1970
RLT

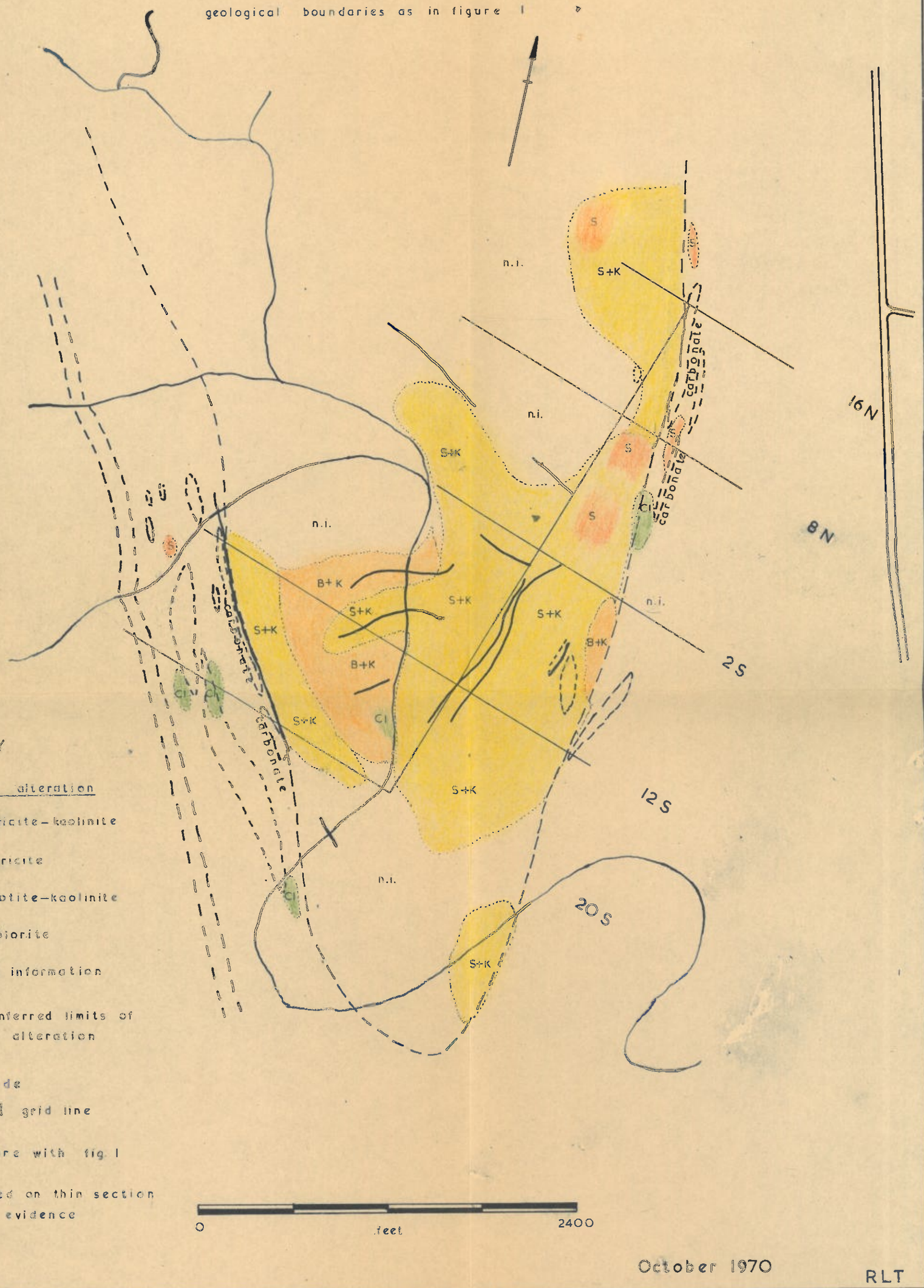
FIGURE 7

sketch map of the limits of hydrothermal alteration at

KITTICOOLA COPPER MINE

Palmer S.A.

geological boundaries as in figure 1



KEY

dominant alteration

- S+K sericite–kaolinite
- S sericite
- B+K biotite–kaolinite
- Cl chlorite
- n.i no information
- inferred limits of alteration
- lode
- 16N grid line

compare with fig 1

based on thin section evidence

0 feet 2400

October 1970

RLT

exsolved parallel to the cleavage directions.

6. HYDROTHERMAL ALTERATION:

Obviously the best method of determining the sequence and pattern of hydrothermal alteration when present, is by establishing some means of control, such as the study of drill core in conjunction with surface geology. Notwithstanding this, approximately fifty rock specimens of the granite together with wall rock from the mine workings, have been studied to try and establish some indication as to the nature of the alteration.

The zone of alteration extends from the southern portion of the granite to at least the northern limits of the mapped area, as shown in fig. 7, alteration being more intensive within the main area of mineralisation east of Horne lode.

The most abundant alteration constituent is sericite, the term here being used to denote a very finely divided colourless to pale green mica (muscovite?) occurring in scaly and shred-like masses. The sericite preferentially replaces plagioclase, the degree of alteration varying from incipient development along cracks and cleavage planes to the formation of complete pseudomorphs with no trace of original twinning. When it is most intense as in the latter case, the sericite becomes coarser in grain size and may form muscovite. This commonly occurs in the vicinity of

the lodes, and in shear zones.

Kaolinite, of lesser abundance than sericite, usually forms as an amorphous clay-like alteration product of K-feldspar. X-ray diffraction studies of the kaolinite would accurately determine the composition of this mineral; however Deer et al (1966, p259), indicate that the rocks which alter to kaolinite are usually the more acid types (granite, quarts diorites, etc.) while calcium- or sodium-rich rocks generally yield montonorillonite. Until proved otherwise the use of the term therefore seems justifiable.

Where sericite and kaolinite occur in an intermixed fashion, sericite replaces the kaolinite. This is further demonstrated by instances of muscovite replacing kaolinised feldspar and of associated quartz and kaolinite in veinlets. Where sericitisation is intense, generally kaolinisation is of minor extent, (and the proportion of K-feldspar is less).

Quarts is ubiquitous in all of the specimens studied. It occurs in two separate phases, (a),as euhedral shaped crystals with hexagonal and pseudo hexagonal cross sections (e.g. DDH 1A thin sections) and (b), as small anhedral grains associated with fine scaly sericite, especially in specimens of the oxidised ore.

Carbonate and/or quartz in veinlets is observed to penetrate earlier kaolinite, sericite, and potassium feldspar. In surface specimens it is of limited occurrence however, being observed in amphibolite and some quartzo feldspathics occurring in the shear zones; and as carbonate "blows" (e.g. 11.5N 4E), in isolated instances.

As can be seen from the table of specimens in Appendix 1, there is a variation in perthite-antiperthite and microcline content within the granite.

Microcline, quartz and plagioclase exhibit textural relationships that could be interpreted as replacement by microcline and the same observations on the northern section of the granite led Battigan and Wegener (1951) to cite textural features as evidence for granitization.

White (1967) notes that perthite is virtually absent in the northern section of the granite. Williams et al (1954, p133) have remarked that perthite may form as a product of deformation, especially where associated quartz shows the effects of strain. Hence it is probable that deformation may be responsible for the formation of the perthite-antiperthite intergrowths observed.

Chlorite occurs sporadically in intergrowths with muscovite and biotite in shear zones (e.g. BDH 1A/4, 1A/5 and K37). It also occurs with muscovite and with ankerite in veinlets penetrating sericite.

Biotite is virtually absent within the area east of Reedy Creek, but occurs either fresh or partly replaced by chlorite and/or muscovite west of Reedy Creek. As an aside to this the plagioclase associated with the biotite is less sericitised and has more euhedral character than its counterpart in the eastern half.

Further to this, White(1967) notes that biotite occurs perfectly fresh in the northern section of the Palmer Granite.

Opaques and minor minerals as mentioned previously include hematite, magnetite, rutile, ilmenite, leucoxene, zircon and sphene.

In summary it appears that kaolinite was followed by sericite and quartz and later carbonate with chlorite. From the above observations it is difficult to classify the pattern of alteration into the types advocated by Meyer and Hemley (1967) and Creasey (1966), as characteristics applicable to (a) argillic, (b) sericitic and (c) propylitic alteration are exhibited. A complete resume of these types of alteration is not attempted here but the following points are worthy of mention. The absence of orthoclase and/or microcline as recognisable veinlets or rims around relict feldspar appears to rule out potassium silicate alteration, even though iron bearing carbonates and

intergrown chlorite and biotite are some diagnostic features of this type. Both potassium silicate and propylitic types of alteration have associated ore assemblages in which the sulphur to metal ratio is intermediate to low. Propylitic alteration commonly involves chloritisation and carbonatisation with low metal to sulphur ratios, whereas sericite, quartz and pyrite are prominent phases in sericitic alteration. Argillic alteration is self explanatory (Meyer and Hemley 1967). Possibly the sequence may have been argillic followed by propylitic alteration, but there is insufficient field data to confirm this. For comparison, examples of porphyry coppers are presented in Appendix 9.

7. GEOLOGY AND THE LODE SYSTEMS:

Nine lodes outcrop in the area occupying one or the other of the two sets of fractures previously mentioned (see Fig. 2). All of the lodes have been worked for copper and/or gold. As well as the principal lode systems, there are a number of minor centres of mineralisation distributed both within the granite and adjacent to the contacts. Specular and micaceous hematite pervades the whole granite penetrating along joint planes and fractures.

The westernmost lode is Horne lode and this is exposed at intervals over approximately 3000 feet. The

The hanging wall is comprised of amphibolite and quartzo feldspathic schists while the footwall is granitic. The eastern contact is similar in lithology and associated mineralisation, but the latter is of lesser extent and is more sporadic. The carbonated zones associated with both contacts have been mentioned previously.

The Back lode is rich in copper carbonates (azurite and malachite) and appears to have been located along an elongated remnant of quartzo feldspathic schists included in the granite.

The other lodes all occur within the granite, and a description of the mine workings is not attempted here, full details being given by Brown (1908) and Jack(1914). The latter notes the existence of strike faults which dip as a general rule a little more steeply than the lodes, within the Baker-Masterman lode systems. These faults are marked by "filling of kaolinised material, several feet in thickness". Minor faults and fractures are also characterised by an abundance of chlorite and mica.

8. ORE MINERALOGY AND RELATIONSHIPS:

The primary ore consists of chalcopyrite, pyrite and hematite (specularite), with carbonate (ankerite), quartz and sericite as gangue minerals. Minor bornite has been reported also in issues of Mining Review, but this may have been mistaken for tarnished chalcopyrite.

The oxidised ore is composed of quartz, limonite, carbonates and oxides of copper, together with specular hematite and finely subdivided gold. Native copper has occasionally been reported (Hughes 1953), and vugs with crystalline quartz are common.

The partially oxidised primary ore consists of pyrite, specularite, chalcopyrite and cellular limonite with boxwork structures. The cellular pattern is distinctly angular with ribs of silica and limonite forming a coarse boxwork containing finer broken webwork, and minor fluffy, pulverulent limonite. Using the criteria of Blanchard (1968), the limonite would be classified as indigeneous i.e., precipitated within the cavity formerly occupied by the mineral. The majority of the boxwork would appear to be due to chalcopyrite oxidising in a moderately strong neutralizer, the amount of fluffy cellular sponge being small.

From observation of the lode outcrops it appears that the amount of ankerite in the Anstey, Hagen and Cullingworth lodes is proportionately greater than for the Baker-Masterman lodes. Whether this generalisation has any genetic implications, or is purely a function of erosion level, remains to be elucidated.

Examination of hand specimens and thin sections reveals that the relative quantity of pyrite in the primary ore is less than that of chalcopyrite and specularite. On this

basis the ore can be classified as being poor in sulphur. The lack of supergene sulphides in the ore can be partially attributed to this relative paucity of pyrite as well as to a moderately neutralizing gangue (Anderson, 1955).

The chalcopyrite and pyrite both occur in aggregated grains, rather than in a disseminated form. The specular hematite occurs in blades and laths which can form massive close packed accumulations of small micaceous plates.

To establish whether the carbonate exhibits any differences in composition, twenty five thin sections of primary ore and surface rock specimens were stained according to the method of Evamy (1963) (Appendix 1). The ore specimens have a constant ankeritic composition but carbonate from rock specimens on both west and east amphibolite - quartzo feldspathic-granite contacts, appear to be a mixture of ankerite and ferroan dolomite.

The following is a discussion of ore, gangue and wall rock relationships as observed in hand specimen and thin section.

Quartz occurs in two forms (a), as euhedral crystals with hexagonal and pseudo-hexagonal outlines in cross section and elongate in longitudinal section, and (b), as fine grained anhedral quartz in a mosaic. The euhedral quartz has perfect extinction while that of the fine grained variety is undulose. The perfect, euhedral, type may also be fully or partially enclosed by ankerite,

chalcopyrite or later quartz.

The specularite can also occur in two forms: (a), the majority as coarse grained, closely packed micaceous aggregates with a grain size up to 7-8 mm in length, and (b), as small, delicate, skeletal, open meshed aggregates with an average size of 2.0 mm in length. The closely packed specularite is usually associated with large anhedral to subhedral ankerite aggregates, while the open meshed skeletal variety occurs with the anhedral quartz mentioned previously, and occasionally with small anhedral aggregates of ankerite.

The specularite typically shows ragged outlines where it is in contact with ankerite and hence euhedralism is best developed when in the skeletal form associated with quartz. It is worthy of note that rutile in acicular crystals and knee shaped twins, commonly occurs with the fine skeletal specularite, and minute veins of ankerite, specularite and rutile dissect earlier large grained quartz. Pyrite occurs in subhedral massed aggregates (2mm diameter) associated more with quartz, than with carbonate. Euhedral character is developed most strongly where the pyrite is in contact with quartz.

Chalcopyrite in anhedral aggregates (5 mm diameter), often shows corroded textures if in contact with carbonate. As mentioned previously the chalcopyrite often encloses

euhedral grains of quartz and carbonate. Rarely however, chalcopyrite partially encloses pyrite and specularite. In addition, veinlets of anhedral quartz and ankerite cutting across earlier euhedral quartz may be observed. Finally, veins in which the sequence is from the centre outwards: (a) anhedral quartz + pyrite, (b) specularite + rutile + ankerite dissected by later carbonate, (c) fine grained iron and silica, are shown in hand specimen.

Although the above observations are based only on specimens collected from both sets of lode systems, a tentative hypothesis for the ore genesis may be put forward.

It would appear that initial deposition from the hydrothermal fluid resulted in the formation of euhedral quartz crystals, with later development of subhedral forms. At this stage there was a significant change in the composition of the fluid with the simultaneous precipitation of ankerite and specularite. A subsequent decline in the amount of ankerite and specularite (with minor formation of rutile), would lead to the deposition of pyrite, (only a minor content since the iron content of the fluid would be severely depleted), and then chalcopyrite; anhedral quartz being formed as the amount of specularite being deposited, diminished. Changes in the composition of the ore forming solution would be transitional, as indicated by the mineral relations. However this suggested sequence is an obvious oversimplification, as can be seen from the following reasons.

Selected samples from the Anstey lode west of Reedy Creek differ macroscopically from those of the Baker Masterman lodes, in that the specularite: chalcopyrite relationships are more confused. The hematite and chalcopyrite appear to be intermixed to a greater extent in the Anstey lode samples, and also the ankerite and hematite content appears to be proportionately greater. Some of the samples have a banded appearance, with layers of quartz and chalcopyrite alternating with layers of chalcopyrite specularite and ankerite (c.f. with banded "gossan" in plate 3). As well, specularite veinlets dissecting earlier formed chalcopyrite and quartz, are exhibited in some of these samples.

From these additional observations it can be further suggested that deposition may have taken place in pulses and that specularite has formed both before and after the sulphides.

In regard to the latter suggestion, specularite can be variable in its place in the mineralisation sequence. For example at Ajo, Gilluly (1942) notes that specularite is late after most of the sulphides, as it follows cracks through the sulphide ore, whereas at Chuquicamata, Lopez (1939) remarks that earlier work indicates specularite is prior to the copper mineralisation.

McKinstry (1959) notes that in the quaternary system Cu-Fe-S-O, the trend of the sequence usually observed in primary deposits is toward assemblages progressively richer in sulphur and poorer in oxygen with or without an increase in the ratio of copper to iron. This observation helps in understanding the formation of the high iron to copper assemblage hematite-pyrite-chalcopyrite at Kitticoola. In other circumstances hematite would be progressively eliminated by sulphidisation but Gilbert (1926), notes that hematite is most abundant in deposits which are sulphur poor. Thus the considerable amount of specularite and the relative paucity of pyrite suggests that the ore forming solutions were sulphur deficient.

It now remains to suggest an explanation for the formation of specularite and ankerite. McKinstry and Kennedy (1957) note that hydrothermal magnetite and hematite in appreciable quantity are found almost exclusively in high temperature limestone environments. It is probable that the formation of metasomatic calcium silicates frees CO_2, which at the relatively high temperature of these deposits partially dissociates and oxidises the iron in the hydrothermal solutions.

As mentioned previously, the Tungkillo and Milendella marbles and calc silicates (White 1959) occur at the base of the Kanmantoo succession.

As well, scapolite bearing rocks are abundant on a regional scale.

To extend this further, Holland (1967) states that the solubility product of calcite and dolomite increases steadily with increasing temperature and hence these minerals cannot be precipitated by simple cooling, but release of CO_2 by boiling off could cause deposition. As well, highly magnesium rich solutions are not required to form dolomite or an ankeritic carbonate at temperatures above 250°C.

The amount of specularite and ankerite, their mutual relationship, the anhedral small grained nature of the carbonate aggregates and the hypothesis of pulses of deposition, (due to sudden release of pressure), are consistent with the suggestion that the ore forming solutions were contaminated by a representative of the above-mentioned marbles and calc-silicates, to give the particular ore mineral assemblage at Kitticoola.

9. GEOCHEMISTRY - SOIL SAMPLES:

General

The soils within the area are coarse-grained and shallow in depth, (approximately 3 inches), except for gentle slopes where a depth of 1 to 2 feet is attained. On this basis the soils can be classed as juvenile and residual.

A combination of slight weathering, a siliceous and ferruginous environment (near the lodes), a low content of organic matter and clays, and free drainage and active erosion, leads to the expectation that anomaly contrast will tend to be preserved within the area. Consequently soil sampling should be a valid exploration technique for locating geochemical anomalies.

A soil sampling programme was carried out in the area using an I.P. grid system for sample location. An orientation survey on channel samples revealed that a suitable geochemical contrast is obtained using an aqua regia digestion (Appendix 3). Because of the coarse nature of the soil, large samples (500g), were collected to allow the sieved fractions to be representative of the site (Kleeman 1967). As a result of the orientation survey, samples were collected from just above bedrock and sieved to -88 mesh for analysis.

Elements analysed for were selected on the basis of results of X-ray spectrographic analyses carried out on ore specimens (Appendix 6). Of the 6 elements chosen, only Cu, Zn and Co were analysed for consistently, Pb, Ni and Mn analyses being carried out only in areas of interest. The results of the soil sampling programme are tabulated in Appendix 4a.

Discussion of Results - Copper

A geochemical soil sampling programme based on an I.P. grid system, has been carried out in the area, the values varying from 5 to approximately 2000 ppm. From a histogram (Appendix 4), the mode of concentration (the most frequently occurring concentration), is found to be 10-20 ppm, and the arithmetic mean is 68 ppm (Smirnov, 1963). This latter figure could be taken as a regional threshold for the Kitticoola area (see Hawkes and Webb, 1962 for definitions).

Figure 3 is a plot of geochemical profiles for copper. This shows the higher background values usually associated more with the granite, than with the quartzo feldspathic schists (c.f. fig. 2). In general the localisation of the mineralisation is clearly shown by the sharpness of the anomalies along the traverses. Note that the profiles are discontinuous because some of the traverses cross Reedy Creek.

Figure 4 is a geochemical contour map for copper showing also the location of the lodes and minor specularite occurrences within the grid area. The contours here are inferred across Reedy Creek. Note that the 50 ppm contour surrounds the main lodes and areas of intense mineralisation (c.f. with the regional threshold of 70 ppm). However not all the specularite occurrences contain Cu.

The intensely worked lodes: Baker, Masterman, Anstey, Cottage and Horne, have all given rise to high anomalous values. Extensions of the Baker lode southwards; Masterman lode southwards; and the Cullingworth lode northwards, are indicated by the anomalous values at 16S 2W, 3W; 14S 1E; and 6S 3W, respectively. The higher Cu values at 12S 2W and 3W may indicate a possible extension of the Hagen lode on the east side of Reedy Creek. Most important however, fig. 4 shows the discontinuous nature of the mineralisation along selected lodes and the very slight asymmetry of the anomalies downslope towards Reedy Creek.

Discussion of Results-Zinc, Cobalt, Manganese.

Figure 5 shows geochemical profiles for zinc, cobalt and manganese. A comparison of the profiles for these elements and copper in fig. 3, shows that the degree of correlation between them is practically non existent. The variation in Mn values could be explained in two ways (a), variation in Mn content of the ore, and (b), variation in the ferromagnesian content of the silicate minerals in the underlying rocks. For example, the higher Mn values along both contacts can be attributed to the presence of the amphibolite bodies, and also to the higher biotite content in the quartzo feldspathic schists.

Again a shear zone with associated chlorite, biotite and mineralisation is probably responsible for the higher Mn values from 6S6E to 6S 10E.

Dispersion.

Figure 6 shows selected geochemical soil sample traverses, with corresponding geological sections and schematic topography.

Note that where the ground surface has a significant slope, the Cu anomalies are usually situated centrally over the lode outcrop (except for the Baker lode traverse). Thus, the extent of dispersion of the copper is small, with higher anomalous values dwindling to background proportions within a distance of thirty feet from the lode. The traverse S_1 - S_8 was carried out to test whether there was a concentration of the elements in the presumably highly silicic residual fluids. There is an increase in Cu at the western end of the traverse which implies a source of Cu to the west in the quartzo feldspathics. There may be a connection between these higher Cu values and the presence of the shaft at 24S 8W along the contact of the granitic gneiss.

In summary then, dispersion of the elements within the soils is very limited and this has resulted in some or part of the lodes being undetected e.g. Hagen lode.

10. GEOCHEMISTRY - ROCK SAMPLES:

The results are tabulated in Appendix 5, and they show that there is no correlation between Cu, Ni and Co content, the values being comparable with the soils. The zinc values for the granites are low in comparison with those of the quartzo feldspathic schists (micaceous), and hence this is a reflection of the higher biotite content in the latter rocks, as Belt (1964), notes that biotite in granites usually contains a large percentage of the zinc in granitic rocks. Note that the manganese and copper content of the amphibolites is higher than that of the quartzo feldspathics, and further, Cu values are higher in the unmineralised granite than in the quartzo feldspathic schists. Finally specimens in which chlorite is present have relatively greater Ni values (Deer et al 1966, p236).

11. GEOCHEMISTRY - ORE AND GOSSAN SAMPLES:

The results are tabulated in Appendices 6 and 7. Analyses on ore samples for Cu, Pb, Zn, Ni, Co, Mo, Ag, Au by an independent laboratory show the tenor of the gold within the ore from the Baker Masterman lode system.

Analyses of specularite samples indicate that they are variable in copper content, and that the Co : Ni ratio is commonly greater than 1.5. Duplicate and original analyses on gossan samples are in excellent agreement, which therefore gives analytical reliability to the results.

The fact that the mineralisation at Kitticoola occurs in two sets of fracture systems prompts the suggestion as to whether ore emplacement was simultaneous in both sets. Hence, Davidson (1962), notes that there is less cobalt than nickel in granites but cobalt is concentrated in several ores apparently derived from granite. As well it is suggested that in some granitic provinces it is probable that a marked excess of cobalt over nickel is to be found only in the late hydrothermal emanations. Hawley and Nichol (1961), indicate that the cobalt and nickel contents of pyrite are higher for early magmatic ores than for hydrothermal pyrite, while Loftus-Hills and Solomon (1967), have reviewed earlier research which shows that in hydrothermal sulphides the Co : Ni ratio is greater than 0.1, and often greater than 1.0. The Co : Ni ratios in the ore and gossan samples from the lodes are therefore consistent with a late hydrothermal origin from a granitic source. However the Co : Ni ratios for the two sets of lode systems are inconclusive, and the question of simultaneous emplacement remains unresolved.

12. pH MEASUREMENTS:

The pH of a soil is defined as the pH of the slurry prepared by adding distilled water or a neutral solution to the solid material. In this study, pH measure-

ments have been carried out on twelve soil and fine rock samples, considered to be representative of the area (Appendix 8). As the soils and rocks are subject to oxidation insitu, and hence are in contact with the atmosphere, it is probable that the pH values measured do represent fairly accurately the pH of the interstitial solution (c.f. Garrels 1960, p66).

The results show that collectively the soils are more acidic than the rocks, hence there is a decrease in pH with increase in the extent of weathering. Also it appears that in non mineralised areas soils derived from amphibolite are more basic than those derived from granite. In near lode outcrops, the pH values of soils and rocks are lower, but still greater than the pH (5.0 to 5.5) at which Cu goes out of solution (Hawkes and Webb 1962, p116). This is no doubt due to the relative paucity of pyrite as compared to chalcopyrite and the abundance of carbonate. It is thus concluded that the mobility of Cu in the area is very limited.

13. SUMMARY:

The field and microscopic evidence is in accord with the suggestion that the Palmer Granite was intruded into the quartzo feldspathic schists during the later stages of metamorphism. The granite subsequently crystallised in the stress field of the same metamorphic deformation producing two fracture systems which later

became the sites of ore deposition.

Chemical and isotopic data by White et al (1967) has confirmed the intrusion hypothesis. The assemblages exhibited by the amphibolite and quartzo feldspathic rocks within the area are those of the sillimanite-almandine-orthoclase subfacies (Turner and Verhoogen, 1960). The occurrence of the amphibolite lenses, their variable sheared nature and structural trends suggest that they were part of a dolerite sill intruded during metamorphism and presumably before the Palmer Granite.

The granite has been extensively altered, the dominant phase being sericitisation. The sequence appears to be kaolinite, sericite-quartz, quartz-carbonate, chlorite. Without a more systematic and intensive field study it is difficult to place the alteration in terms of facies - but the sequence is consistent with argillic, sericite, and perhaps propylitic alteration.

The lodes all exhibit structural control, but the presence of amphibolite and quartzo feldspathic schist may have had some influence on the degree of ore deposition.

Mineralogical studies of the ore and gangue indicate that the generalised depositional sequence is quartz, quartz-ankerite-specularite, (rutile), quartz-sericite-pyrite and chalcopyrite. It is suggested that contamination of the hydrothermal fluids by a member of the Tungkillo-Milendella-Marble-Calc-silicate group may have

resulted in the formation of ankerite and specularite within the ore, and that deposition took place by a boiling off mechanism. The ore assemblage indicates a deficiency in sulphur in the ore forming solutions.

A soil sampling programme has outlined the anomalous areas within the mine region, the intensity of mineralisation being consistent with the degree of hydrothermal alteration. In an environment such as that at Kitticoola, Cu lode systems can be detected by geochemical soil sampling. Small anomalies however, may remain unnoticed if using a grid with 400 feet traverses and sample points at intervals of 100 feet. Depending on the target size required, a more intensive grid pattern may still locate small anomalies which do not register on a more open grid. Rock, ore and gossan geochemistry as well as petrological and mineralogical data is consistent with the derivation of hydrothermal fluids from a granitic source.

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PLATE 1

A.

View south from 11N 1E. Palmer Fault zone on left. Access roads to mine on right. Note sparse vegetation and cobble strewn soil.

B.

View west from 4S 10W. Tailings pond in centre of photograph. Trees define Reedy Creek. Treatment plant obscures the main entrance to the mine. Note kaolinised cliff face in right hand portion of photograph.





PLATE 2

C.

View north east from 12S 8W. Note steep topography and bare rounded hills. Wooton shaft (S/L OO) on horizon. Reedy Creek is in gully.

D.

View southwest from 7S 5W. Granite is foreground and steeply dipping migmatite-quartzo feldspathic schists in background.





PLATE 3

E.

Migmatite boulders with ptygmatic vein, in the bed of Reedy Creek (2S 11W).

F.

Banded quartz-specularite-ankerite gossan from lode outcrop.
Dark ankerite-hematite-limonite gossan from lode outcrop.
Cullingworth lode.




METRIC
CONVERSION

APPENDIX 1

PETROLOGICAL DESCRIPTIONS

The following descriptions are brief summaries only and are not intended to be complete. Space does not permit the inclusion of full petrological analyses here, since many of the samples are repetitive. Emphasis is therefore on mineral identification and textural variation.

Percentage modal values where given are by visual estimation only.

Note: (1) Not all samples taken have been described.
(2) T.S. = Thin section description.
(3) H.S. = Hand specimen description.

K1 H.S. carbonate ore - azurite and malachite shaft sample.

K2 T.S. Plagioclase An_{40} complex twinning; Hornblende $Z \wedge C = 20^{o}$, pleochroic green blue green, occasionally twinned; Biotite corroded and ragged; Magnetite minor and occasional Sericite. Av.grain size 1mm.
Texture: Granoblastic, equidimensional aggregated.
Name: Originally a dolerite, now Amphibolite.

K3 T.S. Malachite in masses and radiating veinlets (10%); Muscovite ragged laths (10%); Sericite (40%); vein Quartz anhedral (40%).
Name: Oxidised carbonate ore.

K4 H.S. Granite (sericitised), from shaft.

K5 T.S. Plagioclase sericitised (30%); Microcline (20%) Quartz (25%); Muscovite and Chlorite intergrown (20%), Opaques 5%, Zircon trace. Av. grain size 2 mm.
Texture: Allotriomorphic granular.
Name: Granite (altered).

K6 T.S. Plagioclase An_{12} sericitised (30%); Quartz strained (30%); Biotite, Muscovite and Chlorite intergrown in a felted mass showing strong orientation (30%); Magnetite (5%);
Texture: Cataclastic and lineated.
Name: Quartzo feldspathic schist (altered).

PETROLOGICAL DESCRIPTIONS

K7 T.S. Plagioclase (45%) Subhedral; Hornblende (45%)
Pleochroic scheme X = light yellow green
Y = green brown
Z = deep blue green
Muscovite (5%); Magnetite (5%); Sphene (trace).
Av. grain size 0.5-1 mm
Texture: Relict Intergranular and Ophitic with poikiloblastic.
Name: Amphibolite.

K8 T.S. Plagioclase An_{32} (45%); Hornblende Z C = 28° (45%); Sericite (5%); Magnetite (5%).
Texture: Alignment of Hornblende and Plagioclase. Dominant texture is granoblastic. Av. grain size 0.5mm.
Name: Amphibolite.

K9 T.S. Plagioclase (20%); Quartz sagenitic (30%); Muscovite (30%); Biotite (15%); Magnetite (5%).
Texture: Foliated strong alignment of mica.
Name: Quartzo feldspathic schist (micaceous).

K10 H.S. Quartzo feldspathic schist (micaceous).

K11 T.S. Sericite and quartz matrix cut by numerous quartz veinlets.
Name: Veined and altered wall rock from adit.

K12 H.S. Sericitised wall rock from Anstey Lode adit.

K13 H.S. Intensely silicified wall rock from Anstey Lode adit.

K14 H.S. Oxidised ore with specularite.

K15 T.S. Quartz (95%) forms fine grained matrix; Disseminated opaques (5%) include Rutile, Leucoxene, and Ilmenite.
Name: Silicified vein outcrop.

K16 H.S. Similar appearance to K15.

K18 T.S. Plagioclase sericitised (20%); Microcline Kaolinised (30%); Perthite and Antiperthite (30%); Quartz (20%). Kaolinisation extensive. Magnetite, Hematite and Leucoxene.
Texture: Allotriomorphic granular.
Name: altered Granite.

K20 T.S. Quartz (40%); Muscovite (25%); Sericitised Feldspar (30%); Limonite-Hematite veinlet (5%); Apatite trace. Partially aligned mica crystals.
Name: Sericitised feldspathic quartzite.

K21 T.S. Hornblende (45%); Plagioclase (40%); Sericite (5%); Chlorite in veinlets; Magnetite (10%). Av. grain size 1 mm.
Texture: Cataclastic strong alignment of Hornblende and Plagioclase.
Name: sheared Amphibolite.

K22 T.S. Quartz (30%); Plagioclase (20%); Microcline (30%); Biotite (20%) strongly aligned; Plagioclase partly sericitised, and minor chlorite present.
Name: Quartzo feldspathic schist.

K23 T.S. Hornblende; Plagioclase; Orthoclase; Quartz and sericite together with Sphene and Magnetite. Minor intergrown Biotite, Muscovite and Chlorite.
Texture: Cataclastic, poikiloblastic, alignment of Hornblende and Plagioclase.
Name: Sheared and altered Amphibolite.

K24 T.S. Quartz (30%); Plagioclase sericitised (30%); K-feldspar (15%); Muscovite and Biotite (25%). Av. grain size 1mm.
Texture: Cataclastic, alignment of mica.
Name: Migmatite.

K26 T.S. Malachite (20%) in masses with radiating veinlets in a fine grained sericite and quartz (80%) matrix.
Name: Carbonate ore from shaft.

K27 H.S. Fine grained sheared granite.

K28 H.S. Brecciated quartzo feldspathic schist.

K29 H.S. Quartzo feldspathic schist grading to Migmatite.

K30 H.S. Quartzo feldspathic gneiss.

K31 T.S. Quartz (30%); Microcline (40%); Plagioclase sericitised (20%); Biotite (5%); Muscovite (5%).
Name: Well jointed gneissic Granite.

PETROLOGICAL DESCRIPTIONS

K32, K33 H.S. Amphibolite.

K34 T.S. Quartz (40%); Microcline and Antiperthite Kaolinised (30%); Plagioclase sericitised (30%).
Name: Altered wall rock from adit.

K35 H.S. Kaolinised and sericitised granite.

K36 T.S. Quartz (30%); K-feldspar (20%); Plagioclase (30%); Biotite (15%); Muscovite (5%).
Av. grain size 1 mm.
Texture: Cataclastic strongly aligned mica flakes.
Name: Migmatite.

K37 T.S. Chlorite (60%); Quartz (30%) Muscovite (10%) Minor Leucoxene and Sphene inclusions in chlorite masses.
Texture: strongly deformed chlorite forming twisted masses,
Name: Quartz chlorite schist.

K38 T.S. Quartz (60%); Plagioclase (20%); K-feldspar (10%); Hornblende (10%); minor Zircon.
Texture: Equidimensional mosaic.
Name: Feldspathic quartzite.

K39 H.S. Quartz vein with limonitic boxwork and specularite.

K40 H.S. Massive crystalline specularite (foliated).

K41 T.S. Quartz (40%); Plagioclase (20%); Microcline (20%); Biotite (20%) showing strong orientation; minor Magnetite and Sericite.
Name: Migmatite.

K43 T.S. Hornblende (40%); Plagioclase (40%); Sericite (15%); Chlorite (5%); Sphene; Magnetite; Apatite.
Av. grain size 0.5 mm.
Texture: Poikiloblastic Hornblende; relict intergranular.
Name: Amphibolite.

K44 T.S. Hornblende (35%); Plagioclase (45%); Sericite (20%); Sphene; Biotite, Magnetite.
Name: Amphibolite.

K45 T.S. Hornblende; Plagioclase; Sphene and Magnetite, Chlorite. Av. grain size 0.5 mm.
Texture: Strongly cataclastic, foliated and poikiloblastic.
Name: Highly sheared Amphibolite.

K46 T.S. Sericite and Quartz in a felted mass, minor Muscovite (fine grained).
Name: Silicified sericitised wall rock from adit.

K47 T.S. Plagioclase: Quartz; Sericite; Numerous quartz veins some later than sericite. Av. grain size 4 mm.
Name: Replaced Granite from adit.

K48 T.S. Plagioclase Sericitised; Microcline Kaolinised Quartz veinlets.
Names: Altered Granite from adit.

K76 T.S. Hornblende; Sericite; Muscovite, Chlorite. (replacing Hornblende); Sphene; Magnetite; Rutile.
Name: Strongly sheared Amphibolite.

PETROLOGICAL DESCRIPTIONS.

Table of Mineral Constituents.

Thin Sections K50 to K90 - granite (altered)

Abbreviations: P = Plagioclase; Mi = Microcline;
Q = Quartz; S = Sericite; K = Kaolinite;
L = Leucoxene; M = Muscovite;
B = Biotite; PA = Perthite-Antiperthite;
Cl = Chlorite; d = dominant; m = minor.

Sample	P	Mi	Q	S	K	L	M	Cl	P.A.	Remarks.
K50	X	X	X	X	X	X	X			
K51	X	X	X	X	X		X		X	
K52	X	X	X	X	X		X	X		Sd.
K53	X	X	X	X	X	X	X		X	Sd, Km
K54	X		X	X			X			Sd. Zircon
K55	X	X	X	X		X	X			Sd.
K56	X	X	X	X		X	X		X	S fine gr.
K57	X	X	X	X	X		X		X	S veinlets
K58	X	X	X	X	X		X	X	X	Sd, Km
K59	X	X	X	X	X		X			Sm, Km
K60	X	X	X	X	X		X		X	Sd, Km
K61			X	X						S fine gr.
K62	X	X	X	X	X	X			X	Sd, Km
K63	X		X	X		X	X			Sd, Pd
K64	X	X	X	X	X	X	X	X	X	Q vein
K65	X	X	X	X		X	X		X	Q vein
K66		X	X	X	X				X	Kd
K67	X	X	X	X						B
K68	X	X	X	X			X		X	B and M
K69		X	X	X	X		X		X	Sd, f. gr.
K70	X	X	X	X	X	X	X			Kd,
K71	X	X	X	X	X	X	X	X	X	B, Kd
K74	X	X	X	X	X			X	X	B & Cl
K75	X	X	X	X	X		X	X	X	B, Km

PETROLOGICAL DESCRIPTIONS

Sample	P	Mi	C	S	K	L	M	Cl	PA	Remarks.
K79		X	X	X	X		X			Sd, Lim
K80		X	X	X	X		X			Sd, Kd
K85		X	X	X	X				X	Sd, Kd
K87		X	X	X	X		X		X	Spec.
K88		X	X	X	X		X		X	Kd.
K89	X	X	X	X	X		X			Sd.
K91	X	X	X	X	X		X		X	Kd, Sd.

K72 T.S. Malachite opaque green aggregates and radiating veinlets (20%); Microcline and Perthite-Antiperthite extensively kaolinised (25%); Sericite (30%); Quarts (20%); Muscovite (5%).
Av. grain size 2-3 mm.
Name; Granite with carbonate ore.

K77 T.S. Quarts subhedral and fine grained anhedral; Limonite; and Ankerite.
Numerous fractures.

K78 T.S. Quarts. Subhedral and anhedral fine grained; Massive Ankerite grain aggregates.

K86 T.S. Quarts euhedral and fine grained; Massive Ankerite grains; Carbonate veinlets penetrate fractures.

PETROLOGICAL DESCRIPTIONS

DDH 1A/1 352 ft. T.S. Quartz (25%); Plagioclase sericitised (70%) showing excellent twinning; Muscovite (5%).
Av. grain size 1 - 2 mm.
Veinlet penetrating rock contains: Carbonate (Ankerite), euhedral Quartz; Muscovite; Chalcopyrite anhedral outlines; Chalcopyrite encloses euhedral Quartz crystals. Limonite present in veinlet also. Euhedral Quartz has complete extinction. Finer grained Quartz (anhedral) present also. Texture: Allotriomorphic granular with strong foliation due to oriented Muscovite. Name: Sericitised Quartzo feldspathic schist.

DDH 1A/2 382 ft. T.S. Veinlet of Ankerite and euhedral Quartz enclosed by outer zone of fine grained Sericite and Quartz and aligned Muscovite flakes; Plagioclase sericitised and minor Chalcopyrite (3-4 mm diameter); Muscovite occurs in twisted and deformed crystals. Grain size variable.
Minor Sericite-Quartz and Carbonate-Quartz veinlets traverse the rock.
Name: Altered Quartzo feldspathic schist.

DDH 1A/3 422 ft. T.S. Sericitisation complete; all record of original rock lost; Muscovite and Chlorite intergrown; numerous Carbonate veinlets penetrate rock; Chlorite also associated with Carbonate in veinlets.
Disseminated grains of Leucoxene.
Minor anhedral Quartz grains.
Micro fractures have displaced some veinlets in the rock.
Av. grain size 0.5 mm.

PETROLOGICAL DESCRIPTIONS

DDH 1A/4 424 ft. Quartz (50%); Plagioclase sericitised (45%); Muscovite and Chlorite intergrown (5%). Av. grain size 1-2 mm. Muscovite and Chlorite shows a strong orientation and occur in felted twisted, masses. It appears that Chlorite and Muscovite are replacing Biotite.
Name: Well foliated sericitised Quartzo feldspathic schist (minor fault zone?).

DDH 1A/5 429 ft. Quartz; Plagioclase sericitised and abundant intergrown Biotite and Chlorite with a strongly developed orientation and alignment of crystals. Av. grain size 1 - 2 mm.
Name: Well foliated sericitised Quartzo feldspathic schist (minor fault zone?).

PETROLOGICAL DESCRIPTIONS

ORE AND GANGUE SAMPLES

Note: (BM) = Baker-Masterman Lodes (A) = Anstey Lodes

M2 (BM) Quartz in grains and veinlets enclosing Kaolinised feldspar (sieve texture); Microline intruded by Ankerite veinlets; Sericite fine grained; Ankerite veinlets cutting across Quartz veinlets; K-feldspar veinlets kaolinised, cut by later Quatz; Perthite, Leucoxene.

M3 (BM) Sericite: fine grained and extensive; Quartz elongated grains up to 3 mm length; Microcline small grains, appears to be invading; Chlorite and Muscovite intergrown; Muscovite and Sericite replacing K-feldspar; Quartz (sagenitic); Sericite veinlets invading Leucoxene grains.

M4 (BM) Microcline altered to Kaolinite; Sericite fine grained and extensive; Quartz occurs in anhedral grains and in veinlets; Chlorite and Muscovite intergrown; Ankerite - Quartz veinlets cutting sericitised feldspar; Ankerite grains enclosing euhedral Quartz; Kaolinised-Quartz veinlet cutting feldspar.

M5 (BM) Microcline intensely Kaolinised cut by Quartz veinlets; Biotite and Muscovite intergrown; some Perthite-Antiperthite Kaolinised; Sericitised Plagioclase; Leucoxene (minor) and Muscovite; Quartz anhedral.

M7 (BM) Quartz fine grained set in a matrix of Sericite; Limonite and Sericite veinlets; Feldspar partially Kaolinised.

M9 (BM) Quartz large grains up to 5 mm length and fine grained anhedral; Sericite occurs with anhedral Quartz and is cut by later Quartz veinlets; Small disseminated grains of Pyrite occur in Sericite; fibrous ragged Muscovite; Ankerite occurs in small anhedral crystals;
Note: small anhedral Quartz grains have undulose extinction.
Later Quartz veinlets intrude the rock.

PETROLOGICAL DESCRIPTIONS

ORE AND GANGUE SAMPLES

M10 (BM) Quartz euhedral up to 2 mm length enclosed by Ankerite; fine grained anhedral Quartz has associated Pyrite; Ankerite aggregates up to 10 mm diameter.

M11 (BM) Quartz euhedral enclosed by Ankerite; Sericite associated with fine grained anhedral Quartz and small disseminated euhedral grains of Pyrite. Subhedral Quartz grains up to 10 mm length.

M12 (BM) Specularite (1 mm length) ragged outline associated with Ankerite; Chalcopyrite encloses euhedral Quartz grains; Pyrite associated with fine grained anhedral Quartz and has euhedral outlines.

M12A (BM) Quartz euhedral enclosed by Ankerite; Specularite associated with Ankerite; Pyrite 0.5 mm occurs in discrete euhedral grains associated with fine grained anhedral Quartz; Pyrite in contact with Ankerite has irregular outlines.

M13 (BM) Microcline extensively Kaolinised; Sericite replacing Kaolinised feldspar; Quartz subhedral in veinlets; minor Muscovite; Sericite masses associated with fine grained anhedral Quartz; Quartz veinlets penetrating sericitised and Kaolinised feldspar.

M17 (BM) Pyrite masses irregular in outline, in contact with Ankerite; Pyrite encloses euhedral Quartz; Pyrite mostly associated with fine grained anhedral Quartz; minor Specularite enclosed by Ankerite.

PETROLOGICAL DESCRIPTIONS

ORE AND GANGUE SAMPLES

M18 (A) Specularite 2 mm length associated with Ankerite; Specularite interpenetrating Chalcopyrite; Skeletal Specularite 0.5 to 1 mm length, euhedral outlines associated with fine grained Quartz; Quartz euhedral enclosed by Ankerite; Rutile associated with skeletal Specularite.

M18A (A) Quartz euhedral enclosed by Chalcopyrite; Specularite aggregates with corroded outlines associated with Ankerite, Skeletal specularite associated with Quartz forms a meshwork and minor associated Rutile.

M18B (A) Specularite associated with Ankerite in a veinlet cutting subhedral Quartz; Chalcopyrite has anhedral to subhedral outlines.

M19 (A) Quartz euhedral enclosed by rounded Specularite aggregates and Ankerite; Rutile associated with skeletal Specularite and subhedral Quartz; Quartz euhedral cut by veinlets of Quartz, Ankerite, Specularite; Specularite enclosed by Chalcopyrite.

M20 (A) Chalcopyrite partly enveloping Ankerite; Specularite included within Chalcopyrite; Skeletal Specularite in contact with Ankerite has associated Rutile; Corroded Specularite in contact with Ankerite 3 mm length; skeletal Specularite 1 mm length; Chalcopyrite 3 mm diam.

M22 (BM) Specularite meshwork 1 mm length associated with anhedral Quartz; Pyrite cutting Specularite; Chalcopyrite in greater abundance than Specularite; Ankerite is of minor amount; Chalcopyrite 4 mm diameter; Quartz euhedral enclosed by larger Quartz grains (subhedral)

PETROLOGICAL DESCRIPTIONS

ORE AND GANGUE SAMPLES

M24 (A) Ankerite enclosing Chalcopyrite has reaction rims where in contact with Chalcopyrite; Specularite aggregates enclosed by Ankerite have corroded crystal outlines; Quartz euhedral, enclosed by Ankerite.

M25 (A) Skeletal Specularite forming meshworks and radiating aggregates, with polygons enclosing Quartz and Chalcopyrite; Pyrite in contact with Chalcopyrite has subhedral outlines whereas Chalcopyrite has ragged anhedral outlines; euhedral Quartz enclosed by Ankerite; skeletal Specularite associated with Rutile Chalcopyrite partly enclosing euhedral Quartz.

DISCUSSION OF THE STAINING TECHNIQUE OF EVAMY (1963).

The staining solution consists of the following:

0.2% HCl
0.2% Alizarin Red S
0.5 - 1.0% Potassium Ferricyanide

The solution is made up for immediate use as it decomposes after a period of 24 to 48 hours. The strength of HCl required is just below that which causes calcite to effervesce visibly. Gas bubbles adhering to the surface being treated yield unreliable results, therefore it is important to agitate the surface within the solution for a few seconds. A period of approximately a minute and a half gave adequate staining results whereas longer immersion gave a stain which was too intense for thin section work.

Ferrous iron reacts with potassium ferricyanide in dilute hydrochloric acid to form the pigment Turnbull's Blue - the intensity of the stain being proportional to the concentration of ferrous iron present. It has been found that the reactions due to alizarin red S and potassium ferricyanide in the one solution do not interfere.

The colour intensities are shown below:

RED	MAUVE	PURPLE	NOT STAINED	LIGHT BLUE	DARK BLUE
Fe^{2+} free	Fe^{2+} poor	Fe^{2+} rich	Fe^{2+} free	$\frac{Fe^{2+}}{Mg^{2+}} < 1$	$\frac{Fe^{2+}}{Mg^{2+}} > 1$
Calcite	ferroan	calcite	dolomite	ferroan dolomite	ankerite

Of the thin sections stained all showed the carbonate to be of a dark blue colour with the exception of some specimens from the east and west contact zones which developed a light blue colour equivalent to ferroan dolomite.

APPENDIX 2

SAMPLING PROCEDURE AND ANALYTICAL METHODS

General.

Contamination of soil samples due to mine dumps and old excavations is an ever present possibility. However as all samples were taken below surface level and away from dumps and diggings contamination should be minimal.

Stream sediment sampling upstream of the present mine workings was considered but there are inherent problems in taking a representative sample at a particular location due to the cobble strewn creek beds and the coarse nature of the sediments. The tailings pond situated at the junction of Reedy, Talbot's and Harrison's Creeks bars sampling downstream from the mine.

Sampling and Analysis.

Soil samples were collected in water resistant geochemical envelopes, dried in an oven for 24 to 48 hours at a low temperature and were then sieved to - 88 mesh using nylon bolting cloth and plastic rings.

Rock samples (200 to 400 g) were split to 100 to 150 g and crushed using the Siebtechnik Mill, and a chrome steel vessel which contains no Cu, Zn, Pb, Co, Ni, and only minor Mn in its chemical composition.

0.5 ± .002 g of each sample was weighed into a test tube marked at 20 ml capacity. 3 ml of aqua regia was added and the sample digested at 120 to 150°C for 1½ hours. The sample was then diluted to 20 ml. shaken and left to stand prior to analysis.

Stock solutions for the elements Cu, Zn, Pb, Ni and Co were prepared using A.R. grade chemicals, whereas commercial grade reagent was used for Mn. Dilution of the stock solutions yielded calibration standards in the appropriate range for each element.

Analyses were carried out on the Departmental AA-100 and AA-3 atomic absorption spectrophotometers. The conditions used were those advocated in the Techtron instruction manuals for these instruments.

Analytical Errors.

Duplicate soil analyses were carried out to give a measure of the analytical error (related to sampling) as distinct from the determinative error of the instrument (Appendix 4A).

For the elements Cu and Zn the error varies from 0 to 10%. For practicality it would be wise to assume an error of 10%. The error in determination of Co, Pb and Ni has not been estimated but is greater than 10% because the range of values encountered for these elements is close to the limits of sensitivity for the instrument.

Errors in rock analyses are considerably less as shown in the table of results.

APPENDIX 3

GEOCHEMICAL ORIENTATION SURVEY ON SOIL SAMPLES.

GENERAL:

In an orientation survey, consideration of the geochemical contrast, i.e. the values for anomalous areas compared to those of areas of background concentration for a particular element, is usually involved. For a further discussion of these terms and definitions see Hawkes and Webb (1962).

From the orientation survey those factors which are found to give the best geochemical contrast are deemed the most appropriate for that particular area. These factors are then used in the geochemical programme.

CONCLUSIONS FROM THE SOIL SAMPLE SURVEY.

The results are shown in tabulated form at the end of the appendix. The following discussion is applicable only to copper, although data for the other elements is presented in the table.

Size Fraction Analysis.

The fractions chosen were:

-44 to + 88 mesh
-88 to + 127 mesh
-127 to +180 mesh
-180 mesh

From the table it can be seen that the finer the size fraction (i.e. the larger the mesh) the better the contrast for copper. Hence it is desirable for maximum geochemical contrast to use the -180 mesh fraction (Size fractions larger than 44 mesh were not considered as it would have been necessary to crush the samples).

Soil Profile Analysis.

Diagrammatic logs of the profiles are shown in the accompanying figure in this appendix. The soil profiles were arbitrarily divided into three horizons A, B and C (where possible), in order of increasing depth. Within the area studied there is no true soil profile development such as that considered in examples quoted by Hawkes and Webb (1962).

Results show that the geochemical contrast increases with the depth of sample. Hence the C horizon (usually just above bedrock is the best depth for sampling).

Because of the coarse nature of the soil over the granite and associated rocks in the majority of the area and hence the limited amount of soil cover, the selection of the -180 mesh fraction for analysis is not practicable. Since the proportion of the -180 mesh fraction is small a large initial amount of sample prior to sieving would have to be taken in order to minimise sampling errors (Kleeman 1967).

Hence the -88 mesh fraction was chosen for the soil sampling programme.

Note that the deeper the sample the closer the value of the -88 mesh fraction analysis approaches that of the -180 mesh fraction. Hence the slight loss of contrast that occurs by choosing the -88 mesh fraction is minimised with increasing depth of sample.

Method of Digestion.

Three methods of sample attack were investigated.

a) 25% HNO_3

b) 70% $HClO_4$

c) aqua regia 1 part HNO_3 to 3 parts HCl

Of these methods, attack by aqua regia was found to give the best geochemical contrast. The attack by 70% $HClO_4$ gives a lower contrast than that obtained by using aqua regia. This is contrary to expectations and is attributed to a depressant effect on the elements in solution, since the perchloric acid was not boiled off. Note that the size fraction and soil profile analyses were carried out using 25% HNO_3, but the conclusions obtained would be the same regardless of the digestant.

Harden and Tooms (1964) investigated the efficiency of the potassium bisulphate fusion in extracting metals from rocks, minerals, soils and stream sediments. It was found that the proportion of metals extracted from the rock forming minerals by $KHSO_4$ attack is extremely variable,

being lowest with the pyroxenes and amphiboles and highest with the micas and feldspars.

Since the rock types in the Kitticoola area consist mainly of quartz, micas, feldspars and clays, it is probable that the values obtained for the soil samples, using a partial extraction method such as aqua regia, may closely approach the total values.

No orientation survey was carried out on rock powders (including ore and gossans), since to make any relative correlation of element values between soils and rocks the digestant had to be the same for both cases.

ORIENTATION SURVEY RESULTS

Mesh Fraction Symbols (a) = -44 to +88
(b) = -88 to ±127
(c) = -127 to +180
(d) = -180

Values expressed in ppm

Sample No.	Mesh Fraction	Method of Digestion: 25% HNO_3					$HClO_4$			Aqua Regia		
		Cu	Zn	Pb	Co	Ni	Cu	Zn	Co	Cu	Zn	Co
1A	(a)	56	3	4	4	-						
	(b)	68	3	4	4	-						
	(c)	92	4	6	4	-						
	(d)	130	6	8	10	-						
1B	(a)	72	2	4	4	14						
	(b)	92	3	6	4	14						
	(c)	92	3	8	8	14						
	(d)	115	5	10	8	20						
1C	(a)	140	3	4	4	14	140	3	6	270	4	6
	(b)	132	2	6	4	14	150	2	6	270	4	10
	(c)	132	3	8	4	14	160	3	6	270	4	10
	(d)	156	3	6	4	14	180	3	6	320	4	10
2A	(a)	600	6	16	10	14						
	(b)	600	6	16	10	14						
	(c)	640	6	16	10	14						
	(d)	860	6	26	10	14						

ORIENTATION SURVEY RESULTS

Sample No.	Mesh Fraction	Method of Digestion											
		25% HNO_3					$HClO_4$			Aqua Regia			
		Cu	Zn	Pb	Co	Ni	Cu	Zn	Co	Cu	Zn	Co	
2B	(a)	600	4	8	10	14	650	5	20	880	8	20	
	(b)	620	4	10	10	14	700	5	14	900	7	20	
	(c)	700	5	14	10	14	780	6	14	1040	9	24	
	(d)	900	6	14	10	14	980	8	16	1260	11	26	
3A	(a)	600	6	8	36	20							
	(b)	640	6	10	18	20							
	(c)	680	8	10	22	20							
	(d)	860	8	10	28	28							
3B	(a)	1080	6	8	22	20							
	(b)	1040	6	8	16	20							
	(c)	960	6	8	16	14							
	(d)	1250	7	8	14	28							
3C	(a)	1080	4	8	10	14	650	3	6	1340	6	20	
	(b)	1080	4	8	10	14	680	2	6	1340	6	16	
	(c)	1120	4	4	10	14	760	3	6	1380	7	14	
	(d)	1200	5	8	10	14	920	4	6	1460	8	16	
4A	(a)	10	5	8	8	14							
	(b)	10	5	8	8	14							
	(c)	8	5	8	10	14							
	(d)	12	6	8	14	14							

ORIENTATION SURVEY RESULTS

Sample No.	Mesh Fraction	Method of Digestion											
		25% HNO_3					$HClO_4$			Aqua Regia			
		Cu	Zn	Pb	Co	Ni	Cu	Zn	Co	Cu	Zn	Co	
4B	(a)	14	6	4	10	14							
	(b)	14	6	4	8	14							
	(c)	14	7	8	8	14							
	(d)	20	9	8	10	14							
4C	(a)	12	6	4	10	14	8	5	10	14	8	20	
	(b)	12	6	6	10	14	8	5	6	12	8	14	
	(c)	10	5	6	8	14	12	5	6	12	8	14	
	(d)	12	5	8	8	14	14	8	6	20	12	14	
5A	(a)	14	5	6	10	14							
	(b)	20	6	4	10	14							
	(c)	20	6	4	10	14							
	(d)	28	10	4	14	28							
5B	(a)	20	6	6	10	14	12	3	6	24	6	14	
	(b)	22	6	6	10	14	14	4	14	24	8	14	
	(c)	22	6	8	10	14	14	3	10	24	8	14	
	(d)	26	8	8	16	28	26	7	20	36	12	24	

ORIENTATION SURVEY - LOG

Location	Sample	Depth	Description
5S 1W	1A	0-3"	fine dark soil, some organic content.
	1B	3-6"	rock chips and soil
	1C	6-12"	" " " " bedrock
9.5S 4W	2A	0-3"	organic material and soil
	2B	3-6"	coarse rock chips and soil bedrock
13S 6W	3A	0-3"	dark organic rich layer
	3B	3-9"	light colour, rock chips
	3C	9-15"	" " " " bedrock
8N 7W	4A	0-3"	reddish brown, organic content
	4B	3-11"	mottled soil
	4C	11-19"	rock chips and soil bedrock
18.5S 7.5W	5A	0-3"	dark soil
	5B	3-6"	coarse rock chips and soil bedrock

APPENDIX 4A

GEOCHEMISTRY - SOIL SAMPLES

Note: Some samples not analysed for a particular element

Values in ppm

Sample No.		Cu	Zn	Pb	Co	Ni	Mn
16N	1W	6	8		24		170
	2W	6	9		20		140
	3W	8	5		12		90
	4W	4	4		12		40
	5W	8	4		12		32
B/L	16N	26	9		28		200
16N	1E	14	8		28		360
	2E	16	10		28		440
	3E	8	7		8		72
	4E	10	8		10		130
	5E	10	8		12		370
	6E	6	8		8		120
	7E	10	10		12		370
	8E	10	10		14		260
12N	1W	6	5		16		96
	2W	8	6		12		300
	3W	10	7		12		170
	4W	10	8		12		170
	5W	4	5		12		40
B/L	12N	10	11		28		110
12N	1E	38	10		32		240
	2E	26	12		28		300
	3E	24	10		24		470
	4E	18	10		20		190
	5E	10	9		10		160
	6E	14	10		10		240

GEOCHEMISTRY - SOIL SAMPLES

Sample No.		Cu	Zn	Pb	Co	Ni	Mn
12N	7E	12	8		10		480
	8E	18	13		14		380
8N	1W	26	16		16		300
	2W	16	10		16		200
	3W	80	8		16		260
	4W	20	10		16		300
	5W	14	7		16		140
	6W	14	8		20		250
	7W	22	10		16		400
	8W	10	8		16		110
	9W	18	10		24		220
	10W	20	10		20		260
	11W	18	10		20		220
	12W	10	8		12		210
B/L	8N	10	6		16		64
8N	1E	16	8		16		180
	2E	32	12		28		210
	3E	22	10		28		250
	4E	40	10		24		260
	5E	180	12		24		800
	6E	62	12		18		410
	7E	18	8		10		300
	8E	16	10		10		310
	9E	14	10		10		340
4N	1W	32	10	12	12		
	2W	22	10	6	14		
	3W	26	9	8	12		
	4W	52	15	8	14		
	5W	20	9	8	12		
	6W	16	9	8	12		

GEOCHEMISTRY - SOIL SAMPLES

Sample No.		Cu	Zn	Pb	Co	Ni	Mn
4N	7W	28	12	12	12		
	8W	32	10	6	18		
	9W	170	13	8	28		
	10W	40	11	8	24		
	11W	64	9	12	14		
	12W	32	11	6	24		
	13W	80	11	6	12		
	14W	190	11	6	12		
	15W	370	5	30	20		
	16W	84	16	16	14		
B/L	4N	16	10	6	14		
4N	1E	16	9	6	12		
	2E	12	8	8	10		
	3E	16	9	4	10		
	4E	56	19	12	20		
	5E	68	17	12	14		
	6E	72	19	8	18		
	7E	44	13	8	18		
	8E	44	13	16	18		
	9E	18	9		10		250
	10E	14	10		8		200
1N	1W	26	10	8	14		
	2W	22	9	6	10		
	3W	18	10	8	12		
	4W	22	13	8	14		
	5.2W	22	6	8	8		
	6W	24	7	8	10		
	7W	16	10	8	12		
	8W	22	14	8	14		
	9W	22	13	6	14		

GEOCHEMISTRY - SOIL SAMPLES

Sample No.		Cu	Zn	Pb	Co	Ni	Mn
1N	10W	78	16	12	16		
	11W	110	27	8	30		
	12W	76	17	8	36		
B/L	1N	16	8	8	12		
1N	1E	16	9	8	12		
	2E	18	7	8	10		
	3E	56	13	12	14		
	4E	28	15	8	12		
	5E	52	28	8	18		
	6E	18	13	8	20		
	7E	78	10	8	18		
	8E	56	14	8	16		
	9E	22	15	8	10		
	10E	20	10		8		160
	11E	36	11		10		210
2S	1W	130	8	10	18		
	2W	92	14	16	30		
	3W	180	12	16	36		
	4W	62	10	14	30		
	5W	74	10	10	26		
	6W	38	8	10	18		
	7W	24	7	10	20		
B/L	2S	120	10	14	20		
2S	1E	125	8	6	12		
	2E	64	4	10	12		
	4E	52	6	4	18		
	5E	50	11	4	30		
	6E	30	14	6	30		
	7E	62	14	4	30		
	8E	60	11	4	20		

GEOCHEMISTRY - SOIL SAMPLES

Sample No.		Cu	Zn	Pb	Co	Ni	Mn
2S	9E	64	16	10	30		
	10E	92	19	20	30		
	11E	40	14		14		540
6S	1W	270	6	6	20	12	200
	2W	180	13	10	30	14	630
	3W	620	10	16	48	14	1350
	4W	44	11	10	20	12	300
	5W	84	9	10	20	14	820
	5.5W	98	10	10	20		
B/L	6S	1580	6	10	18	12	250
6S	1E	130	4	10	12	8	48
	2E	90	3	6	12	6	280
	3E	40	3	6	8	4	40
	4E	30	3	6	8	8	32
	5E	130	25	10	40	36	280
	6E	130	11	6	30	24	100
	7E	82	15	10	54	34	300
	8E	135	11	10	36	22	640
	9E	110	14	10	26	22	700
	10E	96	10	6	26	22	380
	11E	46	6		16	14	300
	12E	40	6		10	14	160
9S	1W	88	6	6	20		
	2W	200	8	10	20		
	3W	80	10	18	24		
	4W	60	9	14	20		
	5.5W	285	17	28	34		
	9W	130	7	14	20		
	10W	60	8	14	18		
	11W	125	12	20	20		

GEOCHEMISTRY - SOIL SAMPLES

Sample No.		Cu	Zn	Pb	Co	Ni	Mn
8.5S	11.5W	310	12	18	24		
9S	16W	24	8	14	20		
B/L	9S	96	5	4	20		
9S	1E	84	7	14	20		
	2E	225	6	14	18		
	3E	170	6	14	18		
	4E	92	12	14	14		
	5E	125	9	14	18		
	6E	125	16	14	24		
	7E	150	22	18	48		
	8E	145	16	16	34		
	9E	150	19	10	30		
	10E	125	15	14	30		
	11E	88	16	10	24		
12S	1W	180	12	14	24		
	2W	205	8	14	20		
	3W	190	9	10	20		
	6W	475	8	14	20		
	7W	300	10	14	20		
	8W	36	9	4	14		
	9W	24	10	10	14		
	10W	28	9	10	20		
	11W	96	8	10	18		
	12W	150	7	14	20		
	13W	170	8	14	24		
	14W	48	7	10	20		
	15W	28	9	10	18		
	16W	8	5	4	8		
	16.5W	16	8	10	18		
	17W	32	9	10	20		

GEOCHEMISTRY - SOIL SAMPLES

Sample No.		Cu	Zn	Pb	Co	Ni	Mn
12S	17.5W	24	10	10	24		
	18W	20	9	10	20		
	18.5W	16	9	10	20		
	19W	40	20	20	30		
B/L	12S	110	6	10	18		
12S	1E	12	9	14	18		
	2E	16	8	10	20		
	3E	8	8	14	18		
	4E	16	6	10	18		
	5E	68	5	10	14		
	6E	48	3	4	14		
	7E	88	9	14	20		
	8E	96	9	10	30		
	9E	98	22		40		500
	10E	228	10		20		380
16S	1W	420	6		26		680
	2W	1350	6		18		240
	4W	310	10		26		920
	5W	50	6		14		240
	6W	50	13		20		240
	7W	40	6		18		200
	8W	40	6		18		180
	9W	24	6		10		60
	10W	28	7		18		280
	11W	12	7		14		220
	12W	20	6		26		300
	13W	48	11		30		540
	14W	52	12		26		620
	15W	30	11		30		340
	16W	36	12		26		320

GEOCHEMISTRY - SOIL SAMPLES

Sample No.		Cu	Zn	Pb	Co	Ni	Mn
16S	17W	40	12		26		340
	18W	8	6		22		100
B/L	16S	130	9		22		600
20S	2W	20	6		14		360
	3W	14	6		14		340
	4W	26	7		14		200
	5W	20	6		10		100
	6W	56	8		26		500
	7W	56	9		30		420
	8W	170	9		34		760
	9W	1120	6		34		140
	10W	80	11		30		220
	11W	46	12		30		280
	12W	90	34		40		440
	13W	36	7		36		220
	14W	54	16		30		280
	15W	36	12		22		240
	16W	34	16		26		260
	17W	26	20		26		260
	18W	50	12		26		200
	19W	36	6		30		280
	20W	10	6		14		100
B/L	15N	20	9		32		330
	14N	10	7		16		110
	13N	16	16		40		150
	11N	28	16		24		170
	10N	12	11		24		160
	9N	130	12		20		200
	7N	18	10		24		70
	6N	10	5		12		90

GEOCHEMISTRY - SOIL SAMPLES

Sample No		Cu	Zn	Pb	Co	Ni	Mn
B/L	5N	22	6		16		95
	3N	36	6	12	16		
	2N	16	7	8	12		
B/L	OO	84	14	14	20		
	1S	38	8	10	20		
	3S	135	6	10	20		
	4S	350	84	240	30		
	4SA	315	80	260	30		
	5S	1840	7	10	30		
	7S	280	7	14	18		
	8S	145	7	10	20		
	10S	120	6	10	20		
	11S	125	8	10	30		
ST	A	32	11		24		180
	B	98	14		28		420
	C	40	22		34		340
	D	14	14		34		200
	S1	360	10		12	10	600
	2	380	10		14	14	1150
	3	180	13		14	14	1200
	4	140	12		12	16	1350
	5	145	11		8	16	820
	6	26	8		8	10	620
	7	46	6		8	10	620
	8	64	10		8	22	500
6S	2W	200	12	duplicate			
	3W	610	11	"			
B/L	6S	1700	6	"			
6S	5E	145	23	"			
	9E	120	12	"			

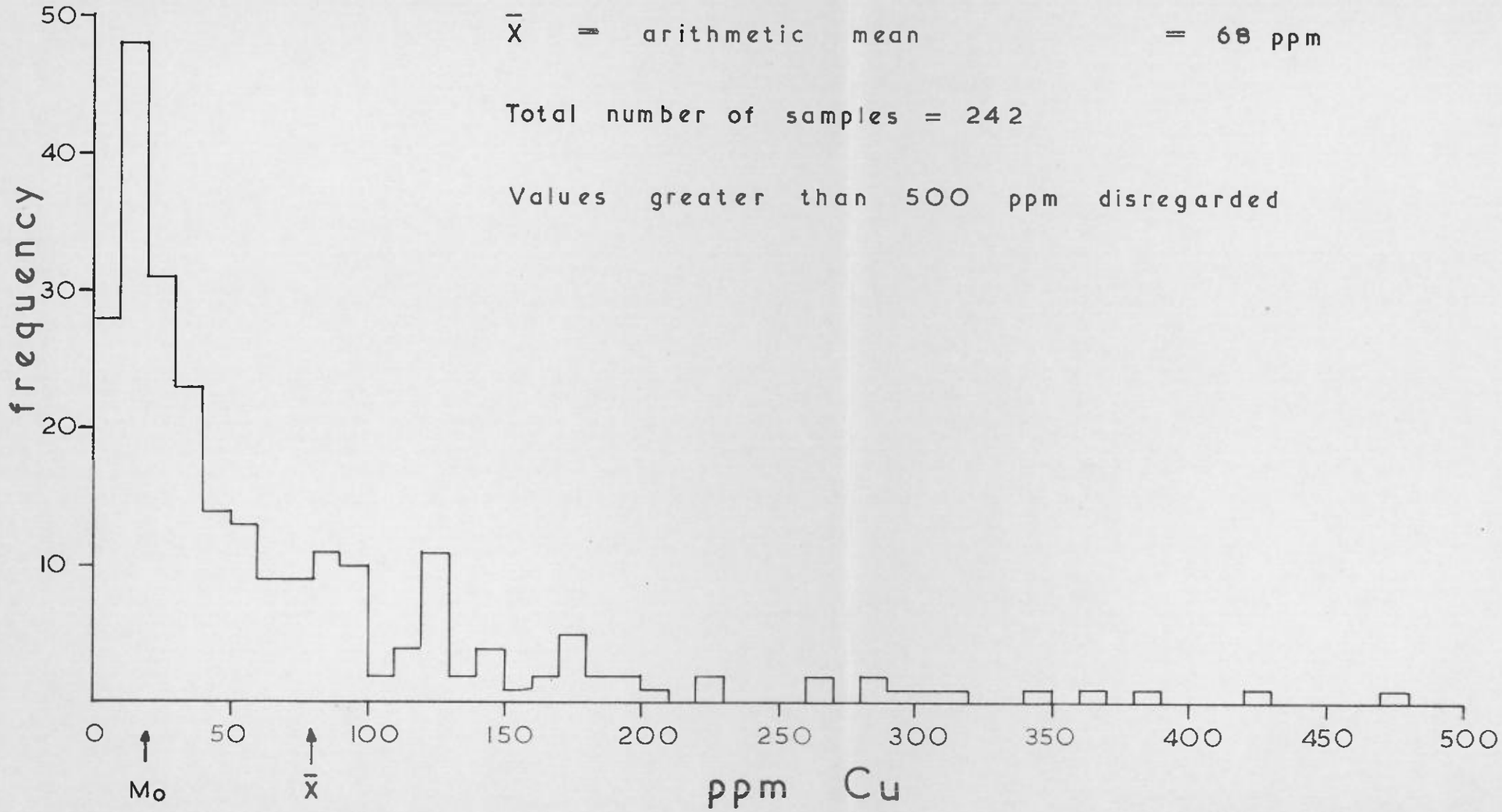
Histogram Cu soil samples

M = most frequent concentration = 10—20 ppm

$\bar{X}$ = arithmetic mean = 68 ppm

Total number of samples = 242

Values greater than 500 ppm disregarded



APPENDIX 4B

SOIL SAMPLE TRAVERSES

Values in ppm

Lode	Traverse Location	Sample No.	Cu	Zn	Co	Mn
Anstey	9.5S 4W	1	130	8	10	460
		2	200	8	12	700
		3	360	10	16	620
		4	160	8	25	500
		5	260	6	25	840
		6	800	8	30	460
		7	1340	10	36	1100
		8	380	9	24	460
		9	560	9	10	620
		10	640	10	14	520
		11	720	10	22	1150
Anstey	14S 8W	1	22	6	8	180
		2	42	6	8	200
		3	66	11	8	200
		4	64	5	10	120
		5	450	6	14	200
		6	145	7	14	240
		7	180	8	14	240
		8	145	6	14	200
		9	78	7	8	200
		10	48	5	8	200
Baker	7S 0.5E	1	280	8	14	360
		2	210	7	14	280
		3	145	4	10	40
		4	170	4	14	140
		5	150	4	10	160

SOIL SAMPLE TRAVERSES

Lode	Traverse Location	Sample No.	Cu	Zn	Co	Mn
Baker	7S 0.5E	6	190	4	4	40
		7	180	4	4	72
		8	8	110	4	56
		9	170	5	4	140
Hagen	15S 5W	1	70	6	10	290
		2	80	6	8	200
		3	50	5	8	140
		4	88	6	14	100
		5	150	7	18	160
		6	410	6	22	440
		7	170	6	14	220
		8	110	7	14	120
		9	135	8	10	250
		10	110	8	10	220
		11	86	5	8	180
Horne	16S 12W	1	72	16	24	840
		2	66	14	26	1020
		3	88	14	44	840
		4	92	13	50	1080
		5	130	12	40	780
		6	88	12	40	920
		7	52	10	40	920
		8	54	10	28	1060
		9	44	10	34	1060

APPENDIX 5

GEOCHEMISTRY - ROCK SAMPLES

Values in ppm except where indicated.

Sample No.	Cu	Zn	Co	Ni	Mn	Rock Type
K2	56	7	12	30	400	amphibolite
K5	24	4	6	12	250	wall rock granite
K8	30	12	6	14	160	amphibolite
K9	6	12	12	24	240	qtz.feld.(micaceous)
K10	32	8	22	30	220	" " "
K18	8	1	6	6	130	granite
K23	4	10	14	24	300	amphibolite
K29	6	12	14	34	200	
K31	12	1	4	12	25	qtz. feldspathic
K36	16	11	14	28	225	migmatite
K37	4	18	12	86	320	qtz chlorite, schist
K38	8	1	<4	8	50	feldsp. qtzite.
K51	24	1	<4	6	25	granite
K56	24	2	<4	4	170	"
K57	32	2	<4	12	90	"
K83	12	1	<4	6	25	"
K84	>1%	4	34	22	200	carbonate ore
DDH1A/1 depth = 352 feet	6400	6	8	16	920	altered sheared qtz. feldsp. and chalcopy.
DD1A/2 depth = 382 feet	72	2	<4	14	500	altered sheared qtz. feldsp.
DDH1A/3 depth = 422 feet	10	18	42	52	840	altered sheared qtz. feldspar and leucox.
DDH1A/4 depth = 424 feet	10	9	10	40	225	altered qtzofeld. minor fault zone.
DDH1A/5 depth = 429 feet	12	15	24	64	340	altered qtz. feld. minor fault zone.

APPENDIX 6

GEOCHEMISTRY - GOSSAN AND HEMATITE SAMPLES

Values in ppm except where indicated.
N.B. spec = specularite ank = ankerite lim = limonite
hem = hematite.

Sample Location	Cu	Zn	Co	Ni	Mn	Fe	Remarks.
6S 0.5E (A)	28	3	6	<4	36	>5%	Baker Lode spec, qtz.
B/L 11S	12	3	6	4	76	>5%	Baker Lode spec.foliated qtz.
3.2S 2W	220	3	6	14			Unnamed Lode vug qtz. lim, minor spec.
14S 1E	440	8	18	10	480	>5%	Masterman Lode vug qtz, lim, hem.
9.5S 4W	1.1%	16	30	38	1.84%	>5%	Anstey Lode spec, ank, lim.
12S 6W	1.16%	6	20	84	40	>5%	Anstey Lode lim, hem, spec, qtz.
B/L 4.5S (A)	2000	6	190	82	580	>5%	Baker Lode spec, qtz. lim, boxwork.
16S 12W	8000	3	270	62	900	3.6%	Horne Lode chalcopy, lim, hem, qtz.
6S 0.5E (B)	2060	4	14	10	50	>5%	Baker Lode qtz. hem, lim.

GEOCHEMISTRY - GOSSAN AND HEMATITE SAMPLES

Sample Location	Cu	Zn	Co	Ni	Mn	Fe	Remarks
10S 8W	1.4%	12	34	24	2.7%	>5%	Cullingworth Lode ank, lim, pseudomorphs.
B/L 4.5S B	4000	22	160	58	1.8%	>5%	Baker Lode hem, and qtz.
4.5S 1E	2280	4	84	34	240	>5%	Masterman Lode qtz, hem, lim, boxwork.
24.5S 13E	860	6	18	34	2.1%	>5%	Shaft sample hem, vug, qtz.
7N 6E	36	4	30	52	1900	>5%	Spec, qtz. massive hem, and lim.
2N 6.5E	32	4	240	30	700	4%	Quartz minor spec. from excavation.
9N 1E	12	4	34	14	480	>5%	Spec, qtz. ank, possible siderite.
18.5S 18W	8	3	8	4	140	>5%	specularite foliated and micaceous
6S 8E	5200	2	22	8	520	3800	excavation East contact, lim, granitic.
9.5S 4W	1.14%	16	30	38	1.84%	>5%	duplicate
6S 0.5E(B)	2000	4	12	10	45	>5%	"
10S 8W	1.44%	13	30	24	2.7%	>5%	"

APPENDIX 7

GEOCHEMISTRY - OFF SAMPLES.

Values in ppm except where indicated

Sample No.	Cu	Zn	Co	Ni	Mn	Remarks.
M15	>1%	4	62	34	3400	Baker-Masterman Lode system crystalline specularite.
M17	>1%	4	180	82	2400	Baker-Masterman Lode system contains cp, py, ank, qtz.
M18	>1%	2	20	28	700	Anatey Lode spec, cp, qtz, ank.
M20	>1%	3	18	22	680	Anatey Lode cp, spec,,qtz. ank.
M23	>1%	12	180	140	9600	Baker-Masterman Lode system cp, spec, ank, qtz.

N.B. Aqua Regia digestion
cp = chalcopyrite, spec = specularite
ank = ankerite, qtz = quartz
py = pyrite

GEOCHEMISTRY - ORE SAMPLES

Semi-Quantitative Spectrographic Analysis by AMDEL South Australia

(1) Results in ppm
(2) Detection limits in brackets
(3) Analyses performed on bulk sample of one days production Kitticoola Mine.
(4) X = not detected at limit quoted

Element		Sample Value	Element		Sample Value
Co	(5)	1500	Sn	(1)	2
Ni	(5)	1000	Cd	(3)	X
Cr	(20)	100	Bi	(1)	30
V	(10)	X	Ag	(0.1)	1
W	(50)	X	Au	(3)	X
Mo	(3)	X	Ga	(1)	X
Mn	(10)	1000	Ge	(1)	X
Ta	(100)	X	As	(50)	X
Nb	(20)	X	Sb	(30)	X
Be	(1)	X	Ba	(50)	50
Th	(100)	X	Sr	(10)	X
Pt	(10)	X	Y	(10)	10
Pd	(10)	X	La	(100)	X
Os	(10)	X	Ce	(300)	X
Ir	(2)	X	Ti	(1500)	X
Rh	(2)	X			
Ru	(2)	X			
Cu	(0.5)	10000			
Pb	(1)	8			
Zn	(20)	100			

GEOCHEMISTRY - ORE SAMPLES

Sample Description	Cu	Pb	Zn	Ni	Co	Mo	Ag	Au	Fe
0031 Cu ore	800	27	12	220	196	1	1	6.7	12%
0032 Cu ore	2800	36	10	290	220	<1	3	6.3	18%
0033 Cu ore and spec	2350	20	3	20	38	<1	1	0.1	20%
0034 Hematite micaceous	171	72	11	40	110	2	1	5.1	42%
Copper concentrate	10.0%	70	19	570	1800	<1	7	8.4	34%

Analyses by Sheen Laboratories W.A.

Note: Perchloric acid digestion - 2 hours at 180°C.
Gold in dwt/short ton.
Other values in ppm except where indicated.
Iron figures and highest copper value may not be accurate.

APPENDIX 8

pH MEASUREMENTS

A Jones Model 0 pH Meter was used to determine the pH of selected soil and rock samples.

A pH buffer was used as a standard, its value selected to be near the expected range of the samples. This buffer is 0.05M Borax which gives a pH of 9.3 at 20°C (9.2 at 25°C).

Rock samples were first crushed but soil samples were sieved to -88 mesh, to correlate with the geochemical programme.

To establish electrochemical equilibrium between the sample and the electrodes CO_2 free distilled water (boiled for one hour) was added to the samples. The sample and water mixture was then stirred and allowed to stand for one hour before the measurements were made.

McKay (1968) has found that the amount of water added to a given amount of sample is critical. Solomin (1965) notes an average increase of +0.6 pH units for a 1:1 soil to water solution compared to the same soil only slightly moistened.

A 1:1 soil to water volume was therefore used in the following pH determinations and a 0.6 pH unit correction was subtracted from the measured pH values to give the corrected values.

The reading error of the instrument is ± 0.1 pH unit. In the range considered this gives an error in determination of ± 1 to 2 per cent.

TABLE OF pH MEASUREMENTS

Sample to water ratio of 1:1
Measured pH value -0.6 = corrected value
Temperature 20°C

Material	Sample Number	Corrected pH	Bedrock
Soil	2S 1W	5.8	granite
"	12N 3W	5.3	"
"	16N 4W	5.4	"
"	4N 5W	4.9	"
"	12S 9W	5.6	"
"	2S 6W	5.8	"
"	6S 2E	5.1	"
"	8N 1E	5.3	"
"	16S 17W	7.5	amphibolite
"	9S 7E	6.3	"
"	1N 10E	6.3	quartzo feldspathic
"	20S 16W	5.9	" "
Rock	K5	8.6	granite (wall rock)
"	K18	7.5	" (fresh)
"	K83	6.8	" (weathered)
"	K2	8.4	amphibolite
"	K10	8.3	quartzo feldspathic

APPENDIX 9

Although the size and emplacement of the mineralisation at Kitticoola are not typically those of a porphyry copper, the deposit however does have similarities with respect to the hypogene ore and the hydrothermal alteration. The following examples of copper deposits are presented for comparison with Kitticoola.

Ore * Assemblage	Hypogene * Alteration	Example	Source
Chalcopyrite, Pyrite	Zoned sericite (K-feldspar); intermediate argillic (propylitic)	Butte, Montana deep chalco-pyrite zone	Meyer and Hemley (1967)
Chalcopyrite, (Pyrite), Hematite	K-Silicate (anhydrite) (ankerite); red feldspars (propylitic)	Chilean coast Range copper deposits.	"
Specularite, Chalcopyrite, Pyrite, Bornite, Molybdenite, Magnetite	Potassic; Sericitic; Propyritic;	Ajo, Arizona	Lowell and Guilbert (1970)
Pyrite, Ag, Galena, Au, Sphalerite, Pyrite, Chalcopyrite, Bornite, Molybdenite where Py > Cp	Potassic; Sericitic; Argillic; Propylitic	Typical Porphyry Copper	"

Parentheses indicate minor phases which are subordinate or may be absent.

APPENDIX 10

LIST OF SPECIMENS AND THIN SECTIONS SUBMITTED WITH THESIS.

THIN SECTIONS (locations shown in fig. 2)
(prepared by author)

K 2, 3, 5, 6, 7, 8, 9, 11, 12, 15, 18, 20, 21, 22, 23, 24, 26, 31, 34, 35, 36, 37, 38, 41, 43, 44, 45, 46, 47, 48, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 74, 75, 76, 77, 78, 79, 80, 84, 85, 87, 89, 91, 96, 656E.

M 2, 3, 4, 5, 7, 9, 10, 11, 12, 13, 17, 18, 19, 20, 22, 24, 25.

(prepared by McPhar)
DDH 1A/1, 1A/2, 1A/3, 1A/4, 1A/5.

HAND SPECIMENS

Surface rocks

K 1, 7, 10, 18, 20, 23, 24, 34, 52, 57, 60, 62, 67, 71, 72, 74, 76, 78, 85, 91, 93.

Gossans

16S 12W, 9N 1E, 10S 8W, 14S 1E.

Ore and Gangue

A. Baker Masterman Lode System

M 2, 4, 5, 6, 10, 14, 15, 22.

B. Anstey lode.

M 18, 19, 20, 24.