DEPARTMENT OF MINERALS AND ENERGY

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD NO. 1976/77

A PRELIMINARY INVESTIGATION OF THE NATURE, ORIGIN, AND ECONOMIC POTENTIAL OF THE JUBILEE PLUNGER GOLD DEPOSIT, CENTRAL GEORGETOWN INLIER, NORTH QUEENSLAND.

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SUMMARY

The Jubilee Plunger gold deposit is contained within a zone of sericitized and quartz-veined Siluro-Devonian granodiorite, about 1200 m by 100 m or more in area; it lies about 30 km south-southeast of Forsayth in the central part of the Georgetown Inlier. Shallow collapsed workings are scattered along the length of the quartz vein system; incomplete mining records indicate that more than 46 kg of gold/silver bullion was extracted from some 2400 tonnes of easily crushed, oxidized ore between 1894 and 1897.

The Jubilee Plunger has recently been the object of various geological, geochemical, and geophysical studies that are part of a BMR-GSQ program of revision of the regional geological maps, investigation of the regional and mineral deposit geology, and assessment of the mineral resources and potential of the region.

In 1973 and 1974 the geochemistry of the soils and related stream sediments of the Jubilee Plunger area was investigated, and two large areas up to 250 m wide and totalling more than 1100 m long were found to contain anomalous levels of Au, Ag, Pb, Zn and Cu (10-60 times background levels for Pb and Zn) in the soil.

In 1975 the resistivity, IP effect, Turam, VLF, and magnetic characteristics of the same area were measured. Although IP values were found to be mostly low and uniform, a low-order anomaly (max. 2 x background) at least 150 m x 300 m was found, roughly coincident with the main northern geochemical anomaly.

(b)

Later in 1975 two diamond-drill holes were cored to depths of 100 m and 56 m. The shallower hole intersected several zones rich in sulphides-notably between 37 m and 44.6 m below the surface. The entire core from below the water-table in this hole was analysed for Au, Ag, Pb, Zn, Cu, As, Bi, W, Mo, Li, F, U, Ba, Sr, Rb, and Zr; selected samples were also analysed for S, CO_2, and the major-element oxides. Despite considerable core loss the most strongly mineralized zone (7.6 m wide) averaged 7 g/tonne Au, 86 g/tonne Ag, 2.6% Zn, 1.1% Pb, and 0.35% Cu. Excluding the intervals with less than 95% core recovery, grade averaged 10.7 g/tonne Au, 134 g/tonne Ag, 3.4% Zn, 1.1% Pb, and 0.54% Cu over 4.8 m. The highest values of Au and Ag obtained were 12.7 g/tonne and 205 g/tonne respectively. Indicated 'ore' of the lower grade over 7.6 m amounts to 10 000 tonnes per vertical metre.

Petrographic and mineragraphic studies show that the mineralization consists of pyrite, marmatite, galena (containing Ag), chalcopyrite, and minor gold, marcasite, and covellite, and is mostly confined to quartz-carbonate-filled fractures with hydrothermal alteration envelopes that are zoned in the manner commonly observed in porphyry copper deposits (propylitic, argillic, and phyllic).

The alteration, mineralogy, chemistry, structure, probable age, and regional relationships of this Au-Ag-Zn-Pb-Cu deposit prompt the speculation that it may be an outer part of a deeply buried porphyry copper system.

1. INTRODUCTION

Location

The Jubilee Plunger gold deposit is about 30 km south-southeast of Forsayth and 2 km west of Robin Hood homestead in the central part of the Georgetown Inlier, Qld (Fig. 1).

Object of investigation

The principal object of this investigation was to make a detailed study of the Jubilee Plunger deposit to determine its surface geochemical and geophysical expressions, to identify its ore minerals and structural controls, to ascertain the type of mineralization and the alteration associated with it, and to comment on its origin. This study is part of an extensive investigation of the size, nature, possible origin, and economic potential of the gold deposits of the Georgetown Mining District. This paper is very much of a preliminary nature, as many data have yet to be processed.

Acknowledgements

I am most grateful to numerous colleagues - in particular 'Tas' Armstrong, Max Baker (GSQ), Don Barnes, Bruce Cruikshank, Wally Dallwitz, Dick England, Ian Lambert (CSIRO), Lee Ranford, Bill Roberts, Allan Rossiter, Dave Wilson and Ian Withnall (GSQ) - for generously providing me with essential data, services, assistance, advice and guidance.

A modified form of this paper was presented at a seminar during M.Sc.(Exploration & Mining geology) short course G503 at James Cook University of North Queensland, Townsville, in July 1976.

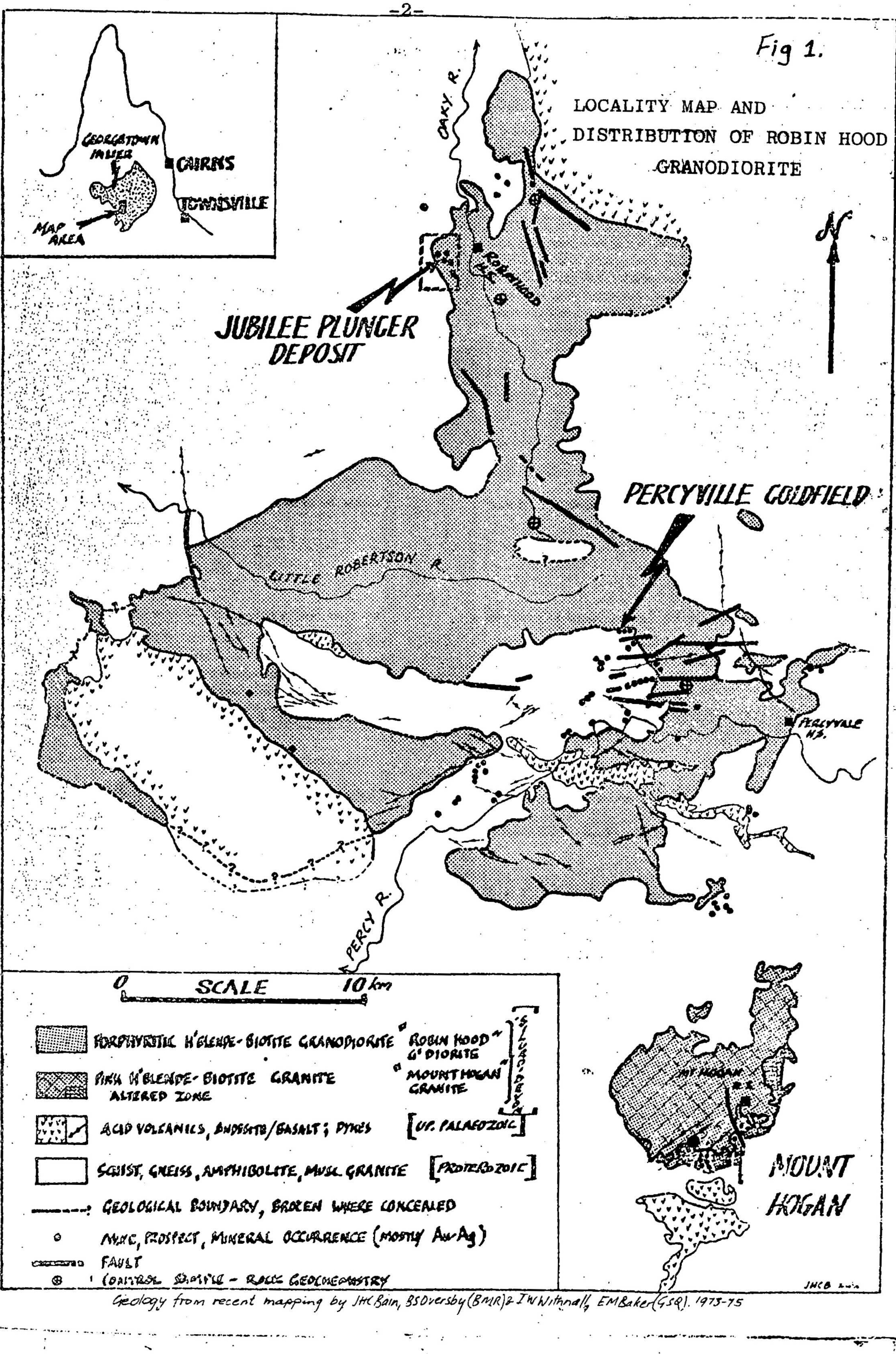


Fig 1.

LOCALITY MAP AND DISTRIBUTION OF ROBIN HOOD GRANODIORITE

Geology from recent mapping by JHC Bain, BS Oversby (BMR) & IW Withnall, EM Baker (GSQ). 1973-75

General background information

The Jubilee Plunger deposit occupies a poorly exposed north-northwest-trending, 1200 m long zone of sericitized and quartz-veined Robin Hood Granodiorite between Oaky Creek and the northwestern margin of the Robin Hood pluton (Fig. 1).

The Robin Hood Granodiorite is a stressed grey medium-grained hornblende-biotite granodiorite containing abundant small quartz phenocrysts. It crops out over 300 km^2 on the southwestern side of the Newcastle Range in the Forsayth and Gilberton 1:100 000 Sheet areas. The topography developed on the granodiorite is characterized by low bouldery hills and extensive alluvial deposits near the main stream channels. Also characteristic are the deeply gullied slopes in strongly weathered rock below Mesozoic sandstone-capped mesas. The granodiorite intrudes Proterozoic metamorphics and granite, is intruded by rhyolite dykes, and is unconformably overlain by mid-Carboniferous and Permian volcanics; it is probably Siluro-Devonian, but its precise age is unknown. Mineral deposits associated with it are few and generally only small. Abandoned shallow workings are scattered along most of the alteration zone (Fig. 7) but the mining records for the Jubilee Plunger area are not sufficiently detailed to permit identification of the various individual mines, viz. the Jubilee Plunger, Lady Mary, and possibly the Better Luck mines, for which some production (Table 1) has been recorded (Withnall, in press).

Table 1. Production for period 1894-1897.

Mine	Ore Crushed (tonnes)	Gold Bullion (g)	Grade (g/tonne)
Jubilee Plunger	996.3	10096	10.73
Lady Mary	669.6	15642	23.36
Better Luck	737.1	20611	27.96

The workings, with the exception of one shaft near the northern end of the line, were confined to easily crushed ore with free-milling gold ('brownstone') within the oxidized zone. The metallurgical problems of extracting the gold from sulphide ore precluded the economic working of the low-grade ore, and doubtless brought about the cessation of mining.

In 1970 Gulf Minerals Pty Ltd mapped the workings (Fig. 2), bulldozed 13 shallow costeans, and analysed about 20 composite rock chip samples from mullock heaps and outcrops. The poor gold values (average 0.9 g/tonne, maximum 4.4 g/tonne) discouraged further work.

In 1973 and 1974 the Bureau of Mineral Resources (BMR) investigated the geochemistry of the soils and related stream sediments of the Jubilee area (Armstrong, 1975), and in 1975 measured its resistivity and its IP, Turam, VLF, and magnetic expression (Wilson, in prep.). Later in 1975 two diamond-drill holes were cored to depths of 100 m and 56 m. The shallower hole intersected several zones rich in sulphides. The entire core from below the water-table in this hole was analysed (54 samples) for Au, Ag, Pb, Zn, Cu, As, Bi, W, Mo, Li, F, U, Ba, Sr, Rb, and Zr. Indicated grade over 7.6 m is 7 g/t Au, 86 g/t Ag, 1.1% Pb, 2.6% Zn, and 0.35% Cu. Selected samples (10) were also analysed for S, CO_2, and the major-element oxides. These investigations provided the basic data for this paper.

2. SURFACE GEOLOGY

Very little of the geology of the Jubilee deposit can be seen on the surface because of lack of exposure. Apart from weathered exposures in the collapsed old mine workings

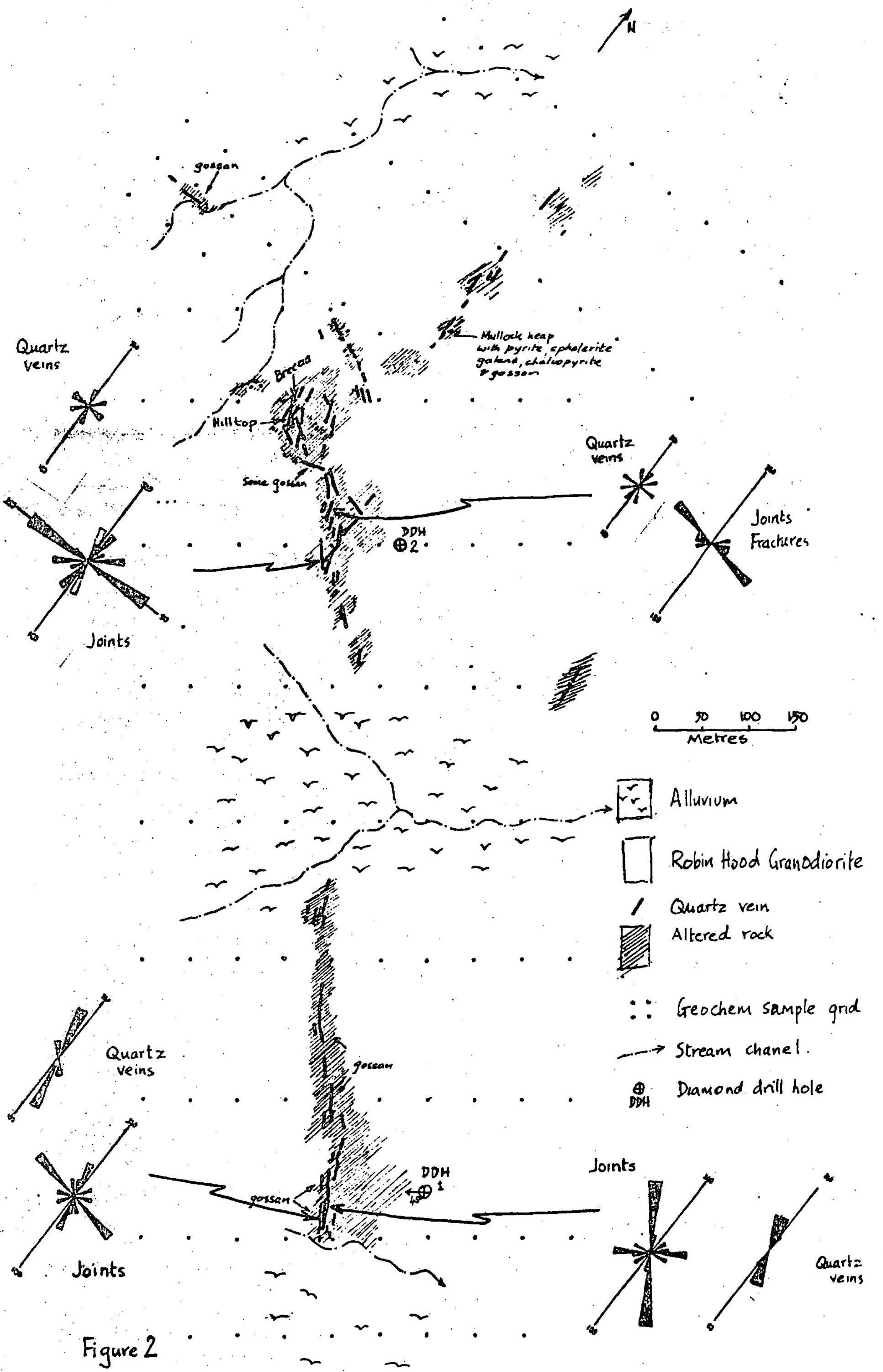


Figure 2

JUBILEE · PLUNGER REEF - GEOLOGY. (after Gulf Minerals Pty Ltd) Modified
vein & fracture data from E M Baker

there are only a few very small outcrops of quartz and weathered granodiorite; the only sizable outcrop of fairly fresh rock forms a low rubbly hill near the northern end of the prospect where the line of workings bifurcates. The rubble is composed of greenish grey sericitized granodiorite ("greisen"), locally with a network of subparallel quartz veins - in places virtually a quartz-cemented breccia. Although all the original silicate minerals have been altered to coarse sericite, and the rock highly fractured and 'flooded' with iron oxides and calcite, the quartz phenocrysts so characteristic of the unaltered granodiorite are preserved.

Quartz veins range in width from a few millimetres to a couple of metres, both along strike and down dip, and from one vein to the next. They are generally anastomosing, fractured, and locally gossanous. Gossan material has not yet been closely scrutinized, but initial examination indicated that a wide range of textures is present, resulting, from various degrees of alteration of copper, lead, zinc, and iron sulphides.

Surface indications are that the zone of highly fractured, altered quartz-veined rock is 20-100 m wide, that it dips eastwards at 35° to 65°, and that it is widest and most irregularly fractured at the northern end of the line (Fig. 2).

Virtually every outcrop of quartz, no matter how small, attracted the attention of the gougers and prospectors, and shallow workings (Fig. 7) are nearly continuous along all but the central alluvium-covered part of the reef. All the workings have collapsed, and none is open to depths of more than 2 m. Recently bulldozed shallow costeans generally have not penetrated the soil and colluvium. In one, highly fractured thin quartz veins and weathered, sheared granodiorite are visible. The nature of the mullock indicates that only one shaft, at the southern end of the north-trending branch of workings north of the hill (Fig. 7), penetrated to the sulphide zone. Composite chip samples of mullock and outcrops have predictably much lower gold and silver values (Gulf, 1970) than the average of recorded ore assays (Table 1), because the ore shoots in the quartz veins have been mined out, and the ore was probably handpicked so that little if any ore-grade material remains in the mullock. Core analyses confirm that virtually all gold in confined to sulphide-bearing quartz veins, and that the wallrock contains less than 0.2 ppm gold.

3. SURFACE GEOCHEMICAL EXPRESSION

One hundred and sixty-two soil samples were collected on a rectilinear grid with 50 x 150 m spacings (Gig. 2). Each sample consisted of about 20 g of 'B' horizon soil from a depth of about 15-20 cm below the surface, and was analysed for Ag, Pb, Zn, and Cu by atomic absorption spectro-photometry (AAS) after digestion in a mixture of perchloric, hydrofluoric, and hydrochloric acids. Au was determined at AMDEL by AAS following aqua regia digestion and organic DIBK extraction (Armstrong, 1975).

The areas of anomalous Au, Ag, Pb, Zn, and Cu contents in the soil samples are shown in Figures 3-5, and are delineated by contour values of 0.1 ppm (Au), 1.0 ppm (Ag), 140 ppm (Pb, Zn), and 30 ppm (Cu). The two largest anomalies are separated by a zone of transported alluvium, which may be masking continuity between the two anomalies. Together anomalies a and B are over 1100 m long, and up to 250 m wide.

SOIL GEOCHEMISTRY

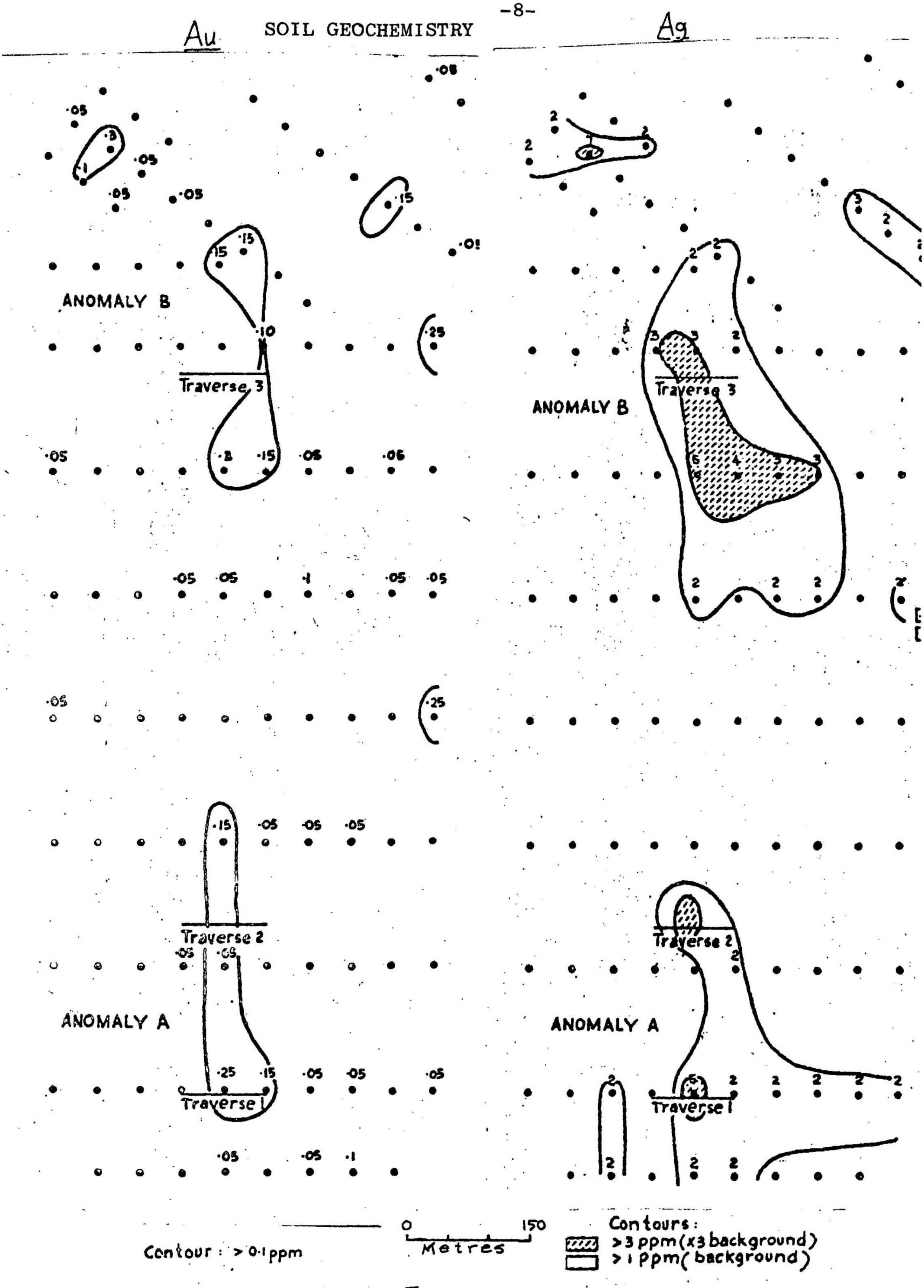


Figure 3

from Armstrong (1975)

SOIL GEOCHEMISTRY

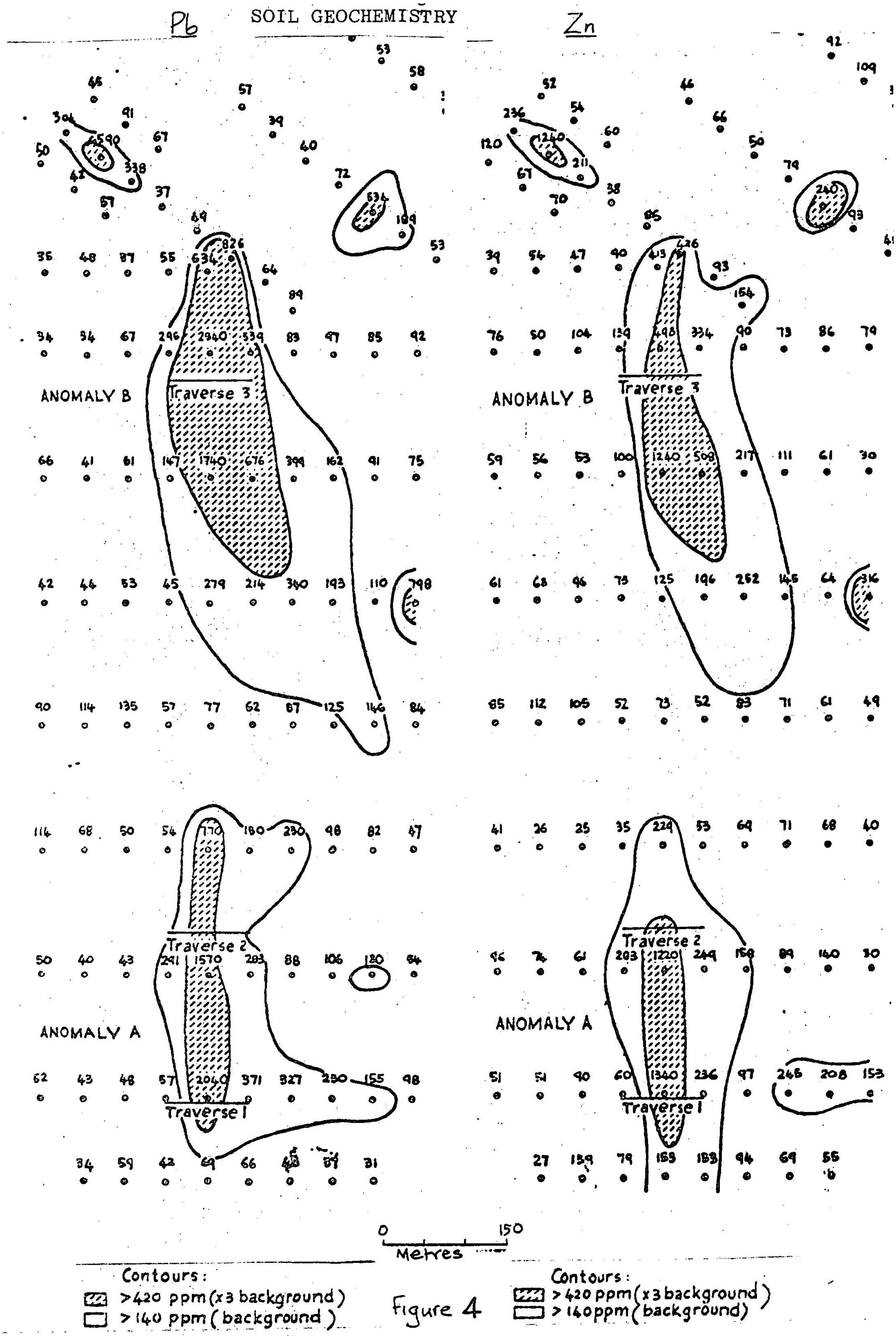


Figure 4

from Armstrong (1975)

Cu

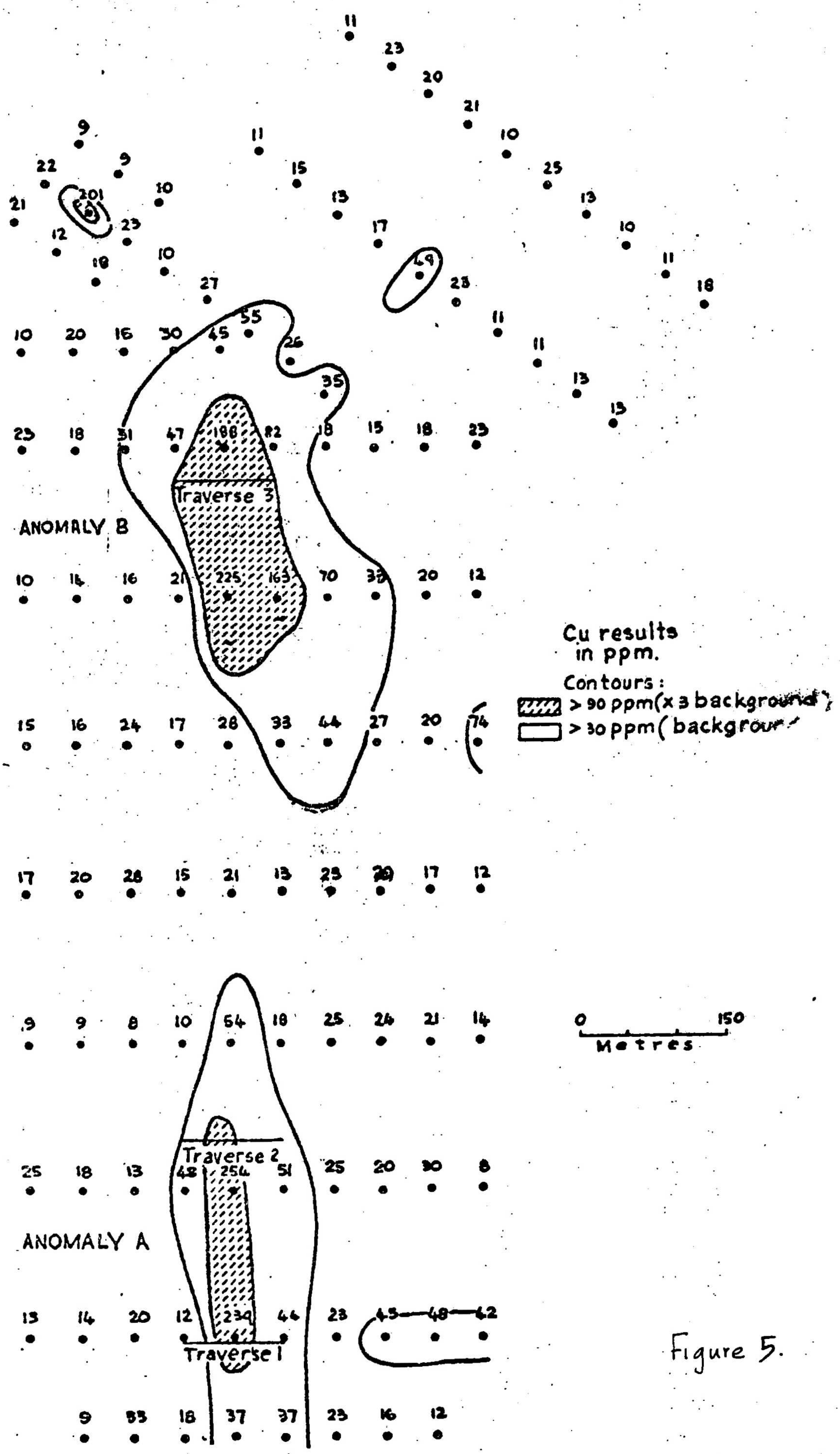
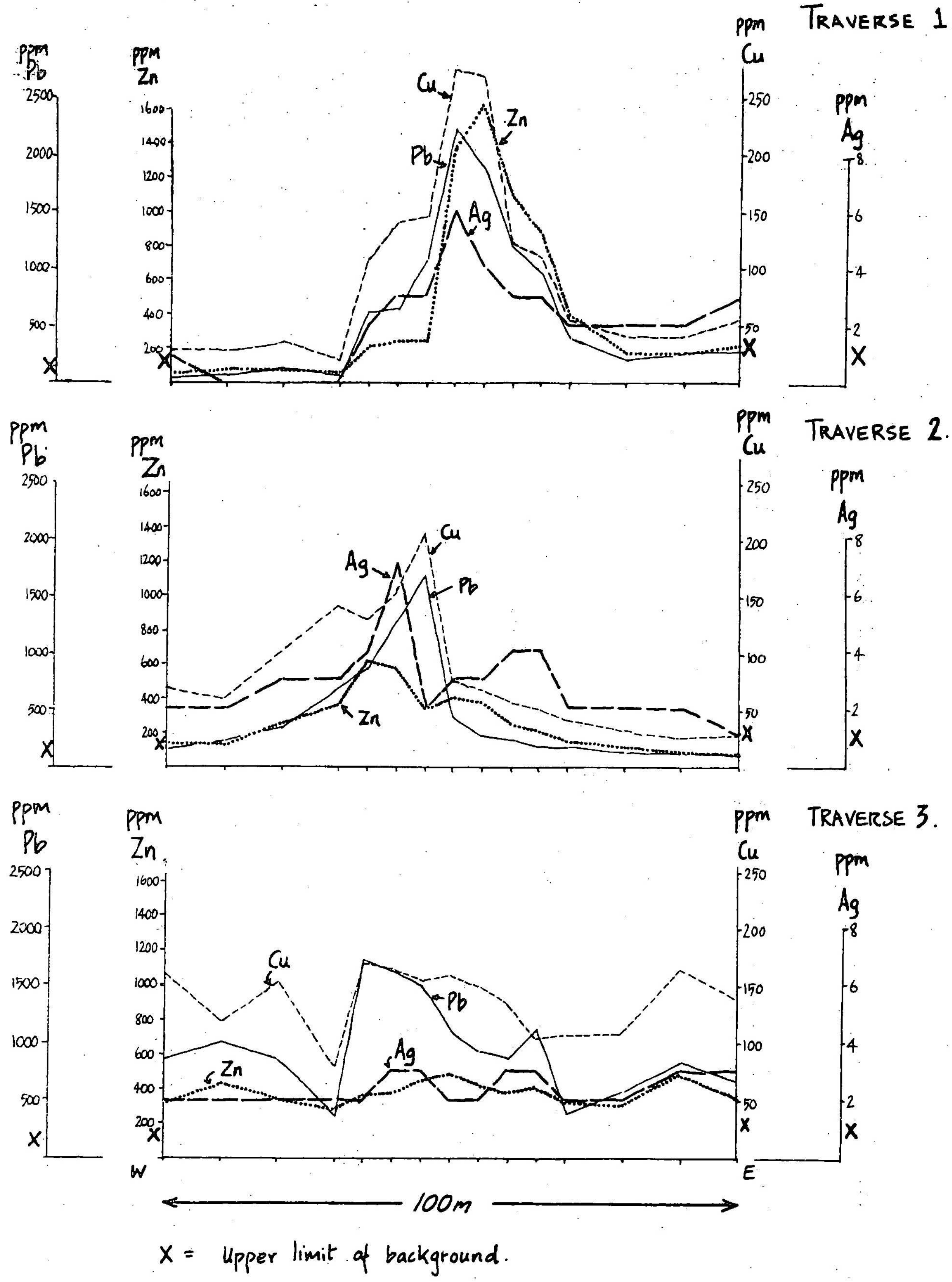


Figure 5.

Copper anomalies in soils surrounding the Jubilee Plunger lode.

from Armstrong (1975)



DETAILED GEOCHEMICAL TRAVERSES Figure 6.

(from Armstrong, 1975)

To determine the true width of the anomalous zone, and to test the effect of contamination due to mining, samples were collected at 5-10 m spacings along three traverse lines in areas least disturbed by mining (Fig. 3). The results are shown in Figure 6. Along traverses 1 and 2, Ag, Pb, Zn, and Cu mostly show very high values in a zone 30-40 m wide, and markedly lower, but none-the-less anomalous, values either side. The highly anomalous zone appears to correspond with the alteration zone. The peaks on traverse 3 are broader and flatter; the line lies entirely within the alteration zone, and all values are anomalous.

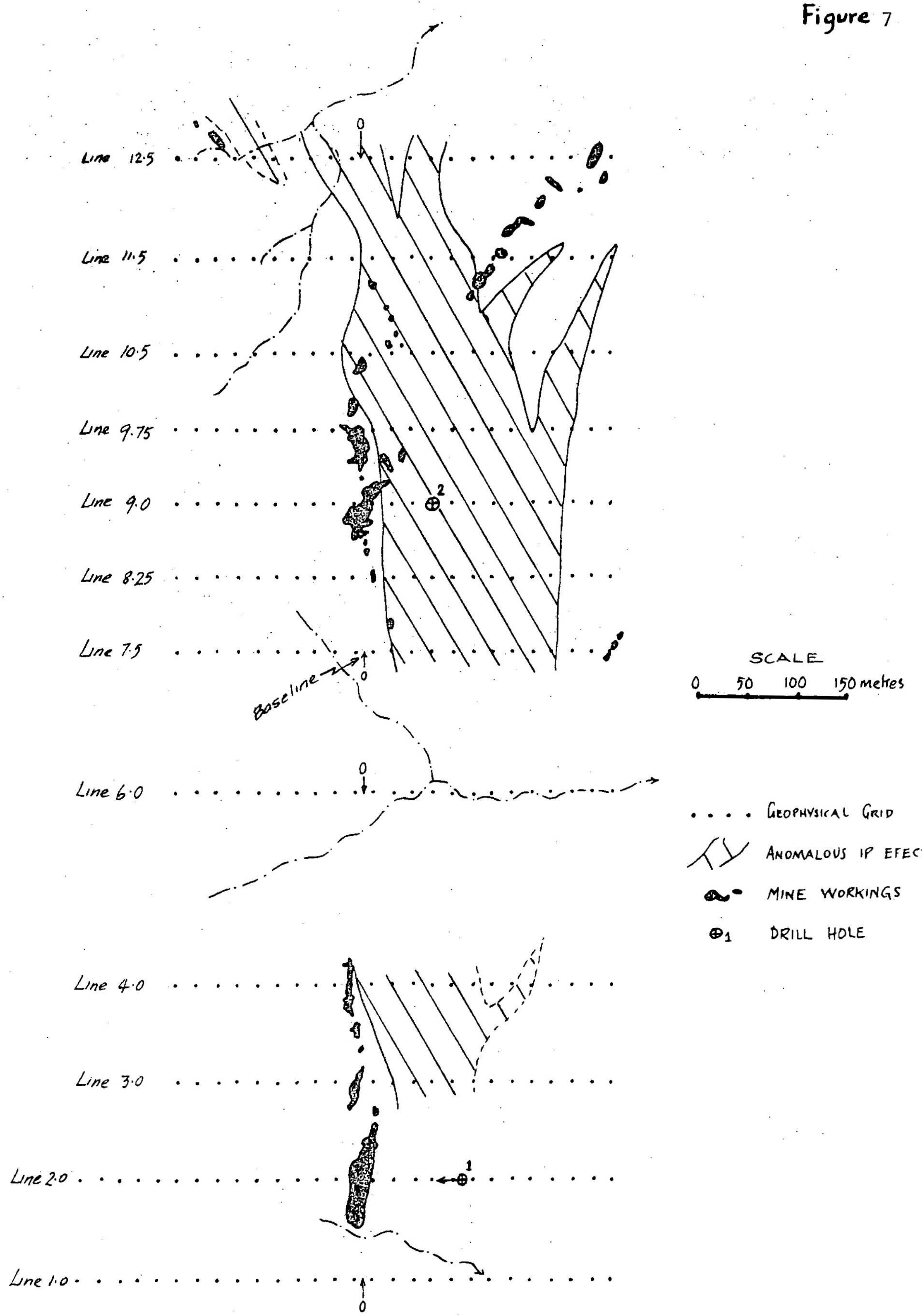
Clearly there is an extensive and readily detectable, naturally occurring, high value Au-Ag-Pb-Zn-Cu anomaly in soils overlying the Jubilee Plunger deposit.

4. SURFACE GEOPHYSICAL EXPRESSION

The following techniques were used to investigate the apparent resistivity, IP effect, magnetic, VLF, and Turam characteristics of the Jubilee Plunger reef (Wilson, in prep.). The apparent resistivity and IP effect were measured using a 1500-m gradient array for lines 1 to 6 (Fig. 7). Current electrodes were placed at 750 m west and 750 m east on line 3. For lines 7.5 to 12.5 a 1000-m gradient array was used. Current electrodes were placed at 600 m east and 400 m west on line 10.5. Measuring electrodes were spaced 20 m apart, and were moved 20 m for each reading.

Total-field magnetic readings were taken on average every 10 m along the traverse lines. Readings were made at 20 m spacings where the gradient was low.

Figure 7



INDUCED POLARIZATION ANOMALY Figure 7

(data from Wilson, in prep)

VLF readings were taken every 10 to 20 m, depending on the gradient of the field. The receiver was oriented at right angles to the beam of the North West Cape transmitter, which was the sole signal source (22.3 kHz).

For the Turam measurements a 400 m x 400 m square loop was laid out west of the main IP anomaly (Fig. 7) on line 9. The leading edge of the loop was along 50 m west, and the sides along lines 7.5 and 11.5. Coil spacings along the measuring lines were 20 m. Frequencies of 220 and 660 Hz were used, and readings were taken every 20 m (Wilson, op.cit.).

Apparent resistivity

There is a prominent central resistive zone corresponding roughly with the main quartz reef and flanked by similar but divergent highs separated by lows corresponding with the strongly altered zones. The apparent resistivity profiles on lines 6 and 7.5 appear to be offset - the northern profile is some 75 m east of the southern one. Similarly offset are the magnetic trends. The offset may be due to a fault trending east-west and with the upthrown block to the north.

IP effect

IP values are mostly low and uniform, but there is a low-order anomaly (maximum 2 x background on line 9 - Fig 7) to the east of the northern group of workings and roughly coincident with geochemical anomaly B; it measures 150 m x 300 m. The easterly 'tail' on the anomaly is consistent with a stratiform sulphide body dipping east at 45°. IP response drops away south of line 7.5, indicating that the sulphide content of the deposit declines markedly beyond that point. The northern and northwestern ends of the anomaly are split, and probably represent mineralization at several levels or following divergent near-vertical fractures.

Magnetics

The contoured total-field magnetics show two distinct highs, one over the southern area of outcrop (line 2) and the other over the northern area of outcrop (lines 9 to 10.5). The highs are broad (200 to 300 m), and trend north-south; the peaks are slightly west of the geochemical anomalies, and are apparently not directly related to the mineralization indicated by the IP response.

Tura

Only the area of the main IP anomaly was tested. The small phase anomalies coincident with the peak IP responses indicate that the IP source is not massive or interconnected. The bulk conductivity of the "ore" is low because it is mostly within quartz.

VLF

Few conductors are traceable from line to line, but the strike of the mineralized zone is unfavourable for VLF reception from the North West Cape transmitter.

5. MINERALIZATION

Sulphide minerals are present to a maximum of about 20% by volume over intervals of 1 m to 1.5 m in the drill core (second hole, DDH2) from below the base level of oxidation (about 12 m vertical depth). Almost all the sulphides are concentrated in the quartz veins and adjacent fractures, but small quantities are also present in the most intensely sericitized zones, mainly as small fracture fillings. Disseminated pyrite is common throughout the alteration zone.

The common minerals as determined by inspection, thin section, and polished thin section are, in order of abundance: quartz, pyrite, sphalerite (marmatite), galena, chalcopyrite, calcite, and iron-stained leucoxene, as well as some covellite and marcasite. Gold and silver, though present (maximum 12.7 g/tonne and 205 g/tonne, respectively), have not yet been seen. Microprobe analysis indicates that all the silver may be contained within the galena lattice (R.N. England, pers. comm). Chemical analyses indicate that arsenic and bismuth are also present in significant quantities - presumably as small amounts of arsenopyrite and tennantite.

Pyrite is in the form of cubes scattered throughout the quartz, carbonates, and the other sulphides, and as massive aggregates in which grain and crystal boundaries are usually not visible. The grains range from about 0.2 mm to less than 0.001 mm. The large grains commonly have many inclusions arranged in zones parallel to the crystal faces. The very small grains are too small to see clearly enough to determine their shapes. They are present as discrete inclusions in sphalerite, and as close-packed grain aggregates in some coarse pyrite concentrations. At low magnification the aggregates appear as single, albeit darker, grains. The massive pyrite zones are brecciated, and some fractures within this pyrite contain unfractured late pyrite cubes. This later pyrite is commonly associated with the latest fracture fillings - the late carbonate veins.

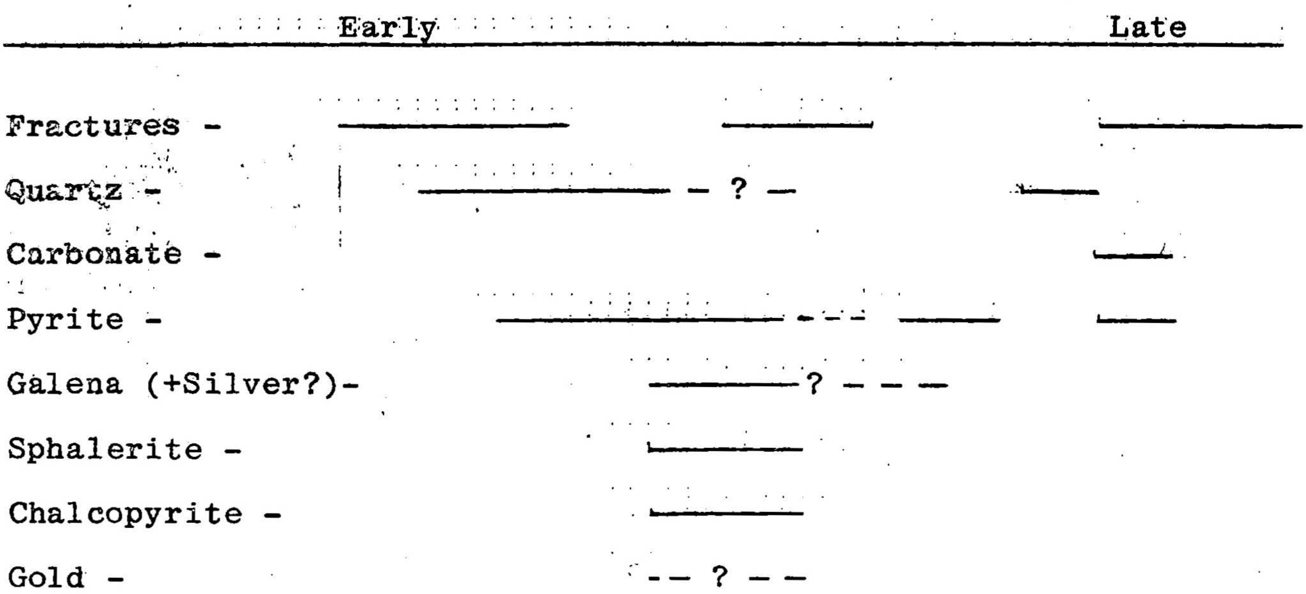
The sphalerite is an iron-rich variety (marmatite), and is commonly full of very small (less than 0.01 mm) inclusions - mostly chalcopyrite and some galena and pyrite. It is generally dark red-brown to opaque, although local recrystallization has resulted in some of the marmatite's 'dumping' iron and reverting to 'normal' sphalerite.

Chalcopyrite commonly occurs as discrete irregular grain aggregates in quartz, as well as small inclusions in sphalerite.

The main sulphide minerals are commonly segregated into zones in which one mineral predominates. For example, a band, 1-10 cm wide, composed mostly of pyrite, grades into a zone of galena and minor pyrite, sphalerite, and chalcopyrite (5-10 mm) which passes to a zone, 5-10 cm wide, composed predominantly of sphalerite with chalcopyrite inclusions and some pyrite. Subsequent fracturing has mixed these zones to some extent and 'late' pyrite has 'swamped' some of the galena and sphalerite zones.

Assay data indicate a very strong relation between gold and silver and the sulphides (Fig. 8). Although the silver is apparently contained within the galena, not all the galena contains silver. Furthermore, not all high gold values are accompanied by proportionately high silver values. Further mineragraphic, microprobe, and scanning electron microscope studies are planned to locate the gold.

Texural and other relationships tentatively indicate the following sequence of fracturing and deposition of the 'ore' minerals:

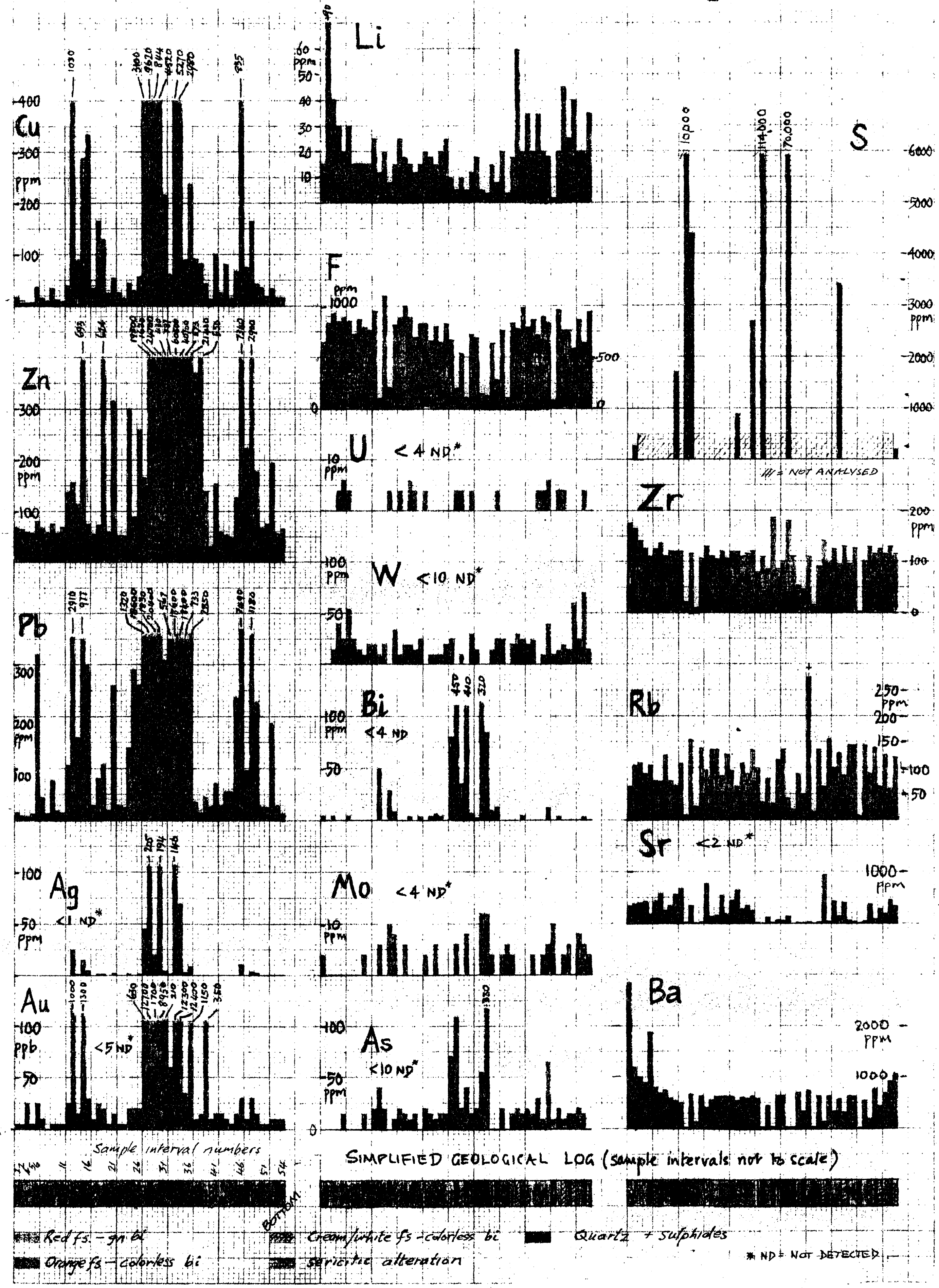


6. GEOCHEMISTRY

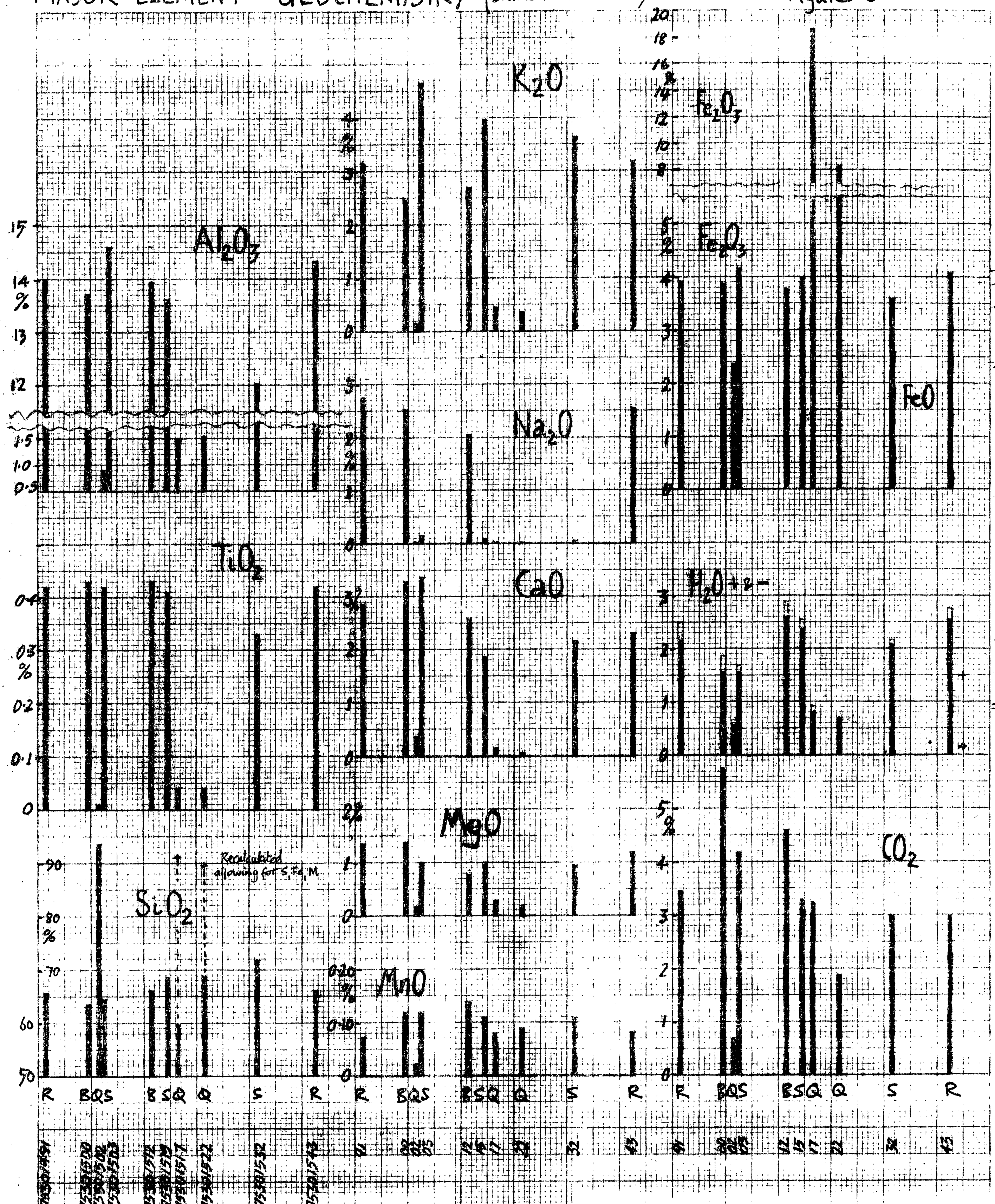
All the drill core (4.5 cm diameter) from below 19.8 m in DDH2 was sawn in halves, split into sections ranging in length from 0.08 to 6.33 m, and analysed for Au, Ag*, Pb*, Zn*, Cu*, Bi, Mo, As, F, Li, U, Ba, Sr, Rb, and Zr (Figs. 8 & 10). An additional two samples were taken at 9.75 m and 15.25 m depth. Ten samples selected as representative of the various rock/alteration types present were also analysed for S, CO_2 and the major element oxides (Figs. 8, 9 & 10, Tables 2 & 3). Sample size was determined by geological contacts and zones of core loss (or poswible core loss). In Figure 10 the core is represented graphically in simplified form and the true sample widths are indicated. In Figures 8 and 9 all samples are represented by equal widths for ease of presentation.

* Analyst: B. Cruikshank, BMR, others by AMDEL

TRACE ELEMENT GEOCHEMISTRY (DRILLHOLE N°2) Figure 8



MAJOR ELEMENT GEOCHEMISTRY (DRILL HOLE N° 2) Figure 9.



Main alteration types:

R = Red colour, B = Buff coloured, S = Sericitic, Q = Quartz-sulphide vein

(see Fig 10 for more detail of alteration types)

An additional three analyses of unaltered (or very slightly altered) granodiorite (Table 2) are taken from Sheraton (1974). These three analyses are useful in comparing the altered rock with the unaltered, but are too few to give much indication of the petrogenesis of the granodiorite. However, Sheraton's data do indicate that this gradodiorite is chemically distinct from the other (Proterozoic and Siluro-Devonian?) granodiorites of the region. For example, it has a markedly higher TiO_2 (relative to biotite content), Fe (particularly FeO), MgO, K_2O, CaO and MnO, and lower Na_2O content than the other granodiorites analysed by Sheraton. The varaiation in major-element chemistry with respect to alteration in the drill core is shown in Figure 11 and discussed in the section on alteration.

Not all the minor elements determined for the drill core samples were determined for Sheraton's (1974, p. 330, samples and vice versa. However, there are sufficient data to provide a reasonably clear picture of the variation of minor elements in the alteration zone. The most notable features are: the coincidence of anomalous levels of Au, Ag, Pb, Zn, Cu, As, and Bi; the considerable and erratic variation of Ba, Sr, Rb, F, and Li; the apparent depletion of Ba and Sr in the strongly altered rocks; and the much lower levels of all elements except Au, Ag, Pb, Zn, Cu, As, and Bi in the quartz veins. The values for U, Mo, and W are too close to detection limits to permit meaningful interpretation other than to conclude that Mo may be higher in some quartz veins and that U and W appear to be lower than "background" in most quartz veins.

Table 2. Chemical analyses, Robin Hood Granodiorite

	1	2	3	4	5	6	7	8	9	10
SiO_2	67.4	69.1	68.5	65.36	66.03	63.52	66.09	64.29	68.46	71.92
TiO_2	0.48	0.44	0.43	0.42	0.42	0.43	0.43	0.42	0.41	0.33
Al_2O_3	15.04	14.49	14.86	13.98	14.33	13.71	13.94	14.61	13.62	12.02
Fe_2O_3	1.73	1.44	1.15	1.26	1.03	0.52	0.34	1.10	0.78	0.99
FeO	2.40	2.40	2.30	2.65	3.05	3.35	3.40	3.05	3.20	2.60
MnO	0.08	0.08	0.07	0.07	0.08	0.12	0.14	0.12	0.11	0.11
MgO	1.54	1.54	1.44	1.36	1.20	1.39	0.78	1.02	1.02	0.95
CaO	3.40	3.22	3.08	2.84	2.32	3.30	2.60	3.37	1.85	2.14
Na_2O	3.5	3.1	3.4	2.74	2.55	2.52	2.05	0.15	0.09	0.05
K_2O	3.29	3.16	3.34	3.14	3.21	2.46	2.71	4.65	3.97	3.65
P_2O_5	0.13	0.11	0.10	0.10	0.10	0.12	0.12	0.12	0.10	0.08
H_2O+	0.94	0.86	0.95	2.14	2.53	1.57	2.61	1.57	2.38	2.12
H_2O-				0.34	0.23	0.29	0.31	0.15	0.18	0.10
CO_2	-	-	-	3.45	3.00	5.75	4.60	4.20	3.30	3.00
S	-	-	-	0.025	0.02	0.17	0.09	0.44	0.27	0.34
Total				99.85	100.09	99.05	100.12	98.84	99.46	100.08

1. 'Unaltered' granodiorite 3km SE of Jubilee BMR70571122 Analyst J. Sheraton
2. " " 12km SSE " BMR70571123 " " (XRF)
3. " " 21km SSE " " BMR70571126 " "
4. Pink granodiorite, interval* 2 Jubilee, BMR 75301491 " AMDEL (XRF)
5. " " " 54 Jubilee, BMR 75301543 " "
6. Buff granodiorite " 11 Jubilee, BMR 75301500 " "
7. " " " 23 Jubilee, BMR 75301512 " "
8. Sericitized granodiorite, " 14 Jubilee, BMR 75301503 " "
9. " " " 26 " BMR 75301515 " "
10. " " " 43 " BMR 75301532 " "

*The interval numbers are marked in Fig. 10

Table 3. Chemical analyses, quartz-sulphide veins.

	1	2	3
SiO_2	93.63	59.86	68.84
TiO_2	0.01	0.04	0.04
Al_2O_3	0.89	1.48	1.53
Fe_2O_3	1.13	18.44	8.33
FeO	1.25	-	-
MnO	0.02	0.08	0.09
MgO	0.18	0.29	0.20
CaO	0.37	0.14	0.06
Na_2O	0.01	0.01	0.01
K_2O	0.15	0.45	0.38
P_2O_5	0.01	0.02	0.03
H_2O+	0.56	0.81	0.67
H_2O^-	0.07	0.13	0.05
CO_2	0.07	3.25	1.90
S	1.00	11.4	7.30
(Metals)	(.4)	(4.8)	(8.45)
Total	100.38	101.19	97.87

1. Mineralized quartz vein, interval* 13 Jubilee BMR75301502 anal. AMDEL
2. " " " " 28 " BMR75301517 " "
3. " " " 33 " BMR75301522 " "

* as indicated in Fig. 10

7. ALTERATION

The hydrothermally altered zone that contains the mineralized quartz veins of the Jubilee Plunger reef (Fig. 10) is zoned in the manner described by Lovering (1950), Sales & Meyer (1950), Meyer & Hemley (1967), Meyer et al. (1968), Lowell & Guilbert (1970), and others. As petrographical and mineralogical studies have not yet advanced far enough to positively 'type' the alteration zones, the following summary (see also Fig. 11) should be taken as only a general guide to the sort of mineralogical and chemical changes in the granodiorite. The main wall-rock alteration types (zones) shown in Figures 10 and 11 are tentatively correlated with the propylitic (1), argillic (2 & 3), and phyllic (4) zones of Lowell & Guilbert (op. cit.).

'Unaltered' rock

The 'unaltered' granodiorite is grey to pinkish grey, and consists of quartz (25-30%), andesine (45-50%), microcline (15-25%), biotite (5%), and hornblende (2%). Chlorite, epidote, sphene, zircon, apatite, muscovite, allanite, fluorite, and opaques are minor constituents. Most of the quartz occurs as subrounded aggregates (7-10 mm diameter) of small grains with highly sutured boundaries and undulose extinction; a small amount is interstitial or graphically intergrown with microcline. The plagioclase is anhedral zoned andesine (1-5 mm), and much of it is pink through being clouded and flecked with very fine sericite(?) and hematite(?). Microcline is commonly slightly perthitic. Biotite and hornblende are green and bluish green, respectively. Scattered small dark fine-grained mafic xenoliths are present locally; they consist of interlocking green biotite and blue-green hornblende crystals, opaques, and some interstitial quartz.

SIMPLIFIED
GRAPHIC LOG OF DRILL CORE DDH 2
JUBILEE PLUNGER

Figure 10.

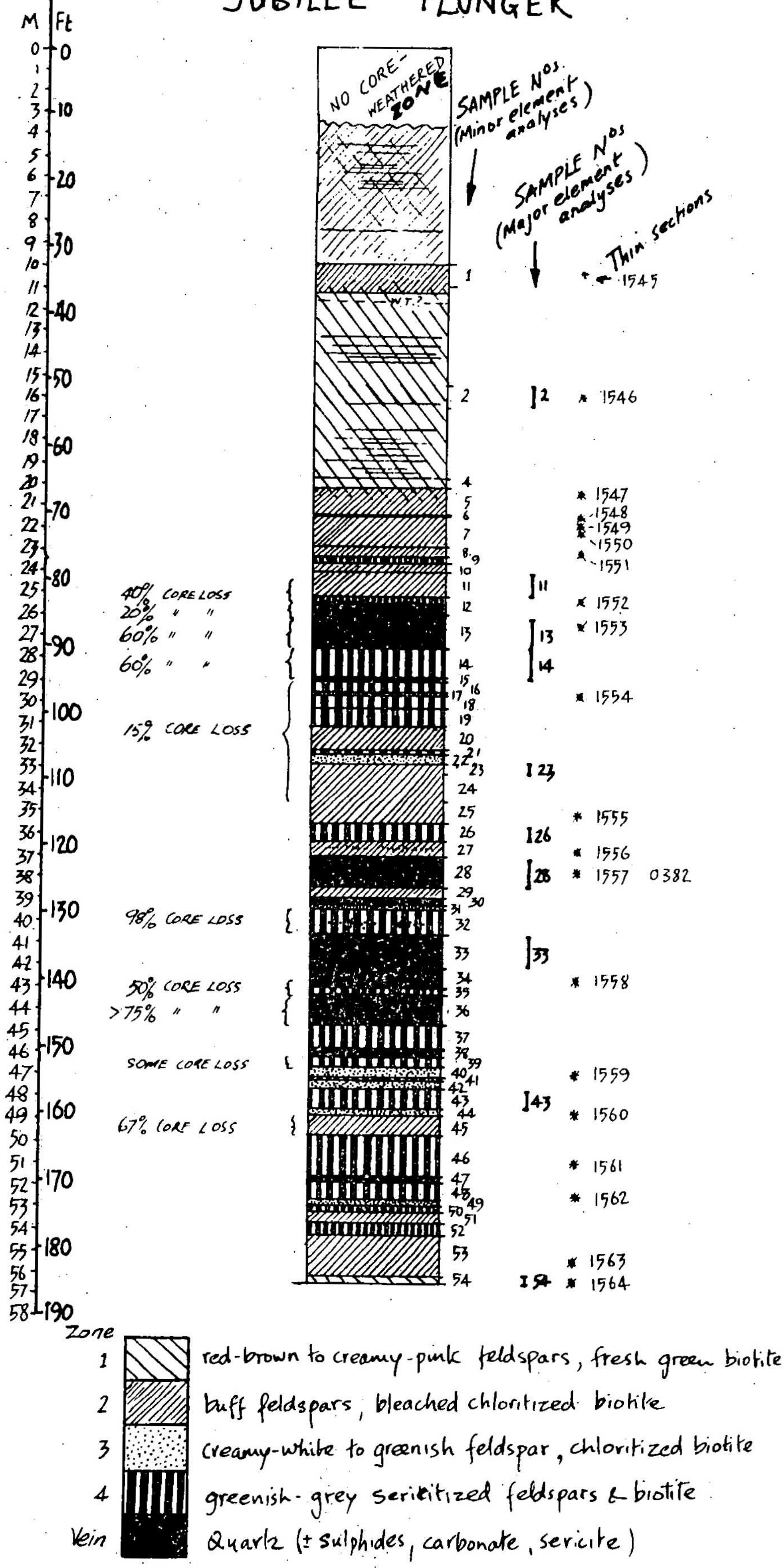
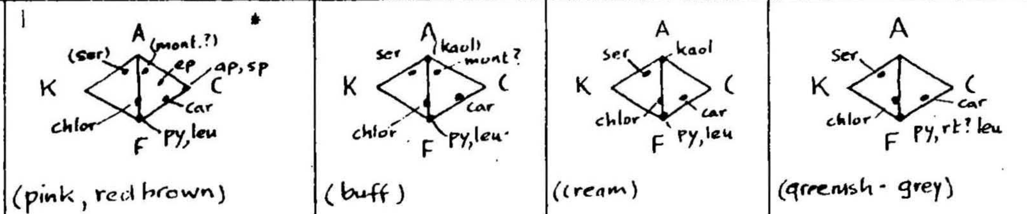


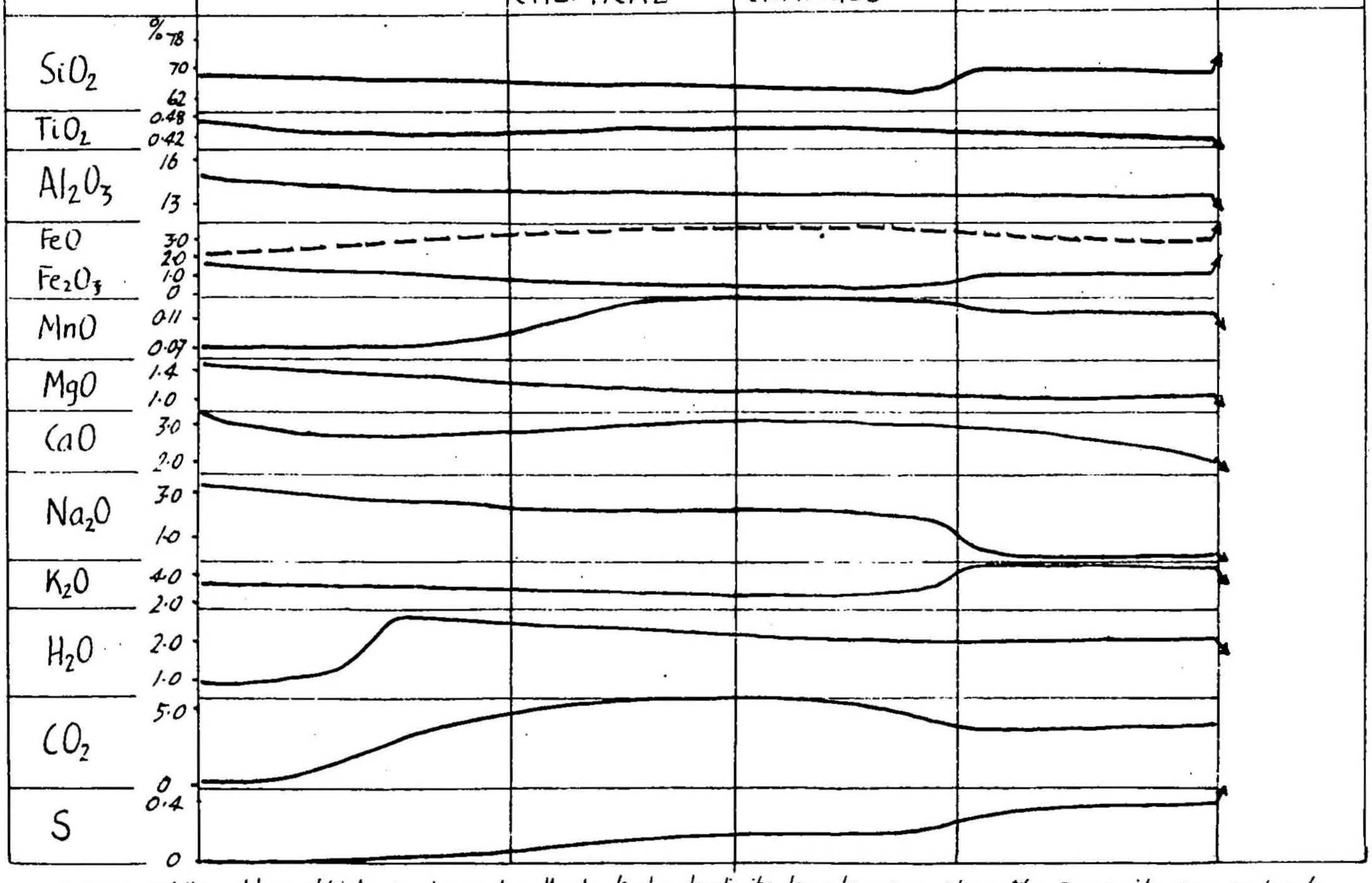
Fig. 11. Diagrammatic summary of mineral assemblages, showing progression of mineralogical changes and variations in chemical composition in wall-rock alteration accompanying the introduction of mineralized quartz veins, Jubilee Plunger reef, Georgetown Inlier, Qld.

UNALTERED ROCK	Zone 1 PROPYLITIC	Zone 2 ARGILLIC	Zone 3 ARGILLIC	Zone 4 PHYLLIC	Vein Quartz/Sulph.
FRESH HORNBLENDE - BIOTITE GRANODIORITE (grey, pink-grey)	(pink, red brown)	(buff)	(cream)	(greenish - grey)	



	MINERALOGICAL CHANGES				
QUARTZ				Quartz added.	Quartz
MICROCLINE (microperthite)	Traces of sericite, kaolinite ⟶		mostly kaolinized, some sericite	sericitized	
PLAGIOCLASE An_{20-30} (zoned)	Red clouded, (allophane?) Some sericite, carbonate chlorite, epidote.	Clays (kaol ± mont?) sericite, carbonate leucoxene (Fe-stain)	Kaolinite, sericite, leucoxene	Sericite (coarse), Some clear fresh plagioclase.	
BIOTITE (green)	Green, interleaved with chlorite, carbonate, leucoxene, Some completely altered Some unaltered.	Bleached, more chlorite, leucoxene and carbonate	Chlorite, leucoxene	Muscovite (sericite), Chlorite, leucoxene (rutile?).	
HORNBLENDE (blue-green)	Blue-green, partly to completely chloritized + leucoxene & carbonate	⟵ chloritized + leucox. ⟶ (Indistinguishable from		Chlorite, muscovite (sericite), leucoxene biotite) ⟶	
VEIN FILLINGS		Carbonate, Fe-leucoxene (± sericite & kaol.)		Quartz, carbonate, leucoxene (± kaol.)	Sulphides (± carb, leuc., ser.)

CHEMICAL CHANGES



* ser = sericite, chlor = chlorite, mont = montmorillonite, kaol = kaolinite, leu = leucoxene, rt = rutile, py = pyrite, car = carbonate, ep = epidote, ap = apatite, sp = sphene, A = $Al_2O_3-(Na_2O+K_2O+CaO)$, C = CaO, F = FeO + MgO + MnO. K = K_2O

Zone 1 (Propylitic)

The extent (outermost limit) of this zone is not known - it presumably grades into unaltered rock over perhaps 500 m or more. In fact even the 'unaltered' rocks show some signs of weak propylitic alteration. Plagioclase is moderately to strongly clouded and locally lightly sericitized and kaolinized? (montmorillonitized?). Small granules and patches of epidote and carbonate (calcite?) are common. Biotite is green, and commonly replaced along cleavage by colourless chlorite, carbonate, and lenses of iron-stained leucoxene, which generally decrease in abundance outwards towards the unaltered rock. Hornblende is almost entirely chloritized. Finely disseminated and coarsely aggregated leucoxene is common. Microcline is mostly unaltered. Pyrite and magnetite? are disseminated throughout the rock.

Zone 2 (Argillic)

A change in colour of the feldspars from red-brown or creamy pink to orangy brown or buff, and a change from dark green biotite to very pale green biotite or colourless chlorite, marks the gradational change from Zone 1 to Zone 2. This zone is characterized by an increase in clays, sericite, and carbonate in the plagioclase, the almost total replacement of biotite and hornblende by chlorite, carbonate, and leucoxene, and by the abundance of iron-stained leucoxene which is commonly present in carbonate veins that are locally fringed with narrow (less than 1 cm) sericitic envelopes.

Zone 3 (Argillic)

This zone is cream to pale buff or greenish white, and characterized by almost totally kaolinized feldspars, abundant carbonate and leucoxene, and a greater abundance of sericite (particularly in the outer parts of plagioclase crystals). All mafics are chloritized. Both Zones 2 and 3 are highly fractured. Carbonate, leucoxene, kaolinite, sericite, and some sulphides occupy these fractures.

Zone 4 (Phyllic)

This zone is characterized by its greenish grey colour and the abundance of fine to very coarse felted sericite. Quartz carbonate, leucoxene (± ilmenite or rutile?), chlorite, and sulphides are the other main constituents. The abundant carbonate was probably introduced by a later fluid, and is not part of the primary phyllic assemblage. Pre-, syn-, and post-sericite fractures are common and locally contain sulphides. This zone commonly forms thick (10 cm-2 m) envelopes about quartz veins (1 mm to 1 m), and much thinner envelopes or selvages (generally less than 1 cm) around small carbonate-leucoxene kaolinite veins in Zones 2 and 3. The contact between this and other zones is commonly very sharp - a single plagioclase crystal may be totally sericitized at one end and completely kaolinized at the other.

Geochemistry of alteration zones and origin of mineralization

The chemical data (Figs. 8, 9, & 11) show clearly that H_2O, CO_2, S, Fe, Mn, Au, Ag, Pb, Zn, Cu, As, and Bi have been introduced into the fractured, veined, and hydrothermally altered zone - the greater part of the Fe, X, and metals being concentrated in the quartz vein. Some of the SiO_2 in the quartz vein may have been carried in with the metals and volatiles, but clearly some if not all was derived from the altered wall-rocks by diffusion processes induced by percolating hot hydrothermal fluids. SiO_2, K_2O, TiO_2, Al_2O_3, MgO, CaO, and Na_2O were all redistributed within the alteration zone -

K_2O was concentrated in Zone 4, and Na_2O was lost from all zones, but especially from Zone 4. The K_2O enrichment in Zone 4 results from the development of large quantities of sericite. The destruction of all or nearly all Na-bearing minerals in this zone is the reason for the marked depletion of Na_2O.

Suggestions as to the ultimate origin of the hydrothermal fluids that introduced the precious and base metals and altered the wall-rocks in this linear fracture zone can only be conjectural. However, circumstantial evidence would appear to favour the hypothesis that magmatism related to the extrusion of the nearby late Carboniferous and Permian acid volcanics, and the intrusion of hypabyssal equivalents (Fig. 1), is the ultimate source of such fluids. This evidence is:

(i) the mineralization postdates the probable Siluro-Devonian Robin Hood Granodiorite;

(ii) the deposit has similar alteration and mineralization to the undoubtedly late Palaeozoic Kidston breccia pipe (Hannes & Dalgarno, 1967);

(iii) a late Palaeozoic rhyolite breccia pipe is only 500 m from the southern end of the Jubilee workings;

(iv) the deposit has similar mineralogy and alteration to the Mount Hogan and Percyville gold deposits (Fig. 1). That these are also probably of late Palaeozoic age is demonstrated by the proximity of late Palaeozoic volcanics and intrusives, and the presence of uranium minerals in their alteration zones (Uranium other than that contained in monazite is almost exclusively of late Palaeozoic origin in this district).

8. SPECULATIONS

There are some features of the Jubilee Plunger deposit which, taken with some characteristics of other gold and related deposits in the region, suggest that this deposit may not be merely a fissure gold deposit but may also be part of a larger mineralized system - possibly a porphyry copper system:

(i) alteration is of the types and intensity commonly but not exclusively associated with porphyry copper deposits;

(ii) mineralization is of the type commonly found in the peripheral alteration/mineralization zones of porphyry copper deposits as shown in the Lowell & Guilbert model, as seen at the Aspasia Ag-Pb deposit on the southern edge of the Mount Turner porphyry copper near Georgetown and as present in the Red Mountain, Arizona porphyry copper system described by Schrader (1915) and Corn (1975);

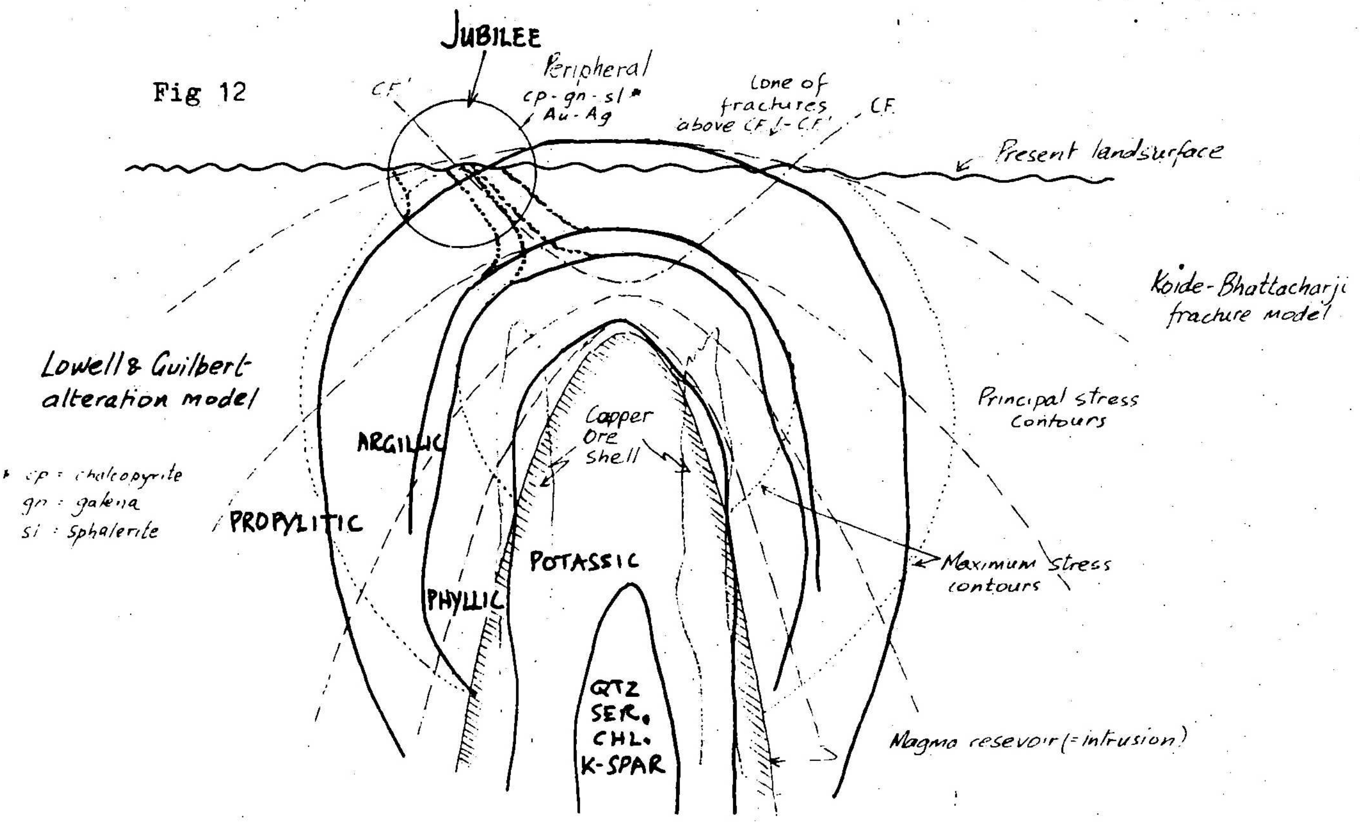
(iii) alteration, mineralization, chemistry, and probably age are similar to those of the Kidston breccia pipe gold deposit, which may be part of a porphyry copper system;

(iv) several porphyry copper deposits of probable late Palaeozoic age are present in the region.

Figure 12 shows how the Jubilee deposit may represent a peripheral 'leakage' zone in the outermost limits of an unexposed porphyry copper hydrothermal system as represented by the classic Lowell & Guilbert (1970) model.

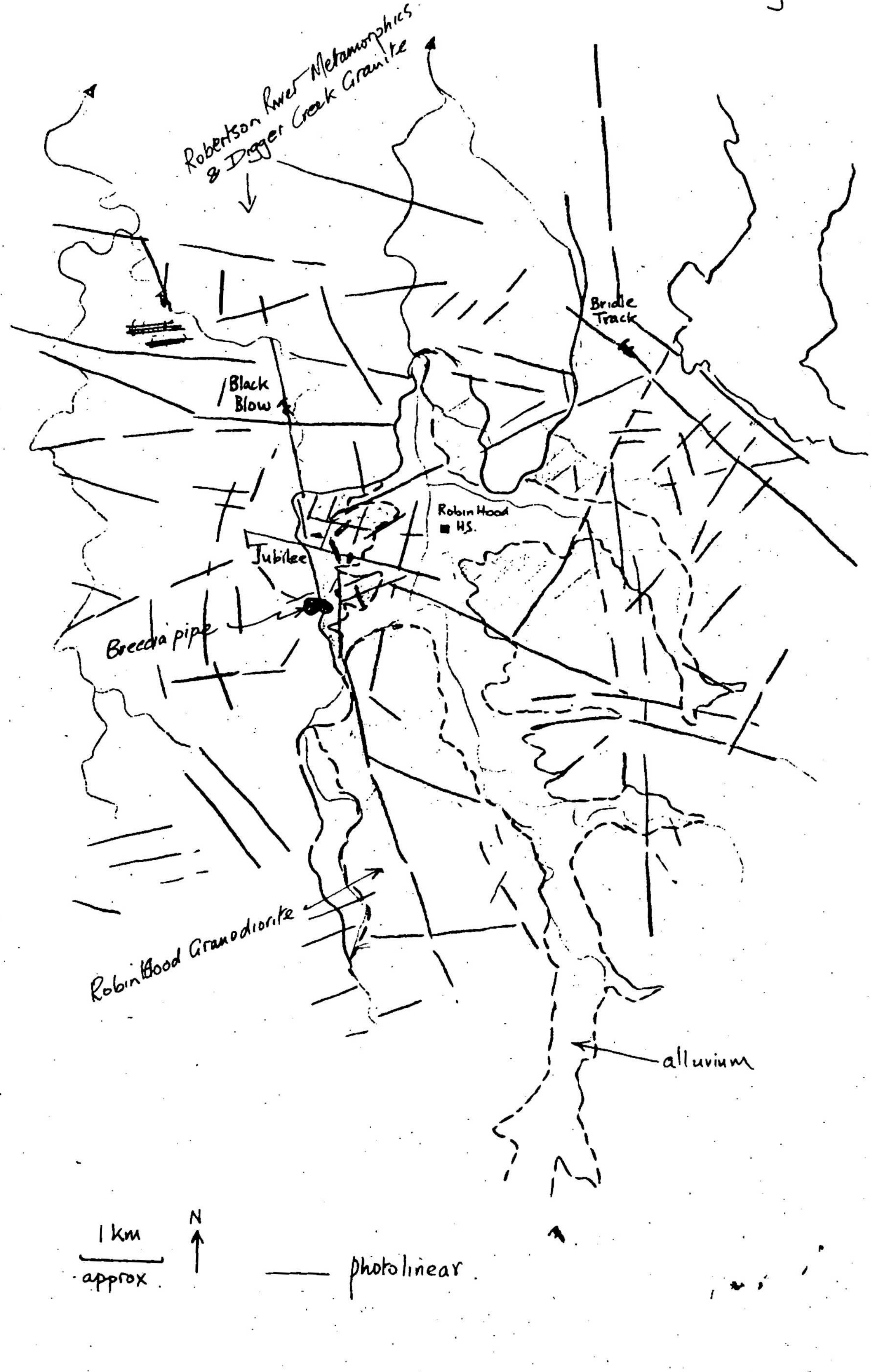
Fig. 12 Postulated relationship of Jubilee Plunger deposit to a model of a porphyry copper system and to a stress field related to an intrusive magma chamber.

Fig 12



PHOTOLINEARS, JUBILEE-PLUNGER

Fig. 13



The hydrothermal fluids have clearly been channelled up along the east-dipping fracture zone. This fracture zone could be part of the zone of inward dipping fractures that Koide & Bhattacharji (1975) postulate forms above vertically elongate prolate magma reservoirs such as one would expect to be associated with the hydrothermal system (Fig. 12). However photolinear analyses of the Jubilee (Fig. 13), Kidston, Mount Hogan, and Mount Turner hydrothermal alteration areas indicate that although the fracturing in these areas is more intense than in the surrounding unaltered areas it mostly lacks the characteristic radial and concentric pattern of the Koide-Bhattacharji model.

Some may argue that porphyry copper systems are represented on the surface by strato-volcanoes, or may be contained therein, and that clearly such structures are absent and always have been from the Jubilee area. This is undeniably true (Sillitoe, 1973, 1975; Branch, 1976), but it is equally plausible to suppose that porphyry copper systems also form without concomitant volcanic edifices, and that Jubilee may be just such a case.

Further evaluation of the small Jubilee Plunger Au-Ag-Zn-Pb-Cu deposit should not overlook the possibility, albeit highly speculative, that the ultimate source of the hydrothermal fluids and related ore minerals may have been a large system which also formed a deeply buried (1500 m or more) porphyry copper deposit.

9. ECONOMIC POTENTIAL

The geochemical data indicate that at Jubilee gold and silver are present in economically interesting concentrations only where there are appreciable base metal sulphides. The

IP and drill-hole No. 1 data indicate that there are no such concentrations of sulphides in the southern half of the line (geochemical anomaly A), so this part of the line appears to have no economic potential.

However, potentially 'ore-grade' mineralization was encountered in drill-hole No. 2 near the centre of geochemical anomaly B in the northern half of the line. The size and grade of this mineral deposit are not known, as only one hole intersected the mineralization and considerable core was lost from the mineralized zone. Nevertheless, the data in Table 4 can be used to obtain a very rough indication of the size and grade of the mineral deposit:

Table 4: Metal content of mineralized section 37 m - 44.6 m

Sample No.	Sample Interval (m)	Metal content (ppm) Au	Ag	Pb	Zn	Cu	Core Recovery
28	1.37	12.7	205	18600	19500	9620	95%
29	0.46	1.7	18	1830	1630	844	95%
30	0.36	8.95	194	20400	24700	4520	95%
31	0.18	0.21	4	308	430	216	95%
32	1.14	0.06	2	567	787	59	5%*
33	1.52	12.3	146	18600	60500	5270	95%
34	0.91	12.4	67	18400	40700	2980	95%
35	0.30	0.035	3	733	573	90	50%*
36	1.37	1.15	7	2850	21400	238	25%*
Total Intersection	7.61	-	-	-	-	-	
Grade (weighted averages)	ppm	6.98	86.1	10974	25732	3466	
	g/t	7	86	-	-	-	
	%	-	-	1.1	2.6	0.35	

*The nature of the core is such that clays, carbonates, and sulphides not strongly bound with quartz are the components most likely to be lost where core recovery is incomplete

Length of intersection (measured)	7.61 m
Length of lode (est. from geophys. data)	400 m
Inclination of lode	45^{o}E
" of hole	vertical
Density of 'ore' (SG)	3.5
Grade of 'ore'	see Table 4
Core recovery	" " "
Depth of lode (down dip)	unknown - probably 100 m or more

Volume per vertical metre of lode = 7.61 x 400 m^3

Tonnage per " " " " = 7.61 x 400 x 3.5 tonnes

= 10 654 tonnes.

Therefore it is inferred that the 'ore zone' contains 10 000 tonnes of ore per vertical metre with an average grade of 7 g/tonne Au, 86 g/tonne Ag, 2.6% Zn, 1.1% Pb, and 0.35% Cu, or better, depending on one's interpretation of the likely composition of the unrecovered core. For instance, in the most optimistic interpretation, Au and Ag values may be lifted to 12 and 150 g/tonne respectively. This deposit may be of sufficient grade and tonnage to warrant further testing. If such testing confirms the indicated size and grade, and establishes that there are no prohibitive mining or metallurgical problems, the deposit would be potentially economically exploitable.

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