Open File Envelope No. 2632

SML 703

ARKAROOLA (WOOLTANA JOINT VENTURE)

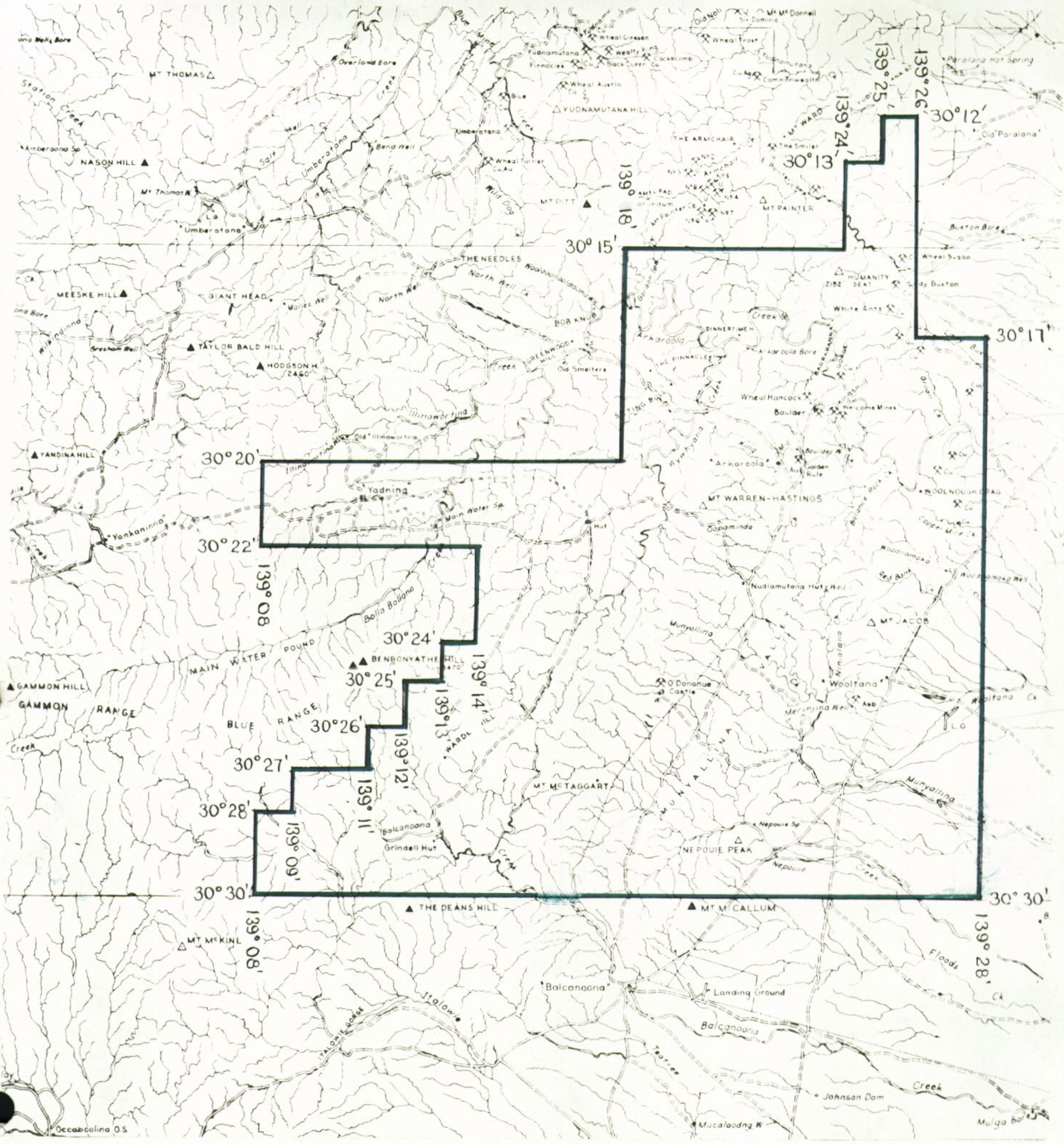
FINAL REPORT AT JOINT VENTURE EXIT FOR THE PERIOD APRIL TO OCTOBER 1972

Submitted by
Shell Minerals Exploration (Australia) Pty Ltd
1973

Enquiries: Customer Services Branch
Minerals and Energy Resources
7th Floor
101 Grenfell Street, Adelaide 5000

Telephone: (08) 8463 3000
Facsimile: (08) 8204 1880

Government of South Australia
Primary Industries and Resources SA



SCALE 1:250000

~~765~~ ✓
~~805~~ ✓
~~806~~ ✓
FO ✓
origin ✓

NORTH FLINDERS MINES LTD.

DOCKET DM 460/72 AREA 268 SQ MILES

1:250000 PLANS COPLEY

LOCALITY ARKAROOLA AREA

S.M.L. No. 703 EXPIRY DATE 19.5.74

FINAL REPORT

WOOLTANA JOINT VENTURE,

NORTH FLINDERS RANGES, SOUTH AUSTRALIA.

SML 703

JANUARY, 1973

2632

J.R. SISE

SUMMARY

In May, 1972, Shell Minerals Exploration (Aust.) Pty. Ltd. proposed entering into the Wooltana joint venture agreement with North Flinders Mines Limited (N.F.M.) to explore part of their Special Mining Lease (S.M.L.) 575.

The S.M.L. is situated in the North Flinders Ranges in South Australia, approximately 640 km north of Adelaide.

The Blue Mine Conglomerate and associated units of Adelaidean age are reported to be shallow marine deposits adjacent to an ancient shoreline. Copper mineralisation is recorded from many occurrences throughout the outcrop length of these units.

Detailed section mapping was carried out in an attempt to find evidence of a Zambian Copperbelt-type environment for the deposition of the lower Adelaidean units.

Some similarity was noted, but this could be applied to most of the Adelaide geosyncline. Many important Copperbelt characteristics could not be found.

The transition shales, which immediately overlie the Wortupa Quartzite, were examined. As the O'Donoghue Castle mine occurs in this horizon, it was considered prospective for further copper mineralisation. Only traces of shear controlled mineralisation were found.

A detailed stream sediment sampling survey of the Skillogalee Dolomite, east of the Paralana Fault, failed to outline any areas of anomalous zinc.

All main copper occurrences in the Wooltana area were visited. The Coup, Claret, Wywhyana and Groan anomalies were examined in detail. It was concluded that structure was the main control of the mineralisation.

The likelihood of there being an economic ore deposit in the Wooltana area is most remote. (Shell Minerals withdrew from the project in October, 1972, for this reason.)

CONTENTS

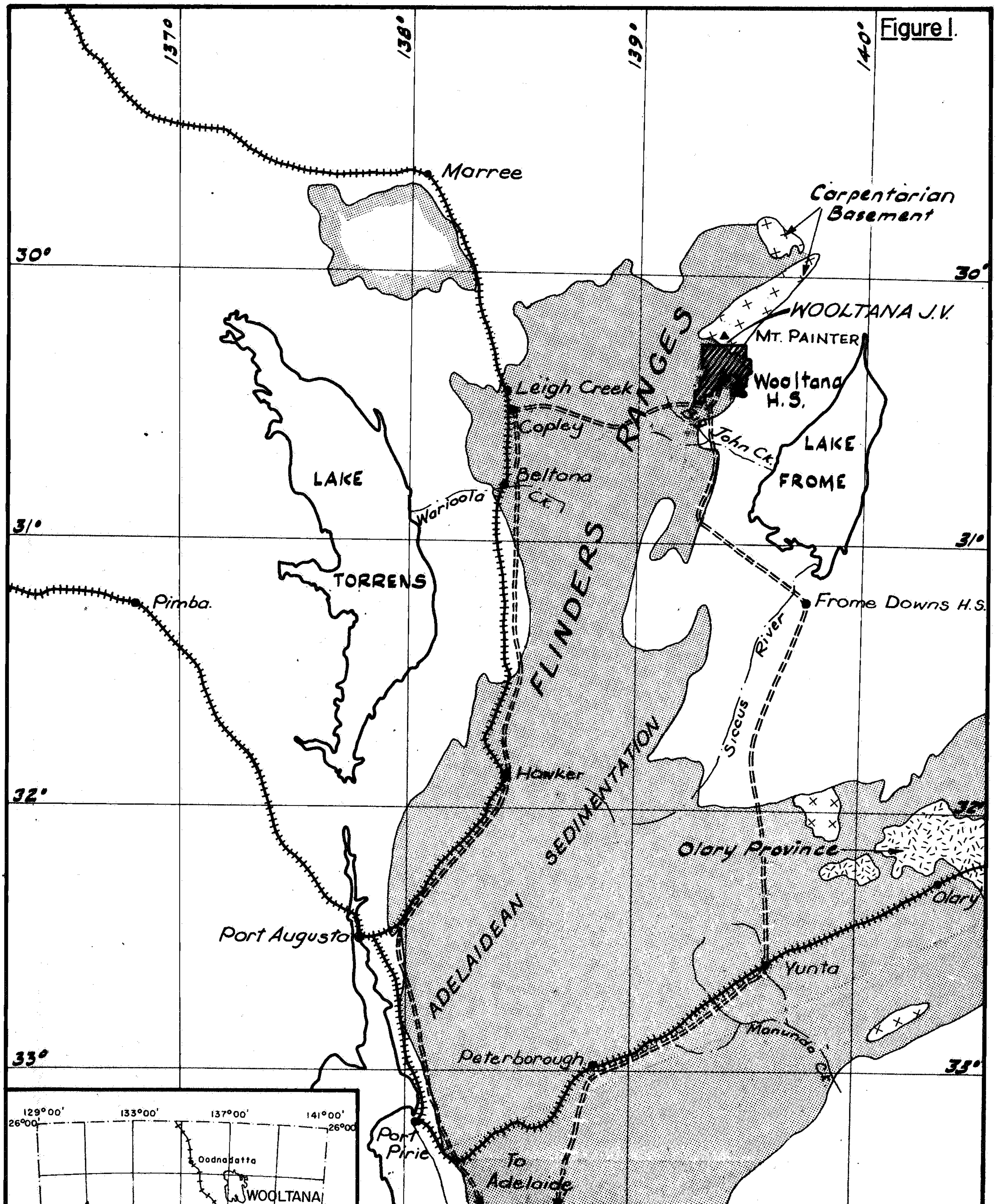
LIST OF FIGURES

LIST OF TABLES

APPENDICES

LIST OF PLANS

Figure I.



SHELL MINERALS EXPLORATION (AUST.) PTY. LTD.

WOOLTANA JOINT VENTURE SOUTH AUSTRALIA

LOCATION OF WOOLTANA JOINT VENTURE AREA

Scale 1: 2,027,520 (1" = 32 miles)

Author: J. R. Sise	Approved:
Report No:	Figure: No. 1
Date: October 1972	Draw. No.:

1. INTRODUCTION

Following a field visit in February, 1972, by geologist C. Newall, Shell Minerals Exploration (Aust.) Pty. Ltd., proposed entering into a joint venture agreement with North Flinders Mines Ltd., (N.F.M.) to explore the Blue Mine Conglomerate and associated units of Adelaidean age within part of their Special Mining Lease (S.M.L.) 575, in the North Flinders Ranges of South Australia. The proposed joint venture area was 221.9 sq. km of S.M.L. 575.

Past geochemical surveys have shown that the Blue Mine Conglomerate, as a unit, is anomalous in copper. Many small occurrences of secondary copper have been discovered along the 27 km strike length of conglomerate within the S.M.L.

Previous mapping by the Geological Survey of South Australia (Coats & Blissett 1971) suggests that the depositional environment of the lower Adelaidean sediments in the North Flinders Ranges was shallow marine and adjacent to an ancient shoreline around a land mass of basement Mt. Painter complex, of Carpentarian age.

It was thought that this proposed shoreline environment, adjacent to an essentially granitic basement, together with the many secondary copper occurrences, could be similar to the depositional regime of the Zambian Copperbelt.

It was to seek evidence for such a similarity that exploration in the joint venture area was initiated by Shell Minerals. Detailed mapping and sampling of the area, with emphasis on sedimentation, was commenced in May 1972. A formal joint venture agreement had not been signed at this stage, but it was agreed that field work should go ahead in order to take advantage of the winter field season. J.R. Sise (geologist) was assigned to the project. D.N. Carter (geologist) and two field assistants were employed on the project during September. The Wooltana joint venture was initially under the supervision of J.W.G. Gilbey (Senior geologist) and later of D.L. Forsythe (Senior geologist).

In October, 1972, the decision was made to withdraw from the proposed joint venture agreement, which was still being finalised.

1.1 LOCATION

The Wooltana joint venture area covered a large part of S.M.L. 575, which is currently held by N.F.M. (see Fig. 1). The S.M.L. is situated in the North Flinders Ranges, approximately 640 km by road north of Adelaide, and 128 km east of Leigh Creek. The northern boundary of the S.M.L. is 4.8 km south of Mt. Painter (790m), while Wooltana homestead is in the south east corner.

1.2 ACCESS

Road access to the area from Adelaide is usually by way of Hawker and Copley, approximately 670 km, although a route through Yunta and Frome Downs station was found to be shorter (572 km) and was used during the later stages. Sealed highways extend from Adelaide to Hawker and Yunta respectively (See Fig. 1).

Regular air access from Adelaide, to an airstrip approximately 5 km south of Arkaroola homestead, is maintained by Arkaroola Pty. Ltd., a local tourist organisation, which operates a motel at Wywhyana Park. The journey from Adelaide to Arkaroola, in the Cessna 206, takes about 2¼ hours. The airstrip can also accommodate larger twin-engine aircraft. A weekly service between Adelaide and Leigh Creek is provided by each of the commercial airlines.

A twice weekly bus service, provided by Thomas Tours Ltd., is used to carry supplies from Adelaide to Arkaroola.

Within the joint venture area, graded roads are maintained by Arkaroola Pty. Ltd., for use by the private motorist. Private station tracks provide additional access. Apart from the exposures of Sturtian tillite and basement in the north of the area, both of which are very rugged, general access is quite suitable for four-wheel drive vehicles.

1.3 SETTLEMENT

The S.M.L. covers parts of the pastoral leases of Arkaroola, Wooltana and Balcanoona. Arkaroola only maintains a few hundred sheep, and is primarily a sanctuary with tourist facilities. The old Arkaroola homestead is now used as a base camp by N.F.M., and was used as such by Shell Minerals.

1.4 CLIMATE AND VEGETATION

The climate of the region is semi-arid with very high temperatures in the summer (up to 44°C)and with mild winters.

Rainfall is both deficient and erratic, averaging less than 25 cm per annum.

Vegetation is generally stunted and sparse with rapid regeneration of plants occurring after heavy rain. Mitchell grass and salt bush predominate on the plains, while mallees favour the more limey horizons (Skillogalee Dolomite) and mulga covers the arenaceous rock types within the ranges. Spinifex occurs throughout the region, and tall red gum trees line the major creeks.

1.5 PHYSIOGRAPHY

The Mt. Painter region forms the rugged, northern extremity of the Flinders Ranges which rise abruptly from the Lake Frome plains to the east and from the Great Artesian Basin in the north. The elevated part of the area is composed of meta-sediments and granites of the Carpentarian basement, while the younger Adelaidean sediments have a more subdued relief with the more resistant units (e.g. Wortupa Quartzite) forming prominent strike ridges. The crystalline basement forms part of the watershed between streams flowing east to Lake Frome and those flowing northwards to Lake Eyre. Arkaroola Creek is the main east flowing stream in the joint venture area, with several semi-permanent waterholes along its length. Due to the general steep drainage gradient, the streams, which flow intermittently after heavy rain, actively degrade and are well suited for stream sediment sampling.

2. GENERAL GEOLOGY

The geology of the eastern half of South Australia is dominated by the sediments of the Adelaide geosyncline which passes under the Mesozoic cover of the Great Artesian Basin to the north. Two areas of crystalline basement, the Mt. Painter and Willyama Provinces, are the only exposures of Carpentarian rocks in this region.

In the Mt. Painter Province, the basement rocks are exposed in two separate blocks, the largely granitic Mt. Babbage Block, and the essentially meta-sedimentary Mt. Painter Block, consisting of a thick predominantly arenaceous sequence intruded by alkali granites.

Strong folding of the Mt. Painter Block took place prior to the Adelaidean sedimentation.

The Adelaide geosyncline is an accumulation of more than 15 km of sediments deposited in Upper Proterozoic times (See Fig. 1). The material forming these sediments was stripped from the shield area to the west as the geosyncline slowly sank. Although the sediments of this trough accumulated to such a vast thickness, the general conditions of sedimentation were those of relatively shallow water.

The Adelaidean sedimentation was initiated by the deposition of the lower Callanna Beds. The rocks of this group are characteristically associated with basic volcanics, generally amygdaloidal basalts and andesites. Other associated rocks are altered limestones which intrude the younger cover rocks as discordant diapiric structures.

In the Wooltana area (See Plan 1), the lower Callanna Beds have been subdivided into four formations, Paralana Quartzite, Wywhyana Formation, Wooltana Volcanics and Humanity Seat Formation.

The Paralana Quartzite is a grey and pink well-bedded felspathic quartzite which attains a maximum thickness of about 1200 m east of the Paralana Fault in the Mt. Painter area. Faulting has been contemporaneous with the sedimentation as the unit thins rapidily to the west and develops conglomeratic members.

The Wywhyana Formation is a metamorphosed dolomitic unit which includes marbles and amphibolites; in the type area it is about 110m thick. It occurs in the diapirs, and is one of the plastic units involved in the diapiric movements.

The Wywhyana Formation is conformably overlain by about 610m of basaltic and andesitic lavas, minor pyroclastics and sediments: the Wooltana Volcanics. The lavas are extensive in the North Flinders Ranges, covering a large area east of the Paralana fault. West of the Fault, Wooltana Volcanics have been recorded 10km north-west of Mt. Painter in the Yudnamutana area and at Arkaroola bore, where they attain a thickness in the order of 2600m (See Plan 1).

Interbedded sediments are comprised of lapilli tuffs and agglomeratic tuffs. Crawford (1963) considered the lavas to be sub-aerially extruded mainly from fissures, with minor contributions of volcanic and pyroclastic material from central vents. The association of the lavas with shallow water sediments supports this contention. The lineament at the foot of the Wooltana scarp is considered to be a major locus of effusion. A feature of the Wooltana lavas and Humanity Seat Formation is an abundance of disseminated hematite which is reflected in the rocks by an overall purple coloration.

The Humanity Seat Formation, which conformably overlies the Wooltana Volcanics, consists of three unnamed members. The lower member (300m) consists essentially of heavy-mineral banded sandstones with rare halite casts. The middle member (1200m) consisting of medium-grained quartzites with laminae of dark micaceous siltstone, lacks the heavy mineral bands and cross-bedding found in the upper member. The upper member (250m) consists predominantly of thickly bedded sandstones. The distinctive features of this member are the small scale aqueous cross-bedding with high angle foreset beds, heavy mineral lamination, ripple marks and abundant halite casts. The difference in thickness between the Humanity Seat sediments on either side of the Paralana Fault is attributed to movement on the fault during the deposition of the formation. A regional unconformity, recognised by Coats & Bliss, exists between the upper and lower Callanna Beds, and is thought to be associated with early Willouran tectonism which may reflect the Musgravian orogenic activity further to the north. The Humanity Seat Formation is generally absent from the margin of the Mt. Painter Block due largely to erosion preceding the deposition of the upper Callanna Beds.

The early Willouran tectonism appears to have reversed the movement on the Paralana Fault creating a depositional basin to the west of the fault. The basal unit of the upper Callanna Beds, the Woodnamoka phyllite, consisting of grits, sandstones and arkoses, filled this basin, attaining a thickness of about 1400m. The unit is not known east of the Fault.

The Woodnamoka Phyllite is overlain by the Blue Mine Conglomerate (B.M.C.) a heavy-mineral laminated, arkosic conglomerate with interbedded sandstones and shales. Inclusion of pebbles of Wooltana Volcanics and Mt. Neill Granite Porphyry (part of the crystalline basement) indicates that both were exposed and being eroded during the deposition of the B.M.C. Variation in thickness across the Paralana Fault demonstrates that faulting was again active during deposition. A shallow water environment is indicated by mud cracks and small scale ripple marks on the sandstones and shales. The preservation of coarse detrital feldspar indicates limited transport, suggesting that the B.M.C. was a shoreline deposit.

The B.M.C. is overlain by the Opaminda Formation which reaches a maximum thickness of 380m west of the Paralana Fault. The unit has thinned considerably on the eastern side, averaging approximately 76m, due to continuing movement on the Paralana Fault. The presence of talcose shales with thin interbedded magnesian dolomite indicates a gross change in sedimentation. Abundant mud cracks, which are sand filled, indicate extremely shallow water conditions of sedimentation. The Opaminda Formation marks the top of the upper Callanna Beds.

The Wortupa Quartzite, although its contact with the underlying Opaminda Formation is gradational, has been assigned to the Burra Group. It is the clastic unit immediately underlying the regional Torrensian marker bed, the Skillogalee Dolomite.

The Wortupa Quartzite is divided into two unnamed members. The lower member consists of well-bedded greyish-green sandstone with minor interbeds of micaceous siltstone. The abundance of ripple marks and large scale mud cracks with sand infilling again indicate shallow water deposition. The upper unit consists of a well-bedded, light grey felspathic quartzite, which is responsible for the very strong topographic expression of this formation. Variations in thickness are again indicative of contemporaneous faulting.

The Skillogalee Dolomite is one of the most persistent marker beds in the Adelaide geosyncline. In the Mt. Painter region the typical magnesite-dolomite succession is largely metamorphosed to an assemblage of tremolite-actinolite rocks.

Three distinct meta-sedimentary units have been recognised (Coats & Bliss.) The lower unnamed member (305m) is a sequence of blue-grey siltstones with minor interbeds of white dolomitic marble; the middle member (200m) includes tremolite-actinolite marbles, whilst the upper member (400m) consists of medium to fine grained siltstone with quartzite interbeds.

Forbes (1961) considers that the magnesite was formed by chemical precipitation in marginal lagoons subjected to periodic advance and retreat of the sea and to the addition of alkaline continental waters. Reverse graded bedding, recognised in the thin conglomeratic magnesite beds, supports periodic marine regression.

The Skillogalee Dolomite passes transitionally upwards into an unnamed greyish-green siltstone-greywacke sequence which is in turn overlain by thinly-bedded, dark grey dolomitic siltstone. A white orthoquartzite occurs at the contact of the two unnamed units.

The Burra Group is conformably overlain by the very extensive Umberatana Group of Sturtian - Marinoan age, which clearly demonstrates the two major late Precambrian ice ages which are of great time significance. Similar glacial episodes are recorded in Zambia, where the sedimentary succession shows a resemblance to the Adelaidean of South Australia (Coats & Bliss.)

Glacial conditions were initiated by the deposition of the Yudnamutana Sub-Group glacio-marine sequence dominated by the Bolla Bollana Formation, a massive greywacke tillite up to 2200m thick.

The two glacial periods are separated by a thick shallow marine and continental succession of non-glacial sediments. The climate change permitted the growth of the algal reefs of the Balcanoona Formation , developed in local shelf environments. The Tapley Hill Formation, a prominent member of the interglacial sequence, consists of dark laminated shale and siltstone. The sediments appear to have been deposited in a shallow marine environment and mark a probable interval of transgression.

The Yerelina Sub-Group upper glacial sequence of Marinoan age, is restricted to the eastern and central part of the geosyncline. The Mount Curtis Tillite is a uniform sequence of dolomitic greywacke with minor quartzite.

The Wilpena Group of upper Marinoan age marked the return of a warmer climate. An extensive blanket of shallow water and continental sediments extended across the geosyncline. Adelaidean sedimentation concluded with the deposition of the Pound Quartzite. The geosynclinal trough commenced to break up in early Palaeozoic time, with faulting and mountain building, accompanied by the intrusion of granite.

The Ordovician Mudnawatana Granite includes soda leucogranites, albitites, granodiorites, aplites and pegmatites. The Sitting Bull intrusion (See Plan 6) is a soda leucogranite, and has been responsible for the strong metamorphism of the adjacent Opaminda Formation.

Mesozoic and Tertiary sediments occur as scattered outcrops around the edge of the North Flinders Ranges, but are very subordinate compared with the vast area of Quaternary deposits on the Lake Frome plains.

2.1 STRUCTURE

The structure in the Mt. Painter region is dominated by the Paralana Fault system running approximately north-east through the area. The fault has been active during much of the Adelaidean sedimentation. During the deposition of the lower Callanna Beds, the movement appears to have been east block down with a greater accumulation of sediments on the eastern side. The movement on the fault was then reversed due to early Willouran tectonism with the result that a large trough was formed west of the fault which was subsequently filled with Woodnamoka Phyllite. Continued movement is demonstrated by changes of thickness of sediments on either side of the fault.

The Adelaidean rocks were folded into open synclines separated by tighter anticlines in the Lower Ordovician. The fold axes trend westerly north of Mt. Painter, and progressively swing south until they almost parallel the main fault trace in the south. Webb (1958) considers that this latter observation supports the latest movement on the fault as being "west block up and to the south". This reverse movement throws upper Callanna Beds against units of the middle Umberatana Group. Numerous splay faults, associated with the main fault, are aligned in a predominantly NE direction. It is on some of these faults that many of the old mineral occurrences are located.

2.2 MINERALISATION

The Cambrian and Precambrian rocks of South Australia contain all the known economic metal deposits apart from the younger alluvial deposits. Evidence indicates that the floor of the Adelaide Geosyncline and part of the bordering regions is shattered by a network of intersecting fractures and shears. Density of regional fracturing and mineralisation appear to be related. Dickinson & Sprigg (1953) have proposed lineament control of a number of the major base metal deposits.

The abundance of base metal mineralisation in outcropping Cambrian and Precambrian rocks in eastern and central South Australia, define the Adelaide geosyncline and its bordering region as a major metallogenic province.

Although many of the base metal occurrences in the geosyncline are obviously structurally controlled or associated with diapiric masses, as at Blinman and Oraparinna, stratiform mineralisation has been reported.

In the Ediacara Mineral Field, 32km west of Beltana Township, extensive low grade stratiform lead mineralisation, with associated copper, occurs in Cambrian dolomites.

Similarly the Nairne pyrite beds, 46km east of Adelaide, are generally accepted as a sedimentary sulphide deposit.

Diamond drilling at the Daly mine 10km north-northwest of Mt. Painter, by Broken Hill Associated Smelters Ltd. in 1943, and by the Department of Mines in 1964, has indicated low grade pyrite, arsenopyrite and chalcopyrite mineralisation throughout the Serle conglomerate. The sulphides occur as crystalline aggregates, irregular blebs and as sporadic disseminations, especially in the matrix of the conglomerate.

The mineral occurrences described above are examples with a sedimentary environment associated with their origin. Although many deposits, with hydrothermal and structural aspects, exist in the Adelaide geosyncline, it is those of sedimentary origin which have renewed exploration interest in the region.

3. PREVIOUS EXPLORATION (See Appendix I for Summary)

Small mining operations in the area began in 1861 at the Oraldana mine, and later in 1862 at the Great Boulder (Welcome) mine. Most of the ore was extracted in the period up to 1910. Production from both mines was small.

McLeashe's prospect is reported to have produced five tons of 40% copper ore (Brown, 1899). There are no other records of this prospect.

Two adits were cut at O'Donoghue Castle mine prior to 1900.

Brown (1908) reported that a little over 66 tons of ore had been sold to the English and Australian Copper Company, 30 tons containing over 2% Cobalt.

The ore is said to have carried 2oz to 8oz of silver per ton and 1 dwt to 2 dwt of gold per ton.

Interest was renewed in the mine in 1968. In the first half of 1969, the claim holders reported that up to 1,000 tons of ore of unknown grade was on hand from drives. How much of this ore was treated is not known.

Gold was discovered in June, 1949, by A. Lively (the mine later became known as Lively's Find). Operations ceased in 1955 after the production of just over 230 ounces of gold from a narrow, north-easterly lode.

In 1964, Australian Selection Pty. Ltd. (A.S.P.L.) was granted S.M.L. 66 which included all but the southern portion of the joint venture area. Between June and October, 1964, all of S.M.L.66 was stream sediment sampled, resulting in an overall sample density of approximately 3 sample locations per square kilometre.

Two samples, approximately 15 to 30 metres apart, were taken at each site and analysed for copper only. Within S.M.L. 66 a total of 4,946 samples was collected and analysed.

Within the joint venture area, four main anomalous areas were located. These were named by A.S.P.L. the Claret, Wywhyana, Coup and Kingsmill prospects. Further work was recommended on these grids, but A.S.P.L. relinquished the S.M.L. early in 1966, in favour of other areas, without any further work being undertaken.

In 1968, Geosurveys of Australia Pty. Ltd. explored three small S.M.L.'s, Nos. 115, 188, 201, within the Wooltana joint venture area. Most of their effort seems to have been concentrated on rotary-percussion drilling, with no recorded surface sampling being done.

Five copper prospects were drilled (See Appendix I, page 2). At the Welcome copper prospect, a cupriferous bed was intersected in drill holes to a depth of 60 metres.

The best intersection, from 42.7m to 59.5m in hole 6, averaged 0.58% Cu.

A prominent copper stained jasper outcrop at the Wall prospect, (See Appendix II,Petrological description (Pet. desc.) NFR 0222T) was drilled. The main copper body is evidently a bedded structure with very low grade copper mineralisation continuing down to 34m. Best intersection, from 0-21.3m in hole 2, averaged 0.42% Cu.

The Pebble and Coxcomb prospects,both with weak copper staining in a silicified host rock, were drilled, but the results were reported to be very poor and were not recorded.

Two holes sited under the old workings at McLeashe's Prospect intersected a zone of secondary copper mineralisation. The reserves were calculated to be between 40,000 and 50,000 tons of ore containing 1% copper.

In 1969, the Wooltana area was granted to N.F.M. as S.M.L. 294 (later renewed to S.M.L. 575). The outcrop area of Blue Mine Conglomerate, and all anomalies found by A.S.P.L. in Special Mining Lease 66 were resampled. A total of 2,265 samples, collected by N.F.M., was analysed for copper, lead and zinc. This sampling confirmed the existing anomalies of A.S.P.L., and showed that the Blue Mine Conglomerate, as a unit, is anomalous in copper.

A new grid was established at The Coup copper prospect, which was then soil sampled and mapped in detail. An I.P. Survey was done over six lines by McPhar Geophysics and several anomalous zones were detected. No drilling was undertaken at The Coup.

The whole zone between McLeashe's prospect and O'Donoghue Castle mine was gridded by N.F.M. Work was concentrated at the two old prospects with detailed geophysical surveys being carried out by both McPhar Geophysics and Austral Exploration Services Pty. Ltd..

At O'Donoghue Castle mine, 6 holes totalling 358m were drilled to test a zone of I.P. anomalies associated with the B.M.C. Drilling demonstrated the presence of a strongly pyritic zone in the upper member of the B.M.C. Only very slightly anomalous copper values were obtained from the deeper intersections in the upper member, these being due to minor fine grained chalcopyrite associated with pyrite. (See Appendix II petrological descriptions NFD 0210T to NFD 0220T).

Two holes drilled under the old workings at O'Donoghue Castle mine produced very disappointing results. In hole N.F.O.D.5, traces of pyrite were logged, and within the Wortupa Quartzite the interval 85.5m to 88.5m assayed 0.14% copper.

At McLeashe's copper prospect, 7 rotary-percussion holes were drilled to test the down-dip extension of the previously delineated lens of secondary copper mineralisation. The grades of mineralisation intersected in the deeper holes were far below the level of economic interest, and did not enhance the reserves already calculated by Geosurveys.

One hole, drilled to test the source of I.P. anomalies in the upper member of the B.M.C., intersected pyrite from 7.6m to 30.05m. No chalcopyrite was recorded in this interval.

Although drilling was disappointing from the aspect of intersecting economic mineralisation, it did clearly demonstrate that Induced Polarisation methods, as a tool for outlining sulphide mineralisation (in this case mainly pyrite), are successful.

4. PRESENT STUDY (SHELL EXPLORATION PROGRAMME, 1972)

A field examination of S.M.L. 575 was made on 22nd and 23rd of February, 1972, when several prospects and sections through the lower Adelaidean sequence were examined. A further visit was completed between 18th - 21st April, 1972, to provide further field information and to plan field operations. The S.M.L. was considered attractive for further exploration for the following main reasons:

(a) Secondary copper mineralisation is often present in the B.M.C. and adjacent units. Cobalt, occurring as sphaerocobaltite, has been reported from O'Donoghue Castle mine. Past geochemical prospecting has established that the B.M.C., as a unit, is anomalous in copper.

(b) It is possible that the proposed shoreline depositional environment, adjacent to an older essentially granitic and probably mineralised (Cu) land mass, could be prospective environment for the deposition of stratabound copper of the Zambian Copperbelt type.

(c) A considerable amount of preliminary work had already been done by A.S.P.L. and N.F.M., but it had not been exhaustive. Although percussion drilling at McLeashe's prospect and O'Donoghue Castle had disappointing results, it did demonstrate the existence of possibly stratabound pyrite and very minor chalcopyrite, and showed that I.P.

could be used in this area for detecting sulphides at depth.

Shell Minerals' initial approach was to establish the depositional environment of the B.M.C. and associated units. Detailed sections were to be mapped and sampled.

If warranted, deep stratigraphic diamond drilling, was to be carried out to determine the nature of the sediments at depth. In particular, a "lagoonal type" reducing environment was sought with mineral zoning away from the shoreline.

At the same time, all known copper occurrences were to be inspected to establish the nature of the mineralisation and whether structure, related to the main Paralana Fault system, had been the main factor in concentrating the mineralisation.

4.1 REGIONAL SEDIMENTARY STUDIES

4.11 West of Paralana Fault

Four sections were mapped in detail and chip sampled west of the Paralana fault. (See Plans 1 and 7). Each section was started as close to the base of the B.M.C. as possible and extended through the upper Callanna Beds and into the Burra Group. The sections were terminated in the Skillogalee Dolomite, the regional Torrensian marker bed.

Comparison of the four sections showed that there is a very close similarity between the lithologies in each section, particularly in respect to the Opaminda Formation and Wortupa Quartzite. The abundance of ripple marks and mud cracks indicated that these units were deposited in shallow water.

Within the B.M.C. the overall sequence was one of conglomerates and sandstones with interbedded shale. The preservation of coarse detrital feldspar indicated limited transport, suggesting a shoreline deposition for the unit.

On the north-westerly trending limb, extending from Arkaroola homestead, there is an apparent thickening of the unit which is not due to the shallowing of the dips around the synclinal nose. In fact, there is a steepening of dips in the north of the area.

South of the homestead, there is a gradual thinning of the B.M.C. until it pinches out south of O'Donoghue Castle. Just how much of this change of thickness is of sedimentary origin is difficult to ascertain. The proximity of the Paralana Fault, acting as a hinge during sedimentation, to the southern limb, is a factor which must be taken into account during the sedimentary studies.

The conglomerate bands south of the homestead are thinner than those to the north, where they are uniformly thick. Similarily, there is a decrease in grain size and coarse feldspar content in the conglomerate, accompanied by better sorting to the south.

These factors suggest that the southern limb, from Arkaroola homestead to south of O'Donoghue Castle, was further from the source area.

The chip samples taken during the detailed mapping programme, were analysed for copper, lead and zinc. The values have been plotted as histograms corresponding to the geology. (See Plan 7).

(a) Copper

There are consistent anomalous values associated with the upper member of the B.M.C. Elsewhere within the unit, the values are sporadic and generally of lesser magnitude. However, the B.M.C., as a unit, is anomalous in copper relative to the other adjacent units.

There is a close relationship between malachite and silicified, (?) tuffaceous siltstone (See Appendix II Pet. desc. NFR0011T), at the Claret, Wywhyana and Quart Pot Bore prospects, where the copper appears to occur within two, possibly three, thin horizons. Malachite also occurs in the conglomerate adjacent to these fine grained sediments, but this appears to be due to leaching and the high porosity of the conglomeratic horizons.

There is also a fairly consistent increase in copper content at the base of the Skillogalee Dolomite. This is probably due to the presence of the dark grey, pyritic, Transition shale (See later discussion).

(b) Zinc

Zinc values in the B.M.C. are low, but generally tend to follow the copper. In the Opaminda Formation, the zinc values are high, particularly towards the base, where the contact with the B.M.C. is marked by a sharp rise in values. The high zinc values tail off towards the top of the Opaminda formation and are low in the Wortupa Quartzite. Once in the Skillogalee Dolomite, the zinc values increase, in most cases exceeding the copper values.

An increase in zinc and a lessening of copper content is characteristic of the Opaminda and Skillogalee Dolomite Formations.

(c) Lead

Values for lead are consistently low in all sections.

4.12 East of Paralana Fault

Mapping of detailed sections east of the Paralana Fault was, with one exception, concentrated at The Coup copper prospect, where the previously established N.F.M. grid was used as a basis for the section lines. One further section, south of The Coup prospect, (see Plans 1 and 8), was included in order to compare the lithologies on the southern limb of the syncline.

Apart from a thinning of the units south of The Coup prospect and west of Groan Creek, there was very little change recorded in the different sedimentary horizons along strike.

The Opaminda Formation and Wortupa Quartzite remain uniform throughout and again give evidence of shallow water deposition as found west of the Paralana Fault.

The B.M.C. was characterised by three well defined conglomerate horizons. The basal conglomerate overlies the Humanity Seat Formation, of the lower Callanna Beds, but the regional unconformity between the upper and lower Callanna Beds was not evident. A massive cobble conglomerate was selected as the main marker horizon, and could be clearly recognised in all sections examined. This massive conglomerate contained large cobbles of Mt. Neil Granite Porphyry as well as fragments of Wooltana Volcanics.

Mapping showed that the B.M.C. is very uniform along strike and much thinner than on the west of the Paralana Fault, having a maximum thickness of about 40m.

Part of the basement and the Wooltana Volcanics were exposed and were evidently being actively eroded during the deposition of the B.M.C. The source area for most of the detritus appears to be to the north with the sea encroaching from the south. No evidence was found for any break in the shoreline due to the 'in-flowing' of major rivers draining the source area. It appears that the main channel for the supply of source material to the basin was close to the trace of the Paralana Fault.

Two detailed sections through the B.M.C. were chip sampled by taking continual chips over each separate horizon. (The sections with accompanying geochemistry are shown on Plan 9).

The copper and zinc values are generally low, with the main anomalies occurring in the shale horizons. The high copper values tend to coincide with the high manganese values, the manganese acting as a scavenger of copper. Anomalous copper in the conglomerate is again attributed to the porosity of the sediment.

4.13 Results of Section Studies

The following conclusions can be drawn from the section studies.

(a) The Paralana Fault was active throughout the deposition of the upper Callanna Beds and Burra Group sediments. Movement on the fault during this period of sedimentation was west block down. During lower Callanna sedimentation the movement on the fault was reversed. This accounts for the large trough filled with Woodnamoka Phyllite to the west of the fault, and the absence of this unit to the east. Variations in thickness across the fault are due to contemporaneous movement during sedimentation.

(b) Mud cracks, ripple marks and halite casts all point to a shallow marine mode of depositon. Preservation of feldspar ovoids in the B.M.C. indicates transport, suggesting that the unit was a shoreline deposit.

(c) There are no extensive carbonaceous shales or massive pyritic beds within the B.M.C. to indicate a reducing environment. It is possible to show some similarity of the sediments to those of the Zambian Copperbelt, but this comparison would hold for most of the Adelaide geosyncline.

4.14 Transition Beds

Directly overlying the Wortupa Quartzite and underlying the characteristic brown, weathered (fluted) crystalline dolomite of the Skillogalee Dolomite, is a thin succession (approx. 60m) of hard, dark grey pyritic siltstone and fine grained quartzites. As these rocks form a transition zone between the two main lithologies in the Burra Group (that is the clear white arkosic sandstones of the Wortupa

Quartzite and the dolomites of the Skillogalee Dolomite), and because transition zones are considered favourable for stratiform mineralisation (Nicolini, 1970), an examination of the transition beds was made for further traces of copper.

The O'Donoghue Castle copper-cobalt mine also occurs in the transition zone making it a prospective horizon for further mineralisation.

The transition beds between the O'Donoghue Castle mine and Arkaroola homestead, and in the vicinity of Wywhyana Park, were examined and interesting outcrops were chip sampled. (See Plan 2 for results and locations). Only one small copper occurrence was located by following up a stream geochemical anomaly. Malachite staining was found in fine grained quartzite along a narrow shear zone. The mineralisation had been exposed in a shallow pit.

Two rotary-percussion holes, drilled by N.F.M., had been sited in the Skillogalee Dolomite to test the down dip extension of the mineralisation in the old workings at O'Donoghue Castle. Both holes intersected the transition zone but the highest copper value in this horizon was only 280 ppm. Trace pyrite was recorded throughout the transition zone.

Examination of the transition shales for a large syngenetic copper orebody is considered to be exhausted. While there is evidence of very weak sedimentary pyrite mineralisation in the horizon, the copper mineralisation, as at O'Donoghue Castle, is structurally controlled and limited in extent.

4.2 REGIONAL GEOCHEMISTRY

The Wooltana area has been subjected to a substantial amount of regional stream sediment sampling by previous investigators.

In 1964, A.S.P.L. covered most of the area at an approximately 400 metre spacing. Two samples were collected at each location. A total of 4,946 samples was analysed for copper only.

Most of the anomalies were followed up by soil sampling on established grids, but the area was suddenly relinquished without any further work being undertaken.

A.S.P.L. concluded that most anomalies could be explained by old workings or surface occurrences of secondary copper. Consistently high copper values were found in a "conglomerate", now recognised as part of the B.M.C.

N.F.M. re-sampled the outcrop area of B.M.C. as well as checking A.S.P.L.'s anomalies. A total of 2,265 samples was collected and analysed by McPhar Geophysics for copper, lead and zinc. N.F.M.'s sampling confirmed anomalies found by A.S.P.L. and again demonstrated that the B.M.C. was anomalous in copper.

A threshold value of 40 ppm for copper had been used in the past for the Wooltana area. Whereas this is quite reasonable for most units, the B.M.C. has a higher background. Re-calculation of the threshold, taking the B.M.C. samples as a separate population, demonstrated that 60 ppm is a more meaningful copper threshold for this horizon. This enabled several previously low order anomalies in the B.M.C. to be eliminated. The only distinctly anomalous areas west of the Paralana Fault, in the B.M.C. were the Claret and Wywhyana prospects. Both these prospects contain surface 'showings' of malachite which account for the stream anomalies.

4.21 Copper

It is considered that the previous stream geochemistry carried out in the joint venture area was quite adequate. As nearly all of the anomalies could be explained by old workings or occurrences of surface malachite, there seems nothing to be gained from further stream sampling for copper.

4.22 Lead

Stream sediment sampling for lead by N.F.M. revealed two anomalous values only, both west of the Coxcomb prospect, analysing 110 ppm and 140 ppm respectively. Chip sampling later detected a thin discontinuous dolomitic horizon thought to be the source (See details under zinc).

Further sampling for lead in the area is not warranted unless done as a secondary analysis to zinc.

4.23 Zinc

Stream sediment analysis indicated a number of anomalous values between O'Donoghue Castle and Arkaroola homestead.

Using the theory that these values had their source in the basal Skillogalee Dolomite sequence, M. Garman (1970) of Watts, Griffis and McOuat, chip sampled six lines in the area for N.F.M. (See Plan 2). Anomalous values up to 1,200 ppm, but more specifically in the range 200-300 ppm, were recorded. However, only discontinuous zinc-anomalous beds were found, and Garman concluded that further exploration for zinc in the particular area examined was not warranted.

It is, however, possible that economic deposits of zinc of the willemite or smithsonite type, as occur in the Cambrian limestones at Beltana and Aroona, could exist elsewhere in the Skillogalee Dolomite. With this in mind, a detailed stream sediment survey was conducted of the entire Skillogalee Dolomite outcrop east of the Paralana Fault. The values obtained were generally poor and did not warrant further invesgation (See Plan 3).

4.24 Conclusions

The Wooltana area, with its steep drainage gradients and actively degrading streams, is ideally suited for stream sediment geochemistry.

With the completion of the sampling of the Skillogalee Dolomite east of the Paralana fault, the entire area of interest in the joint venture area has now been covered by stream geochemistry, in some parts more than once.

All significant anomalies have been investigated and their sources explained. Regional sampling proved very useful in locating old workings and occurrences of secondary copper, but its potential as an exploration technique in the Wooltana area has now been exhausted.

4.3 DETAILED EVALUATION OF PROSPECTS

Although most of the exploration effort in the Wooltana area was concentrated on the sedimentary study of the B.M.C. and associated units of Adelaidean age, all known copper occurrences were visited in an attempt to explain the source of the mineralisation.

With the exception of the O'Donoghue Castle mine and McLeashe's prospect which were rotary-percussion drilled by N.F.M., most of the major anomalies have been soil sampled on grid lines only, with no further attempt made by past workers to establish the origin or extent of the mineralisation.

Most of the old workings in the joint venture area are very small and in them, structure is the main ore control.

Four major stream sediment copper anomalies, The Coup, Claret, Wywhyana and Groan, were examined in more detail.

4.31 <u>The Coup Prospect</u>

The Coup is the name given, presumably by A.S.P.L., to a collection of small copper workings in the north-east corner of the joint venture area (See Plan 1). There is no record of when the mineralisation was discovered or of the amount of ore mined, but production must have been very small, judging by the extent of the workings.

The first mention of The Coup as a copper prospect was made by A.S.P.L., who obtained an anomalous copper response (100 ppm) from the area in their regional geochemical programme. A grid, 975.4m long and 610m wide, was established to cover an area centred on some of the old workings (See Plan 4). Soil sampling delineated a zone of anomalous copper values between 200-500 ppm. The zone was 244 m long and 61m to 122 m wide, but open at the north-western end. Although further work was recommended, A.S.P.L. relinquished their S.M.L. before it could be carried out.

N.F.M. re-gridded The Coup area (see Plan 2), and soil sampled at 15.2m (50 foot) intervals over the grid area measuring approximately 1,829m x 1,220m.

The sampling confirmed the A.S.P.L. anomaly and established that sporadic copper values, up to 800 ppm, follow the trend of the B.M.C.

A 1:1,200 scale detailed map of The Coup grid was produced by N.F.M., and this was followed by an I.P. survey over six lines by McPhar Geophysics. I.P. anomalies were obtained on each of the six surveyed lines.

No further work was undertaken at The Coup prospect until the area was visited by Shell Minerals Exploration in June, 1972.

The aim of the examination of The Coup copper prospect by Shell Minerals was to study in detail the B.M.C. and associated units which were giving the anomalous copper response. It was hoped to establish whether the copper was related to a particular horizon, and if so, whether the I.P. response could be similarly related to that horizon.

If both these factors had a reasonable degree of correlation, and the horizons had the characteristics associated with ore bearing strata, and sufficient dimensions, then testing by diamond drilling was to follow.

4.311 Geology

The oldest unit in The Coup area is the Wooltana Volcanics consisting here of andesitic and trachytic lavas. The volcanics are conformably overlain by a narrow succession of lower Humanity Seat Formation consisting of fine grained quartzites which are locally rich in iron and manganese oxides (See Appendix II, Pet. desc. NFC 0016T).

The regional unconformity between the upper and lower Callanna Beds (Coats & Bliss.) could not be recognised at The Coup prospect. The succession appears to be unbroken.

The B.M.C. is only approximately 43 metres thick at The Coup prospect, where it consists of interbedded shales, sandstones and conglomerates. A very prominent cobble conglomerate, used as a marker bed within the B.M.C., could be traced across the area with very little change in thickness. Pebbles in the conglomerate consist mainly of Wooltana Volcanics and Mt. Neil Granite Porphyry, indicating that both were exposed and were evidently being eroded during the deposition of the B.M.C.

The conformably overlying Opaminda Formation is a fairly well weathered, multicoloured siltstone, which generally is poorly exposed. A few thin grit bands occur towards the base. The vivid pink and purple coloration is thought to be due mainly to iron oxides which locally produce striking Liesegang rings.

The Opaminda Formation is conformably overlain by Wortupa Quartzite. The lower member is a white arkosic quartzite (Appendix II Pet. desc. NFC 0104T) which grades through a shaly sequence into a prominent grit horizon close to the contact with the overlying Skillogalee Dolomite. Mud cracks, infilled with coarse sand, and ripple marks are common throughout the Wortupa Quartzite. It is considered that the supply of detritus was from the north.

4.312 Structure

The Coup prospect is situated very close to the nose of a fairly tightly folded syncline, the axis of which coincides with a major north-easterly trending fault (See Plan 4). With very few exceptions, the direction of all faults is north-easterly. Most of these fault have little strike-slip displacement, and are thought to be splay faults caused by tension on the main Paralana Fault. There is a marked shallowing of dip and increase in outcrop width in the nose of the syncline, particularly evident in the Wortupa Quartzite.

A wedge of upper Callanna Beds, displaced into the Wooltana Volcanics in the centre of The Coup grid, was at first thought to represent a palaeo-valley which had been infilled with coarse sediments. However, close examination revealed its faulted origin.

4.313 Mineralisation

Traces of secondary copper mineralisation are found in all units exposed on The Coup grid with the exception of the Humanity Seat Formation.

Two shafts, 30.5m and 6.1m deep, were sunk on a fault zone in the Wooltana Volcanics (See Plan 5). Mineralisation, in the form of malachite, is very weak and associated with a quartz-hematite gangue. The mineralisation is structurally controlled as are, apparently, all other known copper occurrences in the Wooltana Volcanics.

Traces of malachite are common in the B.M.C. (See occurrences on Plan 4). In detail, the malachite is usually found as a thin paint associated with the fine matrix of the conglomerate beds, or on joint planes and along bedding planes (or sub-parallel to them) in shales. In view of the many small copper occurrences in the Wooltana Volcanics which are structurally controlled, it is likely that some of this copper could have found its way along fractures into the overlying, porous conglomerate of the B.M.C. with the manganese and iron oxides acting as scavengers of the copper ions.

Shale horizons are interbedded with the conglomerates and sandstones, and rarely attain a thickness of more than a few metres (See Plan 9). The rock itself is quite massive and silicified, and lacks the limonite-coated or filled cavities possibly indicative of the once present sulphides. There is no indication of the shales being carbonaceous or that they contained significant pyrite, and it is concluded that the quiet conditions for reduction and precipitation of sulphides did not prevail. As was the case with the conglomerate, it would appear that the copper mineralisation in the shales is structurally controlled with the powerful scavenging properties of the manganese oxide content being important.

Copper mineralisation in the Opaminda Formation was located at four places at approximately the same stratigraphic level. Two of these occurrences are in old workings. In the first, working A (See Plan 4), the malachite is associated with a complex structure in which a block of Opaminda Formation appears to have been wedged into the underlying B.M.C. by a fault. Although the malachite is associated with a (?) tuffaceous horizon (See Appendix II Pet. desc. NFC 0012T), the fault is considered to be the main control in concentrating the copper mineralisation.

The second, working B (See Plan 4), consists of a shallow undercut. Malachite occurs in a leached kaolinitic,(?) tuffaceous siltstone along bedding and on joint planes. The occurrence is close to a fault, and has very limited surface expression.

The remaining two malachite showings are also in a leached kaolinitic siltstone, but are very small and isolated.

Malachite occurs as paint on joint surfaces in the Wortupa Quartzite. Limonitic voids in the quartzite have been identified as "after pyrite" by McPhar Geophysics (See Appendix II Pet. desc. NFC 0104T). In the upper Wortupa Quartzite, copper is exposed in two old workings (workings C and D, Plan 4). The malachite mineralisation occurs in laminated micaceous and?tuffaceous siltstone (See Appendix II Pet. desc. NFC 0105T) where it is in contact with an overlying grit. Both workings are located on prominent shears.

4.314 Geochemistry

The previous soil sampling by A.S.P.L. and N.F.M. had been successful in outlining the areas of anomalous copper. There was nothing to be gained from any further soil sampling. Care had to be taken when determining the dimensions of the soil anomalies due to the steep topography and the tendency for soil values to be transported down slope from their point of origin.

Apart from the sampling of detailed sections (See regional studies), 24 grab samples of ironstones and "gossanous" material were collected from The Coup grid (see Plan 4). Although several high values were recorded from horizons within the Wortupa Quartzite, they were not continuous, and tended to be close to faults and areas of high manganese oxide content.

4.315 Geophysics

Note: In this section reference is made to reports by McPhar Geophysics and Shell Minerals' geophysicist A.H. Brash . (See Plan 4 for location of anomalies).

(a) The anomaly on line 14800E, adjacent to the old "working B" is both weak and near surface and interpreted as coming from above the inferred limit of oxidation. For this reason it cannot represent sulphide. The associated low resistivity probably reflects the steep topography. The anomaly is most likely due to a nearby fault zone.

(b) On line 14400E (122 metres west of working B), the I.P. results do not appear to support any reliable extension of the anomaly on line 14800E, which is further evidence for it reflecting a fault.

(c) A similar anomaly occurs on line 15200E (adjacent to working A). Again, the anomaly is over an old working and, because of its shallow source, could not reflect any sulphide, should it exist in the same horizon exposed in the working.

A large fault running through the mine may have been reflected in the I.P. data.

(d) The anomalies to the north, in the Humanity Seat Formation, are all of similar magnitude. The low resistivities suggest that the rugged topography in this area could be causing this effect. The sources are near-surface, and could also relate to the manganese and iron oxides found in these sediments.

(e) On line 11500E an anomaly was detected using both 61m and 91.4m spreads and was found to strengthen at depth. Although this anomaly appears to occur some distance down-dip from working D, the strong dip-slope in the area suggests that the source of the anomaly is stratigraphically below the horizon exposed in the working. The arkosic sandstone of the Wortupa Quartzite, from this area, is known to contain up to 3% accessory limonite pseudomorphs after pyrite (See Appendix II Pet. desc. NFC 0104T). It is suggested that the anomaly could relate to this syngenetic pyrite in the Wortupa Quartzite.

(f) On line 11900E a strong, deep anomaly cannot be correlated with any known surface mineralisation and is similarly attributed to the pyrite in the Wortupa Quartzite.

The depth of oxidation at The Coup prospect is a critical factor in the interpretation of I.P. As the I.P. technique is designed to locate sulphide sources, it must obviously penetrate below the level of oxidation. All but one of the survey lines was set up using a 61 metres spread, giving a maximum reliable penetration of 61 metres. No drilling has been undertaken at The Coup, with the result that no reliable estimation of oxidation levels can be made. However, using the experience in other areas it seems that the level of oxidation can be expected to be deep and variable.

4.316 Conclusion

Geochemically, the B.M.C. at The Coup prospect is anomalous in copper. When examined in detail it is found that the high values generally occur adjacent to surface occurrences of malachite which are expected to greatly influence any soil samples collected. As already mentioned, the secondary copper occurs in specific horizons within the B.M.C., but structure is considered to be the main factor in concentrating this mineralisation.

The I.P. anomalies cannot be correlated with any downdip extensions of the horizons exposed in old workings or main secondary copper occurrences, nor can they be consistently related to a specific horizon.

Some of the I.P. anomalies may relate to the B.M.C. which is known to contain minor amounts of probably syngenetic pyrite (See Section on McLeashe's - O'Donoghue Castle mine zone). However the B.M.C. at The Coup prospect is quite thin, and most unlikely to contain an economic concentration of syngenetic copper sulphide since the dumping of coarse detritus during sedimentation would dilute any concentration of copper sulphide.

The I.P. could also reflect faults, variation in topography, and manganese and iron oxides.

Due to the lack of correlation between geochemistry and geophysics, and the fact that there is no indication of the shales being carbonaceous, or that they contain significant pyrite, it was concluded that the likelihood of there being an economic concentration of base metal sulphides at The Coup prospect was most remote and that no further work was warranted.

4.32 Claret Prospect

The Claret prospect is situated west of the Paralana Fault and 800 metres south of Arkaroola homestead (See Plan 2). The copper anomaly (105 ppm) was located by A.S.P.L. during their regional sampling programme. Initial bank sampling around two ridges, located a zone of possible mineralisation 1,000m long and 61m wide, with values up to 5,000 ppm copper, over an old working in the B.M.C.

A grid 1,220m long with lines either 304.8m or 609.6m wide was established by A.S.P.L. and soil sampled. The geochemical contour map (See Plan 5), suggests two anomalous discontinuous horizons separated by an area of low geochemical response. The geochemical high occurs over the main old working, where malachite is widely dispersed through shale and the adjacent conglomerate, on a boldly outcropping shear zone. Due to the strong dip slope and the abundance of scree over the Claret grid, the width of the anomalies could be exaggerated by down-hill movement of the soils.

Detailed mapping recommended by A.S.P.L.'s geologists at the Claret prospect had not been carried out when the area was relinquished.

In their re-sampling programme of the B.M.C., N.F.M. relocated the old Claret anomaly, but on this occasion a value of 1,700 ppm was obtained in the stream immediately below the old workings, which were named "McPhar (1)" by N.F.M.

The workings were visited by N.F.M., and a chip sample assayed 0.44% Cu (Carthew, 1971). No further work was undertaken by N.F.M. in the area.

The old A.S.P.L. grid was repegged by Shell Minerals in September 1972. Reconnaissance geological mapping was carried out along the grid lines and a preliminary geological map was produced with the aid of colour aerial photographs (See Plan 5).

Inspection has shown that patchy copper mineralisation occurs in two (possibly three) silicified, feldspathic, argillaceous horizons which are possibly tuffaceous (See Appendix II Pet. desc. NFR 0011T). Sporadic malachite staining also occurs in the conglomerate of the B.M.C., as at the main working.

The mineralised beds have a maximum thickness of two metres. The malachite staining appears diffused along apparent bedding planes and on joints. Later petrological examination (NFR 0011T) has shown the copper minerals to be in veins sub-parallel to bedding and most probably introduced, as the muscovite, marginal to the veins, has been altered to sericite suggesting a hydrothermal origin.

Photomapping and ground mapping has shown that the Claret area is dissected by many sub-parallel faults and shears. The old workings, including the small Oraldana mine (See Plan 5) occur in prominently outcropping zones of shattered B.M.C. Although there is evidence of some stratigraphically-controlled mineralisation in the silicified siltstone horizons, these beds are very narrow and discontinuous. Most of the visible secondary copper mineralisation appears to be structurally controlled and of limited extent.

4.33 Wywhyana Prospect (See Plan 6)

The Wywhyana prospect occurs in a large bulge of B.M.C. adjacent to the "Sitting Bull" soda leucogranite plug. A stream anomaly of 165 ppm Cu was located in the area by A.S.P.L. After preliminary bank soil sampling, a grid measuring 731.5m by 457.2m was established and soil sampled. A small anomaly, (up to 1100 ppm Cu), open to the west, was outlined, but further sampling recommended by A.S.P.L. was never completed.

N.F.M. recorded four copper occurrences in the Wywhyana area. "The occurrences are found in the conglomerate or along the conglomerate-shale contact zones" (Carthew, op.cit.). Chip samples from three of the occurrences assayed 15%, 1.8% and 0.6% copper respectively. No further work was carried out by N.F.M.

Two days of field mapping, aided by photo mapping, were undertaken by Shell Minerals in an attempt to clarify the cause of the mineralisation.

The area was found to be strongly faulted and folded. Metamorphism is of a higher degree than anywhere else in the B.M.C. in the Wooltana area. Along many of the fault traces, the sediments have been metamorphosed to actinolite-tremolite assemblages, and further away from the faults scapolitization is very pronounced. (Appendix II, Pet. desc. NFR 0106T). The original bedding is still preserved. Close inspection of the "Sitting Bull" intrusion has shown that it is not in fact a diapir, but a metamorphic aureole around the soda leucogranite plug, actinolite-tremolite and scapolite being the main products of metamorphism of the Opaminda Formation (Tulp, pers. comm.).

The plug, as well as the large area affected by metamorphism, suggests that the granite is probably very close to the surface over much of this area. The Precambrian structural deformation could have acted as a zone of weakness followed by the Ordovician granite, resulting in further deformation and local remobilisation.

Malachite occurs in extremely fine grained, silicified siltstone interbedded with quartz conglomerate as thin paint on the surface and on bedding and joint planes. Fresh pyrite, commonly associated with the coarse quartz feldspar aggregates, is found at the surface due to the highly silicified nature of the siltstone. Trace chalcopyrite occurs with the pyrite and, as both sulphides are associated with the coarser detrital grains, they could be of sedimentary origin (See Appendix II, Pet. desc. NFW 0221T).

In spite of the suggestion of weak sedimentary pyrite, with associated chalcopyrite, structure is again envisaged as the control of the secondary copper mineralisation. Small dimensions and intense deformation make the prospect unfavourable for further work.

Immediately east of Wywhyana, malachite mineralisation was found at two locations in the vicinity of Quart Pot Bore (See Plan 6). The mineralisation is in a dark, strongly scapolitised sediment close to a fault zone. (See Appendix II Pet. desc. NFR 0106T). These small occurrences are considered to have had a hydrothermal origin.

4.34 Groan Anomaly

The Groan anomaly is situated in the north east corner of the Wooltana area, south of The Coup prospect and west of Groan Creek, from which it takes its name (See Plan 1). A stream value of 70 ppm copper was obtained from this area by A.S.P.L. Initial bank sampling around the two valleys established that the high values were coming from the ridge at the head of each valley.

N.F.M. did not re-sample this anomaly, but two check samples taken by Shell Minerals confirmed a stream anomaly of 80 ppm (See Plan 3).

Examination of the ridge failed to find any copper mineralisation or any B.M.C. The rock type is Wortupa Quartzite, which in places is heavily coated with manganese oxide and strongly jointed. One sample (See Plan 3, NFR 0207A) was taken by scraping the manganese oxide coating from the quartzite. The geochemical analysis showed 3,700 ppm copper and 8.0% manganese. It was concluded that the manganese oxides were acting as powerful scavengers for the available copper ions, and that they in turn were responsible for the weak copper anomalies in the creeks.

4.35 McLeashes - O'Donoghue Castle Mine Zone

In view of the large amount of attention the McLeashes-O'Donoghue zone has received in the past from Geosurveys of Australia Ltd. and N.F.M., and the disappointing results obtained (See Previous Exploration), very little additional work was done in the region by Shell Minerals.

At McLeashe's prospect one rotary-percussion hole was drilled by N.F.M. to test an I.P. anomaly in the upper member of the B.M.C. Disseminated pyrite and graphite were intersected at shallow depth, but there was no associated copper mineralisation. It was concluded that the pyrite and graphite were the probable source of the I.P. response (Wilson, 1970).

Two samples of the ore from McLeashe's prospect were petrologically examined in an attempt to explain the origin of the copper mineralisation.

The following conclusions are made from the examination of sample NFM 0013T and NFM 0014T (See Appendix II).

(a) Both samples are of laminated, fine grained mineralised sandstone.

(b) Each contain evidence of inherent disseminated pyrite - now manifest in various forms of limonite.

(c) Malachite is almost exclusively associated with coarse, more porous clastic bands within a finer matrix and with the greater concentrations of limonite after pyrite.

As no copper sulphide relics were recorded in the sediment, it seems most likely that the malachite has been introduced along the coarser-porous bands after deposition. The dimensions of the "lens-like" orebody have been defined by drilling and shown to be of sub-economic size and grade (See section on previous exploration).

Two samples of Wortupa Quartzite NFD 0102T and NFD 0103T (See Appendix II) from the vicinity of O'Donoghue Castle mine (See Plan 2) were submitted for petrological analysis to determine the origin of limonite cavities.

The cavities were reported (McPhar Geophysics) to be exclusively "after pyrite" with subordinate malachite (< 1%) occurring with the limonite and interstitially among coarser grains.

At O'Donoghue Castle mine, six rotary-percussion holes were drilled by N.F.M. to test a consistent zone of I.P. anomalies associated with the upper member of the B.M.C. A strongly pyritic zone intersected in the upper member was suggested as the probable cause of the I.P. response.

As no petrology was carried out on the drill cuttings by N.F.M., twelve selected five foot (1.52m) intervals were sent to McPhar Geophysics and Central Mineralogical Services by Shell Minerals for detailed comment on the origin of the sulphides. The petrological reports NFD 0210T to NFD 0220T inclusive are enclosed in Appendix II.

The following observations are common to the reports:

(a) The rock chips are of arkosic composition consisting of lithic fragments of trachyte and trachyandesite, microcline and oligoclase feldspars, quartz and muscovite, not necessarily in that order of abundance. Accessory minerals include carbonate, rutile, tourmaline, zircon and opaques.

(b) The composition and mode of occurrence of sulphides is essentially the same in each sample. Pyrite is the main sulphide present with very subordinate chalcopyrite and sphalerite. Sulphides are evenly disseminated, there being no tendency to concentration in veins or fracture fillings.

(c) The rocks have been hornfelsed and are characterised by abundant metamorphic biotite. Tourmaline and carbonate also support thermal metamorphism.

(d) Alteration is not conspicuous. In general feldspars are quite fresh.

(e) In some chips the pyrite exhibits evidence of metablastic growth.

It is difficult to draw any precise conclusion as to the origin of the sulphides from these reports. However, it is clear from the lack of alteration and hydrothermal features (vein and fracture fillings) that the sulphides were not of hydrothermal origin. There is a tendency for the sulphides to be associated with the metasomatic minerals (biotite, carbonate and tourmaline) suggesting that they, too, are products of the same metasomatic process. However, in sample NFD 0214T (See Appendix II) the pyrite is clearly bedded.

The present interpretation is that these arkosic sediments contained minor amounts of syngenetic sulphides (mainly pyrite), which survived partial metasomatism.

5. DISCUSSION AND CONCLUSIONS

The main aim of the regional sedimentary studies was to seek evidence of a Zambian Copperbelt type environment during the deposition of the Adelaidean sediments in the Wooltana area.

Some similarity was recognised and a tentative stratigraphic correlation is made (See Table 1). There are, however, some important gaps in the stratigraphy, namely the lack of volcanics on the Copperbelt and the absence of aeolian quartzites in the Wooltana area. Furthermore, the abundant anhydrite, now so important in the theory of the Copperbelt genesis (Garlick, 1972), was not recognised at Wooltana.

Many years of detailed study, supported by a wealth of sub-surface information, has led to a fairly close understanding of the Copperbelt environment. Some of the main features are: (After Garlick, op.cit).

(a) Palaeo-hills of basement project through the Footwall formation up to the horizon of the ore shale and are overlain by either a barren sandy facies of the ore shale or a barren dolomitic bioherm.

(b) A zonal sequence, from copper-rich to iron-rich sulphide, is interpreted as representing depth zones parallel to a shoreline controlled by the activity of anaerobic bacteria.

(c) The abundance of anhydrite proved that the shales were deposited in a highly saline environment with local supersaturation of $CaSO_4$, such as now occur on the shores of the Persian Gulf.

(d) At the Roan, the deposition of the Footwall conglomerate was followed by rapid subsidence to give a pyritic zone and then a gradual shallowing up to the barren argillite. The crossbedded arkose of the hanging wall quartzite represents the eventual burial of marine muds by deltaic formations.

No evidence could be found in the Wooltana area to support the existence of any of these important features. It is concluded therefore that there is some similarity of the sediments in the Wooltana area to those of the Zambian Copperbelt, but this comparison would hold for most of the Adelaide geosyncline. However, the features indicative of the Copperbelt mineralisation could not be recognised.

TABLE 1. POSSIBLE CORRELATION BETWEEN KATANGA AND ADELAIDE SYSTEMS

Katanga System of the Copperbelt (after Mendelsohn, 1961)			Adelaidean System of South Australia (after Coats & Blissett)
	Upper	Shale Quartzite	Pound Quartzite
Kundelungu Series	Middle	Shale Tillite (Petit Conglomérat)	Nuccaleena Formation Mount Curtis Tillite
	Lower	Shale) Dolomite, shale) Tillite (Grand Conglomérat)	Lyndhurst Formation Bolla Bollana Formation
	Mwashia	Carbonaceous shale and argillite	Unnamed upper member above Skillogalee Dolomite
	Upper Roan	Dolomite and argillite	Skillogalee Dolomite
Mine Series		Hanging wall formation: Pebbly arkose or feldspathic sandstone. Cross bedded quartzite and argillites with minor dolomite.)	Wortupa Quartzite
	Lower Roan	Ore formation: Argillite & impure dolomite. Micaceous or feldspathic dolomite.)	Opaminda Formation
		Footwall formation: Footwall conglomerate Argillaceous and feldspathic quartzite. Aeolian quartzites Conglomerates.	Blue Mine Conglomerate (Humanity Seat Formation (Woodnamoka Phyllite Paralana Quartzite, Shanahan conglomerate member.

Examination of the known secondary copper occurrences in the Wooltana area suggests that structure is the main control of mineralisation. Nearly all the old workings occur on or very close to faults (See Plan 1).

Most stream geochemical anomalies can be explained by old workings or surface occurrences of secondary copper. Where copper staining is not visible, manganese and iron oxides are often present and are known to act as powerful scavengers of the available copper ions.

No gossans or continuously mineralised beds were found. The high copper background for the B.M.C. is probably due to the porosity of the unit and the locally high manganese and iron content.

Rotary-percussion drilling has shown evidence of trace amounts of possibly sedimentary pyrite and chalcopyrite in the upper member of the B.M.C. at the O'Donoghue Castle mine, but there is no evidence of concentrations of these minerals in the area.

There is also no indication of any shale formations being carbonaceous, or that they contain significant amounts of sulphides, and it is concluded that the quiet conditions for reduction and precipitation of sulphides did not prevail, in fact the dumping of coarse detritus during sedimentation would dilute any concentration of copper ion.

The likelihood of there being an economic concentration of base metal sulphide in the B.M.C. or adjacent formations, is very remote.

For this reason the decision was made to withdraw from the proposed Wooltana joint venture area in October, 1972.

REFERENCES

Published

Brown, H.Y.L., 1899, Record of the mines of South Australia.(3rd Ed.),Govt. Printer, Adelaide.

Brown, H.Y.L., 1908, Record of the mines of South Australia (4th Ed.). Govt. Printer, Adelaide.

Coats, R.P. and Blissett, A.H., 1971, Regional and Economic geology of the Mount Painter Province. Geol, Surv. S. Aust., Bulletin 43.

Crawford, A.R., 1963, The Wooltana volcanic belt, South Australia. Trans. Roy. Soc. S. Aust., 87 : 123-154.

Dickinson, S.B. and Sprigg, R.C., 1953, Geological structure of South Australia in relation to mineralisation. In: A.B. Edwards (Editor), Geology of Australian ore deposits. Proc. Vth Emp. Min. metall. Congr., 1:426-448.

Forbes, B.G., 1961, Magnesite of the Adelaide system: a discussion on its origin. Trans. Roy. Soc. S. Aust., 85:217-222.

Garlick, W.G., 1971, Sedimentary environment of Zambian copper deposition. In: De Vletter et al., (Eds), Geologie en Mijnbouw, 51(3):277-298.

Mendelsohn, F., (Ed.), 1961, The Geology of the Northern Rhodesian Copperbelt, Macdonald, London.

Nicolini, P., 1970, Gitologie des concentrations minerales stratiformes. Gauthier-Villars, Paris.

Parkin, L.W. (Editor), 1969, Handbook of South Australian Geology. Geol. Surv. S. Aust.

Webb, B.P., 1958, Summary of tectonics and sedimentation in Geology of South Australia. In: Glaessner, M.F. and Parkin, L.W. (Eds), J. Geol. Soc. Aust. 5(2):136-143.

Unpublished

Burnside, E.D., 1972, Report on the Induced Polarisation and Resistivity survey at The Coup copper prospect, S.A. (McPhar Geophysics Report).

Carthew, S., 1971, Prospecting of anomalous zones as a follow-up to reconnaissance stream sediment sampling. (N.F.M. Report)

Donovan, P.R., 1970, Stream Sediments Reconnaissance Survey Wooltana area, S.M.L. 294 (McPhar Geophysics Report).

Driessen, A.J.B. and Sampey, D, 1964-6, Australian Selection (Pty.) Limited, Special Mining Lease No. 66, Wooltana Area. Quarterly progress reports 1st May, 1964 to 28th Feb., 1966. (A.S.P.L. Reports).

Garman, M., 1970, Report on investigation of S.M.L. 294 for North Flinders Mines Ltd. (Watts, Griffis and McOuat (Aust.) Pty. Ltd. Report).

Wilson, R.B., 1970a, Report on a rotary-percussion drilling programme O'Donoghue Castle area, S.M.L. 294 (N.F.M. Report).

Wilson, R.B., 1970b, Report on a rotary-percussion drilling programme McLeashe's Copper prospect, S.M.L. 294 (N.F.M. Report).

APPENDIX I : SUMMARY OF PREVIOUS EXPLORATION WITHIN THE WOOLTANA JOINT VENTURE AREA

Anomaly	Stream Value (ppm)	Bank sampling	Gridding	Remarks
Arkaroola	60	-	-	Isolated value in similar lithology to Claret anomaly. No follow-up work undertaken.
Claret	105	263 samples	1341m long by 610m and 305m alternate lines every 122m	Two zones (427m x 30.5m and 183m x 30.5m) of anomalous copper values around 500 ppm were outlined. Geological mapping was recommended.
Munyallina	85	-	-	No work was done on this anomaly located on the McLeashe's - O'Donoghue Castle trend.
Coup	100	-	914m x 610m	Values of 200-500 ppm were found in a 244m x 122m zone. Further sampling was recommended to close off the open anomaly.
Groan	70	179 samples	-	No visible secondary copper found.
Bleachmore	80	-	-	No further work done on this anomaly which occurs in the Wooltana Volcanics.
Kingsmill	210	106 samples	7 small coalescing grids	Anomalies limited in size and not enthusiastically viewed by A.S.P.L. geologists. Subsequently drilled by Geosurveys of Australia Pty. Ltd.
Wywhyana	165	130 samples	731.5m x 457m	Small anomaly open to the west. More sampling and mapping was recommended.
Nick	75	-	-	Occurs in Wooltana Volcanics.
Warren Hastings	85	-	-	Anomaly in Bolla Bollana tillite. Re-sampling by North Flinders Mines failed to reproduce the anomaly.

(from Driessen and Sampey, 1964-6)

Prospect	S.M.L.	Rotary-percussion drilling	Remarks
Welcome Copper prospect	188	12 holes to a maximum depth of 91.4m.	Geosurveys state unnecessary footage was drilled owing to lack of daily supervision. Ore body persists down dip to 61m with greatly reduced grades. Best intersection: Hole No. 6 from 42.7m - 59.5m, 16.8m @ 0.58% Cu.
Pebbles	188	2 holes totalling 182.9m	No significant copper mineralisation detected.
Wall	155	11 holes totalling 1981m.	'Bedded structure' with very low grade copper mineralisation down dip to 33.4m. Best intersection: Hole No. 2,0-21m. @ 0.42% Cu.
Coxcomb	155	3 holes totalling 254.4m.	No significant copper intersected.
McLeashe's	201	2 holes totalling 173.7m.	Both holes intersected a 'lode' of secondary copper. Reserves calculated to be between 40,000 and 50,000 tons of 1% Cu.

Prospect	Gridding	I.P.	Rotary-percussion drilling
Coup	Re-gridded to include area not sampled by Australian Selection	6 lines	-
Wheal Hancock	Grid established 1,463m x 610m.	-	-
McLeashe's) O'Donoghue Castle)	The whole zone between the two prospects was gridded. 5,182m x 610m with extensions at each end.	Detailed geophysical surveys were carried out by both McPhar Geophysics and Austral Exploration Services Pty. Ltd.	(8 rotary percussion holes were drilled totalling 466 metres. (7 holes to further explore the zone of secondary copper mineralisation and 1 as a preliminary test of an I.P. anomaly). (8 holes for a total of 527m (6 holes totalling 358m to test a zone of I.P. anomaly associated with the Blue Mine conglomerate and 2 were drilled down-dip from the old workings).

(from Donovan 1970; Garman, 1970;
Wilson, 1970 a; Wilson, 1970 b;
Carthew, 1971; Burnside, 1972)

APPENDIX II : PETROLOGICAL DESCRIPTIONS

NFR OOIIT: Mineralised, tuffaceous, siliceous argillaceous and sericitic, siltstone to fine grained-sandstone.

Macroscopically this rock is seen to be very fine grained, fine bands are due mainly to colour variations of the beds. Very thin, wavy bands or lamellae of malachite occur through a light grey portion of the rock more-or-less conformable to the bedding. These are essentially absent from a more massive pinkish grey band. Rarely these mineralised bands contain limonite pseudomorphs after ? pyrite.

In thin section, most of the rock is seen to consist of very fine (0.15 mm.) angular to subrounded grains of quartz (approximately 12%), felspar crystals of mainly microcline composition (5-7%), flakes of muscovite (7%) and rock fragments (5%), scattered through a much finer matrix of heterogenous composition.

This matrix consists partly of fine detritus having the same composition as the coarser components noted above, but is consists dominantly of ultra fine silica clays and sericite with minor dust-like opaques and accessory zircon. The matrix to clastic component ratio is about 70 to 30.

The quartz, felspar, and lithic clasts have a generally random distribution through the matrix. There is however, vertical and lateral variation in the relative concentration of clasts and matrix which produced a vague banding of intercalated irregular lens-like areas. Muscovite flakes generally lie parallel to the bedding, although many have a random orientation. Almost certainly this is detrital muscovite.

The precise mineralogical composition of the matrix is difficult to determine by optical microscopy because of the extremely fine grain size and the near-isotropic character of the fine silica and clays. The clay appears to be dominantly kaolin.

The "more massive pinkish grey band" referred to above is characterised by a relatively far greater concentration of the coarser components, (total of about 50%) and hence lesser matrix. Also fine limonite pseudomorphs after pyrite and limonite derived from them are more widespread through this band, forming about 10% of it.

Copper mineralisation consists partly of scattered patches of malachite which have a similar size to the coarser quartz grains (0.15 mm.). These are randomly scattered through the matrix although commonly they are attached to, or form composite grains with quartz grains of similar size. Many of these malachite 'spots' are rimmed by limonite, some contain crowded inclusions of limonitised opaques. There is no clear evidence however, that they represent completely replaced copper sulphides in situ.

Malachite more commonly occurs along wavy, irregularly spaced but more-or-less continuous veinlets, generally coincident with the bedding and measuring up to 0.1 mm. wide. Rarely these veinlets cut across apparent bedding at extremely low angles.

Several of these have a narrow but fairly continuous margin of muscovite and rarely include fairly coarse muscovite flakes. This is suggestive of alteration marginal to veins of hydrothermal origin.

One band of malachite along the bedding measures 3 mm. wide. It consists of a relatively coarse aggregate of essential malachite, allotriomorphic quartz grains, limonite pseudomorphs after subhedral pyrite and voids. There is no evidence of marginal rock alteration.

This is interpreted to be a vein of epigenetic origin but it is not clear whether it was introduced during diagenesis, or whether it is a vein produced during local reconstitution under conditions of low grade metamorphism.

Minor veinlets of quartz and of malachite cut across the bedding at acute angles.

The distribution and abundance of the coarser components, notably of the felspathic and lithic grains, indicates that this rock is decidedly tuffaceous. There is some degree of sorting however, indicating sub-aqueous deposition together with clastic or detrital material. Not enough information can be obtained optically from the groundmass to positively ascertain whether it is dominantly detrital or direct volcanogenic origin.

The rock is best classified as a mineralised, tuffaceous, siliceous and sericitic siltstone-fine grained sandstone.

NFR OOIIT: Feldspathic pelite with hydrothermal copper mineralisation.

This is a highly feldspathic pelite approximating to an arkose in composition. Recognisable detritus comprises alkali feldspar (mainly microcline) quartz and large flakes of muscovite. Traces of fine (10-30U) detrital rutile are scattered throughout the section. Quartz and feldspar detritus falls in the size range 50-100U; grains are angular to subrounded. The rock matrix contains a high proportion of K feldspar (5-10U) and a little quartz. Matrix feldspar is partly replaced by fine sericitic white mica. Clots of Fe oxides pseudomorphous after fine grained (probably diagenetic) pyrite (5-15U) are abundant. Malachite concentrations are sub-parallel to relict bedding and to the poorly defined foliation. Malachite appears most prominent in areas rich in detrital mica and is accompanied by marginal sericitisation of the matrix. The edges of detrital mica flakes are also partly replaced by sericite and it appears that copper mineralisation is of hydrothermal origin; replacing mica-rich and pyrite-rich lamellae. In polished section malachite is accompanied by relict traces of pyrite and chalcopyrite and a single grain of gold (3U). Traces of covellite pseudomorph pyrite as do avoid patches of goethite (possibly after framboids). One band of malachite (2mm) includes grains of hematite (0.5 - 1mm) possibly replacing magnetite. The conclusion as to a hydrothermal origin of the mineralisation is, of course, tentative due to the almost complete oxidation of original sulphides.

NFC 0012T: <u>Mineralised, tuffaceous, siliceous, argillaceous and sericitic siltstone to fine grained sandstone</u>.

This is a massive, very fine, leached kaolinitic rock with malachite occurring in localised patches and along rare joint planes.

The rock matrix which forms about 80% of the rock, consists of an intimate mixture of ultrafine silica, clays, sericite and fine (0.04 mm.) detrital quartz grains. There is no clearly defined bedding. The common orientation of most sericite indicates probably primary banding but this is far from regularly planar. Rather, structures depicted in the matrix by variations in concentration and alignment of sericite indicates that the rock consists of irregular intergrown lenses and streaks which tend to flow around ghost-like remnants of original lithic fragments which have essentially the same composition as the matrix.

Scattered at random through this matrix and the obscured, ghost-like structures, are individual subrounded, rarely embayed quartz grains (5%) and grains of felspar (2-3%). These have a maximum size of 1 mm.

Also randomly scattered are lithic "patches" consisting of an equigranular, closely packed aggregate of quartz muscovite flakes and altered felspar grains. These "patches" measure up to 5 mm. x 3 mm. and form about 5% of the sample. They are important in that malachite and fine limonitised opaques are selectively associated with them - occurring in the intersticies of the aggregate. Even where the patches are small (0.6 mm.) or occur as a lamination along the bedding, traces of malachite are almost invariably associated with them.

It is not clear if these "patches" are lithic fragments, or localised lenses developed on an original bedding plane as a micro-facies variant. The latter interpretation is considered most likely since the matrix only rarely "flows around" these. Also they have a common orientation throughout the rock and muscovite within most of them is aligned parallel to the immediately adjacent bedding planes.

This rock is also a dominantly tuffaceous siltstone to fine grained sandstone, siliceous and sericitic.

NFM 0013T: <u>Mineralised, laminated, ? tuffaceous, siliceous and sericitic, argillaceous, fine grained sandstone</u>.

This is a laminated fine grained sandstone with intercalated siltstone bands and secondary copper mineralisation.

In thin section, the rock is seen to consist of a loosely packed aggregate of dominant (50%) subrounded to subangular quartz grains, minor (5-7%) grains of felspar, and rare micro-quartzitic lithic fragments.

Most quartz grains show authigenic quartz over-growths, the outer margins of which are fairly irregular to ragged. The nature of the felspathic components suggests that this rock is also tuffaceous, but not as convincingly so as samples 11T and 12T.

Intersticies within the aggregate are filled by ultrafine amorphous looking clay (25-30%) and finely dispersed limonite (5%). In addition, fine flakes of muscóvite-sericite (7-10%) occur in these areas and invariably these are partly altered to clay (kaolin) which forms distinctive flakes in comparison to the other clay in the sample.

Scattered, radiating clusters of malachite (7-10%) occur at random through the rock, also within intersticies of the quartz aggregate. Maximum concentration of limonite commonly, but by no means exclusively, coincides with the malachite areas. This limonite has derived from opaques which are inherent to the sediment and which generally have the same size as the clastic quartz grains.

NFM 0014T: <u>Mineralised, banded, siliceous, sericitic and argillaceous, fine grained sandstone.</u>

This is a banded fine grained sandstone, with apparently dislocated, somewhat lens-like and discontinuous sedimentary bands which are enriched in malachite.

In thin section, the bands not containing malachite are found to consist of a loosely packed aggregate of subangular quartz grains, (average size 0.15 mm.) together with accessory felspar, lithic fragments, tourmaline and zircon grains of similar size. This aggregate contains interstitial randomly oriented flakes of muscovite which are extensively altered to clay and intergrown with ultrafine, relatively non-flaky clays.

Intercalated bands and rather irregular lenses consist of relatively concentrated argillised muscovite in a matrix of the ultrafine non-flaky clays containing sparse, scattered quartz grains.

Isolated lenses of clay are also intercalated.

Malachite is more-or-less concentrated in bands of similar composition to the quartzose bands described above, except that malachite dominates the interstitial matrix rather than clays. The malachite occurs as groups of fine interlocking prisms, in places it more-or-less invades quartz grains along fractures and irregularities around their boundaries. It does tend to be relatively concentrated in coarser bands.

Clusters of fine limonite are associated with some malachite. Individual limonite pseudomorphs after pyrite are rarely associated with malachite, and locally scattered through other parts of the rock. This suggests a possible relationship (as in previous samples) between copper mineralisation and inherent ? pyrite.

NFC 0016T: Limonitised, fine grained, siliceous, sericitic and argillaceous fine grained sandstone, containing patches of exotic carbonate.

This rock is similar to NFM 0013. It is vaguely banded and consists mainly of a fairly well sorted and tightly packed aggregate of subangular quartz grains, average size 0.3 mm. Subordinate slightly altered felspar grains of similar size and mainly potash variety (15-20%), argillised lithic fragments (5-7%), and rare tourmaline and zircon grains form part of the aggregate. It is not obviously tuffaceous however, the felspar and lithic fragments may be interpreted as such.

In most of the rock intersticies within the aggregate are filled by clays and ubiquitous finely dispersed limonite. The limonite is mainly derived from opaques which are inherent to the sediment, relicts of these remain and appear to be exclusively ironoxides, but this needs to be confirmed in polished section.

Locally the interstitial areas within the essential quartzose aggregate are filled by carbonate ? dolomite. These areas may occur in irregular bands roughly conformable to the bedding or in irregular closed like patches. This carbonate forms up to 10% of the rock and appears to be of exotic origin.

NFD 0102T: <u>Arkosic quartzite containing accessory scattered limonite pseudomorphs after pyrite</u>.

This is a thin bedded arkosic sandstone (or quartzite) consisting of the following components, showing approximate order of abundance:

quartz	50-60%
microcline	15-20%
plagioclase	3-5%
rock fragments	7-10%
sericite-clay	12-15%
tourmaline	trace
zircon	trace
goethite pseudomorphs after pyrite	1-2%

Grains are subrounded to subangular with medium sorting in individual bands of given grain size, average overall size about 0.5mm.

The quartz-felspar grains form a fairly tightly packed aggregate, allowing only some 12-15% interstitial pore space which is filled by detrital clay-sericite.

The rock fragments are generally of chert; siliceous siltstone; rarely of quartz-felspar eutectic inter-growth.

Goethite pseudomorphs after pyrite have a fairly constant dimension of about 0.7 mm; these are randomly scattered. Rare clumps of much smaller (0.3 mm) pyrite are more extensively altered to limonite. Even finer goethite pseudomorphs of pyrite (0.1 mm) are rarely concentrated in a given band.

Several (much less than 1%) near cubic form cavities have a vague limonite margin, these are believed to be leach cavities after original pyrite.

NFD 0103T: Arkosic quartzite, accessory limonite after pyrite and traces of interstitial malachite.

This is also an arkosic quartzite, similar to NFD 102T. The quartz-felspar grains and minor rock fragments are more closely packed and metamorphically fused into a quartzitic aggregate, thus there is less sericite-clay matrix in this sample. Accessory, clumps of sericite and carbonate are randomly scattered.

Several small 0.1 to 0.3 mm limonite pseudomorphs after pyrite are randomly scattered, but less abundant than in 0102T (less than 1%).

Malachite is seen to form an extremely faint or thin veneer on the weathered surface or the hand specimen. In thin section, malachite is also seen in interstitial areas within the arkosic aggregate, commonly associated with:

(a) small clusters of sericite-muscovite.

(b) almost invariably with "spots" of limonite.

(c) with limonite lined leach cavities after pyrite and/or carbonate.

(d) independently in pore spaces or boundaries between quartz grains.

In total however, malachite forms less than 1% of the rock and whereas it is most commonly associated with limonite, many small patches and pseudomorphs of limonite have no associated malachite.

NFC 0104T: Arkosic quartzite with accessory limonite pseudomorphs after pyrite, and pits derived from these.

This is a well consolidated arkosic sandstone containing about 15% felspar, 7-10% rock fragments. It is fairly massive with less than 10% interstitial matrix.

Limonite pseudomorphs after syngenetic subhedral (pyrito-hedral) pyrite, average size 0.6 mm are scattered forming some 3% of the rock. These have a very vague tendency to be relatively more concentrated in several bands parallel to the bedding, although in parts of the rock they are randomly scattered.

Closer to the weathered surface pyrite has been completely leached out leaving pseudo-pyritohedral cavities. The resultant limonitic products of leaching, line these cavities and have permeated immediately adjacent rock along intergranular boundaries and fractures.

Some smaller cavities near the weathered surface are completely leached felspars. These pits are also lined by exotic limonite.

NFC 0105T: Laminated, micaceous and ? tuffaceous siltstone, scattered limonitised pyrite with associated malachite. Malachite also along foliations.

This is a laminated, micaceous and tuffaceous, sericitic quartz siltstone.

Fine, subangular quartz grains (0.1 mm) and subordinate muscovite flakes are sporadically distributed in bands throughout a largely unresolvable siliceous sericite matrix and fine quartz detritus.

Minor large (1.5 mm) quartz grains, cherty, quartzitic and ? volcanic rock fragments occur as individuals or in local lenses, sporadically distributed along the bedding. These are possibly of tuffaceous origin.

Single grains of syngenetic pyritohedral pyrite 0.1 mm to 0.5 mm and small clumps of these are also randomly scattered along the bedding. These are now replaced by goethetic boxwork and/or replicas.

Malachite is almost exclusively associated with these limonite pseudomorphs - most commonly filling limonite pyritohedral boxwork, where it may be accompanied by traces of jarosite. Malachite also occurs along irregular foliation planes along the bedding, and along extremely fine sets of fractures cutting across these planes. Again, therefore there is evidence of enrichment of malachite at limonitised pyrite centres - possibly confirming the suggestion that vadose waters containing copper in solution reacting with the altering pyrite to produce copper sulphate which subsequently transforms to malachite.

Malachite along foliations is secondarily distributed, presumably independent of the occurrence of syngenetic pyrite.

NFR 0106T: Spotted ? scapolite-felspar-biotite hornfels. Malachite associated with limonitised pyrite and alteration products after ? scapolite.

Most of this rock consists of an aphanitic or micro hornfelsic (0.03 mm) aggregate of essential brown biotite, potash felspar and subordinate plagioclase and quartz.

Clusters and minor discontinuous veins of potash felspar and traces of associated quartz, and coarse aggregates of a fibrous-flaky mineral derived by the complete alteration of former scapolite or possibly potash felspar are randomly distributed, giving the rock a spotted or micro-porphyroblastic texture.

Sparse, ($<$1%) very fine (0.3 mm) limonite pseudomorphs after pyrite are scattered, commonly but not exclusively these are associated with clumps of quartz-microcline and alteration products after ? scapolite or microcline.

Malachite fills many of these pyrite boxworks and this is the most consistent mode of occurrence of the malachite - although in hand specimen malachite appears to be commonly associated with the fibrous-flaky alteration spots, in which pyrite remnants are not obvious.

Discontinuous quartz veins carry completely limonitised pyrite or magnetite. Malachite is absent from these.

The field mode of occurrence of this rock is not known. Its texture is characteristic of that developed in contact metamorphic rocks, its composition is also characteristic of some contact meta morphic rocks. Alternatively, the composition may be considered as that of a modified microsyenite.

The classification of spotted ? scapolite-felspar-biotite hornfels is tentatively assigned to the rock. Malachite is related to limonitised pyrite and alteration products after ? scapolite. This fibrous-flaky alteration product can be identified by X-ray diffraction if required.

NFR 0143T: Metasomatised sediments with vague volcanic affinities

This is a finely bedded to laminated rock consisting dominantly of an essentially granoblastic granular aggregate of dominant potash felspar, minor quartz and plagioclase, with intercalated layers and elongate lenses of felspathic argillaceous quartz siltstone.

Minor biotite and accessory very fine grains of sphene and/or rutile and tourmaline are scattered throughout.

Several relatively large (3 mm) lozenge shaped areas are filled by microcrystalline quartz mosaic containing minor plagioclase and ultrafine opaques. They are partly surrounded by fine biotite flakes.

Up to 5% fine (0.3 mm) subhedral (cubic) opaque grains are randomly scattered, examined in polished section these are found to be hematite (variety martite) pseudomorphs after former magnetite.

The gross texture of this rock indicates that it is almost certainly a sediment, or the regionally metamorphosed equivalent. However, such a concentration of potash felspar with this texture is somewhat unusual of a "straight" sediment, (it is however suggestive of a potassic volcanic ?).

The fine quartz and associated felspar and biotite more-or-less pseudomorphing the lozenge shaped areas is unlikely to be of supergene origin, rather these minerals appear to be of metasomatic derivation. Possibly the potash felspar in the sediment is also of metasomatic origin. The lozenge shape may represent former felspar, carbonate ? sphene. There is no evidence that it was former gypsum.

NFD 0210T: Feldspathic metasandstone/meta siltstone

The majority of chips are of a feldspathic metasandstone with lesser arenaceous siltstone. The sandstone approximates to an arkose in composition. It has been hornfelsed but retains some detrital textures. The pelitic matrix has been replaced with greenish brown biotite with traces of calcite, probably of diagenetic origin, but now recrystallised. Occasional thin (0.3 - 0.5 mm) intercalations of siltstone in the sandstone suggest the two rock types to be interbedded. There are no major mineralogical variations and both rocks have a similar detrital heavy mineral assemblage (zircon, rutile, minor green tourmaline). With decreasing content of feldspar and mica the sandstone grades into a metaquartzite. One chip consists of slightly strained mosaic quartz with traces only of buitite and feldspar. Some biotite is replaced by green chlorite, but there is, in general, little evidence of hydrothermal alteration. Pyrite is evenly distributed comprising 1-2% of most chips. Pyrite is euthedral (pyritohedral) to subhedral, most grains falling in the size range 50-100U (max. 300). About 10% of the pyrite occurs a fine anhedral grains 5-10U in diameter. In some chips pyrite is completely pseudomorphed by hematite which shows marginal alteration to goethite. Very minor fine-grained chalcopyrite occurs with pyrite. In one chip chalcopyrite aggregates (50-300U) enclose pyrite euhedra.

NFD 0211T: Poorly sorted, fine to coarse grained lithic, felspathic sandstone; containing evidence of potash, boron and silica metasomatism, accompanied by minor sulphides.

Most rock chips in this section consist of a fine (0.15 mm) blastopsammitic to granoblastic mosaic of generally dominant quartz and felspar, with subordinate to accessory biotite, tourmaline, carbonate, volcanic rock fragments and opaques. There is an apparent equal abundance of plagioclase and potash felspars.

This texture is essentially one of an original, rather poorly sorted, fine to coarse grained clastic or sedimentary aggregate of the listed components, which has been variously reconstituted by metasomatic and/or metamorphic processes. The modification involves intergranular recrystallisation and the metasomatic introduction of brownish green biotite, and lesser carbonate, quartz and tourmaline - indicating potash, CO_2, boron and silica metasomatism.

Lesser numbers of the rock chips consist of single quartz grains; fragments of volcanic (? trachytic) rock; fine quartzose siltstone (orchert), and single felspar grains. Each of these components generally contains traces of metasomatic products noted above, particularly of biotite. Disseminated opaques have an average size of 0.15 mm, they are most commonly but not exclusively, associated with the biotite tourmaline and carbonate.

They vary in concentration from absent to forming 10% of a given rock chip; and form about 3% of the whole sample.

In polished section these opaque minerals are found to consist dominantly of pyrite with only trace amounts of chalcopyrite and sphalerite having similar size and distribution as the pyrite.

The common association of the sulphides with biotite, carbonate (and tourmaline) suggests that they too are products of the same metasomatic processes superimposed on the original felspathic quartz sandstone.

NFD 0212T: <u>Arenaceous siltstone/meta-arkose</u>

Rock types present as chips comprise arenaceous siltstone, feldspathic sandstone (arkosic) and metaquartzite, in order of abundance. The siltstone has a high content of detrital muscovite, quartz and feldspar (oligoclase and microcline), in part, as thin (50-150U) sandy laminations. With increasing grainsize and decreasing pelitic matrix the siltstone grades into a fine-grained meta-arkose similar to that of NFD 0210T. Original pelitic and carbonate cement has recrystallised; pelitic material to greenish-brown biotite. Chips of arkose with a low content of intergranular mica have a distinctly hornfelsic texture. Siltstone chips exhibit a preferred orientation of biotite (001) planes. This parallels bedding defined by detrital white mica flakes and is considered due to replacement of an indurated pelitic matrix rather than to tectonic foliation.

Detrital feldspars are essentially unaltered, a feature typical of arkosic sediments. The sandstone includes a few sericitic aggregates similar to those of 0214T. Pyrite is evenly distributed comprising 2-5% of most chips. Pyrite occurs as fine anhedral grains (4-10U) and as euhedral (pyritohedral) porphyroblasts (40-100U), variably replaced and occasionally pseudomorphed by hematite. One chip contains a single grain of chalcopyrite (100U) with marginal replacement to covellite and hematite.

NFD 0213T: <u>Mainly laminated quartz siltstone, containing abundant biotite, and sparsely scattered tourmaline, sulphides and carbonate - all of metasomatic origin</u>

The rock chips in this sample consist almost exclusively of very fine, laminated quartz siltstone, crowded by ubiquitous randomly oriented, extremely fine brownish green biotite. Minor felspar and patches of sericite can be recognised in most fragments.

Fine sulphide grains (0.05 mm) and fine subhedral metasomatic grains of tourmaline and rarely carbonate are sparsely scattered through the rock.

These chips are interpreted as original siltstone, metasomatised and mineralised by the same processes which have similarly effected the rock chips in sample NFD 02111T.

A subordinate number of chips consists of coarser, poorly sorted, felspathic quartz sandstone, fairly extensively invaded and replaced by biotite, carbonate and associated sulphides.

NFD 0214T: <u>Feldspathic meta sandstone</u>

Most chips are of fine-grained arkosic sandstone similar to that of 0210T and 0212T. A few chips of arenaceous siltstone are present. As in previous specimens these have thin intercalations of sandstone. Sandstone includes aggregates of sericitic mica, apparently of detrital origin. Distribution of these aggregates is controlled by bedding. They are absent from some chips and of limited distribution in others. Individual aggregates have subparallel extinction of sericite, but this is of random orientation over the whole chip. Some aggregates have relict microtextures considered related to simple twins in perthite. Extinction of sericite varies across this plane. Sericitic alteration was evidently pre-depositional since adjacent detrital alkali feldspar is completely unaltered.

One chip includes a thin band of recrystallised chert. Original pelitic material is altered to metamorphic biotite. Recrystallised calcite, however, is present in trace amounts only.

Pyrite comprise 1-3% of most chips, largely as relatively coarse pyritohedra. In some chips the distribution of pyrite is controlled by bedding. Traces of chalcopyrite are present as inclusions in coarse (150-200U) pyrite euhedra.

NFD 0215T: Medium to coarse, poorly sorted, and felspathic quartz sandstone, invaded by biotite, carbonate and commonly associated sulphides.

The rock chips in this sample are very similar to those in 0211T. They consist of medium to coarse, poorly sorted, lithic and richly felspathic quartz sandstone. This rock is invaded and replaced in intergranular areas by greenish brown biotite, subordinate carbonate and minor tourmaline, all of metasomatic origin. Minor veins of carbonate-potash felspar are also present. Some fragments show evidence of argillic-sericitic (hydrothermal) alteration associated with metasomatic minerals.

The grains of pyrite, lesser chalcopyrite and traces of sphalerite are scattered through the matrix within most chips, generally in close association with biotite and tourmaline. Not all biotite has sulphides associated with it however.

One single fragment of volcanic rock appears to be trachyte breccia.

NFD 0216T: Coarse, pebbly, poorly sorted, lithic felspathic quartz sandstone; invaded by metasomatic biotite, carbonate and associated sulphides.

The rock chips in this sample represent all of the types described above. They consist mainly of coarse to pebbly, poorly sorted lithic, felspathic quartz sandstone. Volcanic rock fragments are fairly common in the clastic aggregates, they appear to have a trachyte to trachy-andesite composition. Chert fragments are also common.

A lesser number of fragments consist of sandy, felspathic quartz siltstone.

The matrix of the coarser rocks is sporadically replaced by greenish brown biotite, subordinate carbonate. Disseminated fine granules of pyrite and traces of chalcopyrite are not commonly associated with the biotite, and traces of tourmaline, clearly having the same genesis as the sulphides in other samples.

NFD 0216T: Lithic sandstone

Rock types present comprise lithic sandstone, arkosic sandstone and arenaceous siltstone in order of abundance. The latter are essentially identical to previous material and being minor constituents require no special comment. The major rock type is distinctly coarser-grained than previous material. In addition to alkali feldspars and quartz it includes detrital fragments of chert and quartzite. It is further characterised by a relative abundance of recrystallised carbonate cement. Detrital fragments range up to 4 mm diameter, but most fall in the size range 0.2 - 1.2 mm (medium sand). Detritus is well rounded but poorly sorted and comprises quartz, alkali feldspar (largely microcline) and lithic fragments in order of abundance. Cement is largely calcite but cherty silica and pelitic material are predominant in some chips. Calcite is optically continuous in some chips (lustre mottling); pelitic cement is now replaced by green-brown biotite.

Pyrite is most abundant within the sandstone matrix as aggregates of pyritohedra and fine-grained disseminations. Pyrite is partly replaced by hematite and is free of chalcopyrite inclusions. Opaques comprise 5-10% of most chips.

NFD 0217T: Metasiltstone/metasandstone (feldspathic)

Rock types present are metasiltstone and metasandstone (feldspathic), in approximately equal amounts. Recognisable detritus is quartzo-feldspathic. These rocks however are notably more hornfelsed than previous specimens. There is further, some evidence of metasomatic alteration. Metamorphic green-brown biotite is abundant and forms discontinuous lamellae within siltstone chips. Metamorphism has been of thermal rather than dynamo-thermal character; there being little tendency to preferred orientation of mica (001) planes. Biotite concentrations appear to reflect the original sedimentary fabric. One chip contains numerous large grains of altered, strongly poikilitic (?) cordierite and minor amounts of cordierite accompanying biotite in the hornfelsed siltstone. One fragment of coarser-grained hornfels is veined by microcline with abundant biotite and tourmaline. Metasomatic alteration is evident in a relative abundance of poikilitic tourmaline adjacent to the vein and in development of euhedral zircon and rutile throughout the chip.

Pyrite is disseminated throughout most chips as fine (5-10U) anhedra with sparse development of pyritohedral porphyroblasts. Minor fine-grained chalcopyrite is associated. Pyrite is completely altered to hematite pseudomorphs.

NFD 0218T

The composition of the rock chips and mode of occurrence of scattered fine pyrite and chalcopyrite is essentially the same in this sample as described in detail for NFD 0211T. The abundance (or concentration) of the metasomatic components and of the sulphides is considerably less in this sample however.

Tourmaline is absent.

NFD 0219T

The composition of the rock chips and the mode of occurrence of sulphides is similar to that in NFD 0211T. The sulphides consist almost completely of pyrite but with traces of chalcopyrite and sphalerite.

As in NFD 0218T however the abundance of metasomatic minerals and of sulphides is less than in samples NFD 0211T and NFD 0216T.

Tourmaline is absent.

NFD 0220T: Metasandstone (feldspathic)

All chips sectioned are of metasandstone. Grain size of individual chips varies from fine to medium; one chip being composite. Sedimentary textures are largely destroyed, but some feldspar grains retain detrital outlines. Pelitic matrix (fine sandstone) is replaced by biotite and (?) cordierite. The coarser sandstone has a matrix of recrystallised carbonate and mosaic silica. Authigenic quartz and micro-cline are evident as overgrowths on detrital grains.

Pyrite is sparsely distributed (less than 1%) as porphyroblastic grains 100-200U in diameter. Much of the pyrite is replaced pseudomorphously by hematite which is in turn altered to goethite. Three irregular grains of chalcopyrite were noted associated with pyrite.

NFW 0221T: Silicified siltstone with minor introduced quartz, felspar biotite. Coarser pyrite and chalcopyrite are associated with the introduced minerals. Finer dispersed pyrite may be authogenic.

This sample was examined in polished thin section. It is irregularly laminated and consists mainly of an ultra fine siliceous (cherty) matrix of quartz, containing dispersed fine grains of tourmaline, quartz, felspar, muscovite, and opaques. Quartz and felspar are the most abundant, they occur as separate scattered grains, in small, discrete areas of crystalline aggregate, and in fairly continuous laminae.

Much of the individual grains of quartz-felspar are detrital. The small aggregates of quartz felspar and discontinuous veins of these minerals have almost certainly been introduced, (or possibly they are authogenic). The felspar is dominantly microcline.

The opaque grains (average size 0.2 mm) consist mainly of subhedral to anhedral pyrite crystals. Most of these are more-or-less concentrated in laminations commonly closely associated with the coarser quartz felspar aggregates. Some pyrite is randomly dispersed in the matrix. The pyrite is locally altered to jarosite, particularly adjacent to a quartz-muscovite vein which cuts across the laminations.

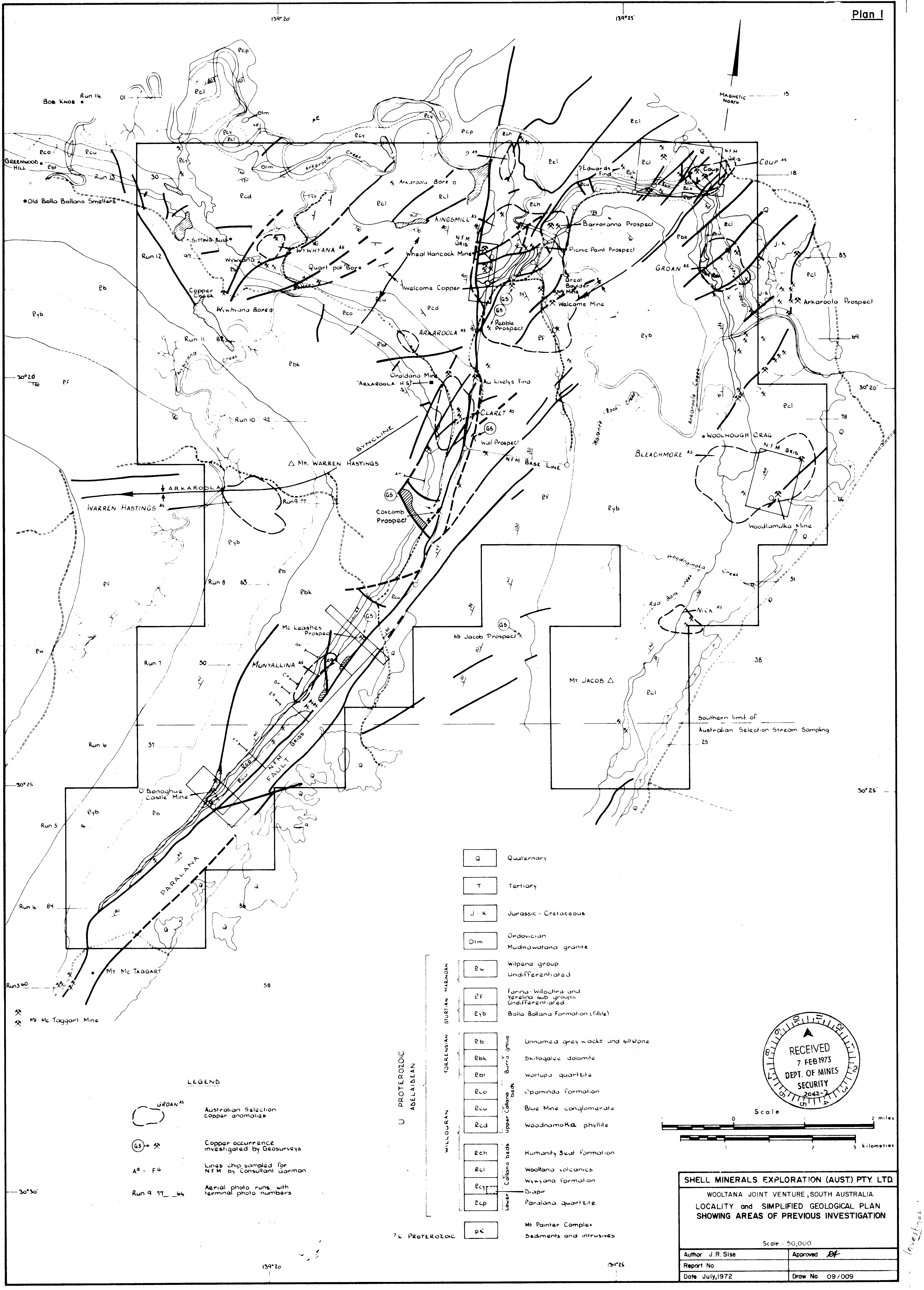
Anhedral grains of chalcopyrite up to 0.8 mm occur sporadically in trace abundance, generally in discontinuous trains and associated with fine veins of biotite and felspar quartz aggregates. The chalcopyrite is almost completely altered to covellite.

The precise genesis of this rock and contained sulphides is not clear. It is however, interpreted to be a silicified siltstone which contained accessory, detrital quartz, felspar and tourmaline grains. The silicification is conceivably of metasomatic origin. Minor, relatively coarser (potash) felspar, quartz and biotite were also introduced along primary laminations probably derived from the same metasomatic source.

The coarser pyrite, and all chalcopyrite is spatially, and therefore almost certainly genetically related to these introduced minerals. Finely dispersed pyrite may be authogenic.

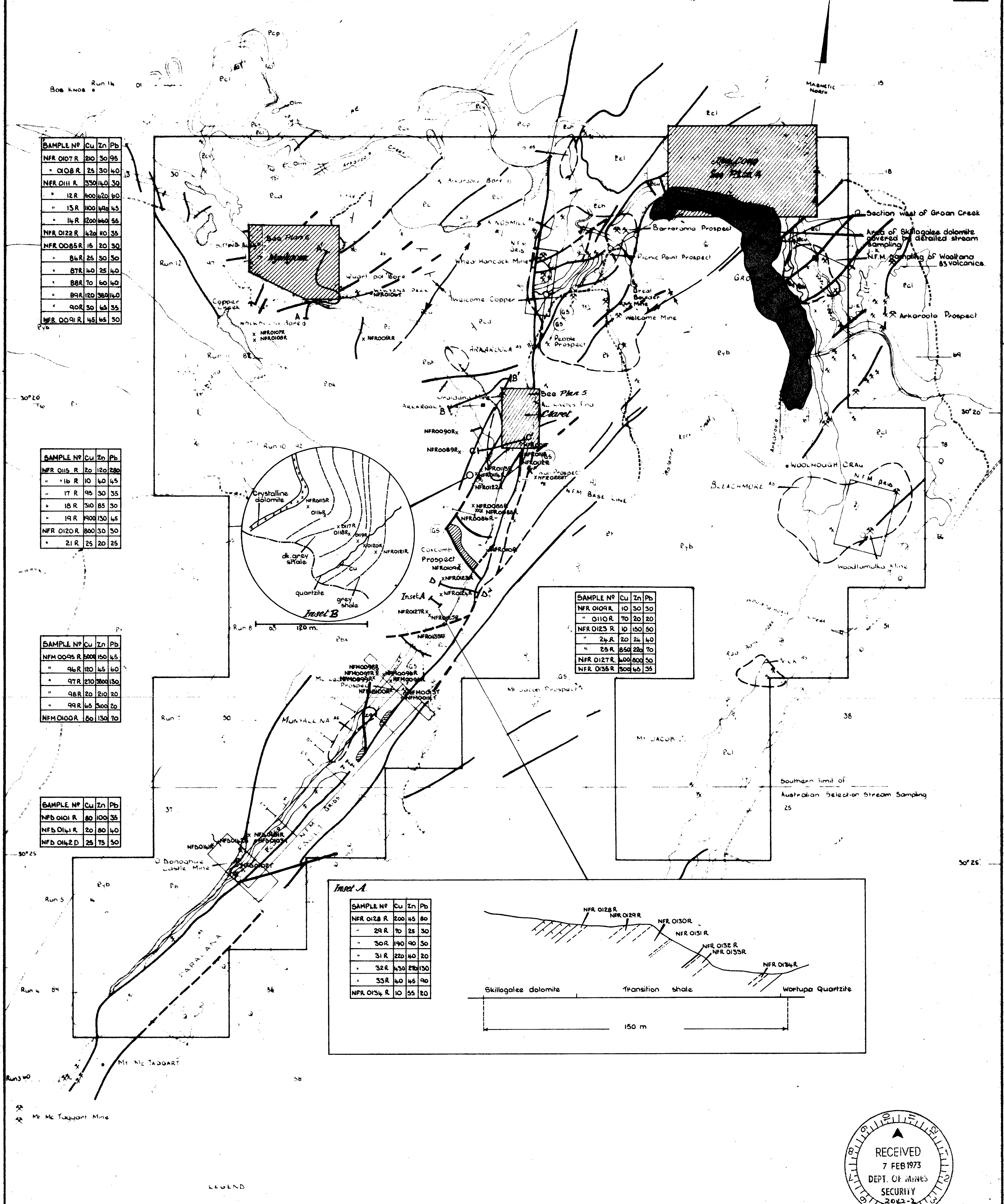
NFR 0222T: <u>Stressed ? vein quartz with malachite, limonite and minor chalcocite and covellite.</u>

Much of the section consists of a stressed polygonal mosaic of quartz. There are also large diffuse patches of finer-grained cherty silica. The two habits are apparently related as both types are clouded with dusty submicroscopic inclusions. The cherty silica is considered derived from sheared vein quartz by granulation and annealing recrystallisation. Breccia planes are infilled with limonite and malachite. The polished section reveals limonite boxworks after chalcopyrite, some of which include small corroded grains of marcasite at their cores. Traces of an anisotropic manganese oxide (? manganite) are present. Minor amounts of covellite and chalcocite are disseminated throughout the limonite aggregates.



Plan I
139°20'
139°25'
Magnetic North
Bob Knob
Run 14
Greenwood Hill
Run 13
Old Bolla Bollana Smelters
Sitting Bull
Run 12
Wywyana
Wywhyana
Quartpot Bore
Copper Creek
Wywhyana Bore
Run 11
Run 10
Arkaroola Creek
Arkaroola Bore
Kingsmill
NFM Grid
Wheal Hancock Mine
Welcome Copper
Arkaroola
Oroldana Mine
Arkaroola H.S.
Au Lively's Find
Claret
Wall Prospect
NFM Base Line
Pebble Prospect
Edwards Find
Barraranna Prospect
Picnic Point Prospect
Great Boulder Mine
Welcome Mine
Coup
Groan
Arkaroola Prospect
Woolnough Crag
Bleachmore
Woodlamulka Mine
Woodnamoka Creek
Nick
Balance Rock Creek
Syncline
Mt Warren Hastings
Arkaroola
Warren Hastings
Run 9
Coxcomb Prospect
Run 8
Mc Leashes Prospect
Mt Jacob Prospect
Munyallina
Run 7
Mt Jacob
Southern limit of Australian Selection Stream Sampling
Run 6
NFM Grids
NFM Fault
O'Donoghue Castle Mine
Run 5
Paralana
Run 4
Mt Mc Taggart
Run 3
Mt Mc Taggart Mine
30°20'
30°25'
30°30'
LEGEND
Australian Selection copper anomalies
Copper occurrence investigated by Geosurveys
A° - F° Lines chip sampled for NFM by Consultant Gorman
Run 9 77__64 Aerial photo runs with terminal photo numbers
Q Quaternary
T Tertiary
J-K Jurassic - Cretaceous
Olm Ordovician Mudnawatana granite
U PROTEROZOIC ADELAIDEAN
MARINOAN Ꝑw Wilpena group Undifferentiated
STURTIAN Ꝑf Farina - Willochra and Yerelina sub groups Undifferentiated
Ꝑyb Bolla Bollana formation (tillite)
TORRENSIAN Burra group Ꝑb Unnamed greywacke and siltstone
Ꝑbk Skillogalee dolomite
Ꝑbl Wortupa quartzite
WILLOURAN Upper Callana beds Ꝑco Opaminda formation
Ꝑcu Blue Mine conglomerate
Ꝑcd Woodnamoka phyllite
Lower Callana beds Ꝑch Humanity Seat formation
Ꝑcl Woolana volcanics
Ꝑcy Wywyana formation
Diapir
Ꝑcp Paralana quartzite
?L PROTEROZOIC pꞒ Mt Painter Complex Sediments and intrusives
Scale
0 2 miles
1 2 3 kilometres
RECEIVED 7 FEB 1973 DEPT. OF MINES SECURITY 2042-2
SHELL MINERALS EXPLORATION (AUST.) PTY. LTD.
WOOLTANA JOINT VENTURE, SOUTH AUSTRALIA.
LOCALITY and SIMPLIFIED GEOLOGICAL PLAN
SHOWING AREAS OF PREVIOUS INVESTIGATION
Scale 1:50,000
Author J.R. Sise
Approved
Report No
Date July, 1972
Draw No. 09/009

Plan 2



SAMPLE Nº	Cu	Zn	Pb
NFR 0107 R	210	30	95
" 0108 R	25	30	40
NFR 0111 R	330	140	30
" 12 R	600	620	60
" 13 R	1100	490	45
" 14 R	1200	660	55
NFR 0122 R	420	110	35
NFR 0085 R	15	20	30
" 86 R	25	30	30
" 87 R	40	25	40
" 88 R	70	60	40
" 89 R	120	380	140
" 90 R	30	65	35
NFR 0091 R	45	65	30

SAMPLE Nº	Cu	Zn	Pb
NFR 0115 R	20	120	280
" "16 R	10	40	45
" 17 R	95	30	35
" 18 R	310	85	30
" 19 R	1900	130	45
NFR 0120 R	800	30	30
" 21 R	25	20	25

SAMPLE Nº	Cu	Zn	Pb
NFM 0095 R	5000	150	45
" 96 R	120	45	60
" 97 R	270	3800	130
" 98 R	20	210	20
" 99 R	65	3100	20
NFM 0100 R	80	130	70

SAMPLE Nº	Cu	Zn	Pb
NFD 0101 R	80	100	35
NFD 0141 R	20	80	40
NFD 0142 D	25	75	50

SAMPLE Nº	Cu	Zn	Pb
NFR 0109 R	10	30	30
" 0110 R	70	20	20
NFR 0123 R	10	150	50
" 24 R	20	24	40
" 25 R	850	220	70
NFR 0127 R	400	800	50
NFR 0135 R	300	45	35

Inset A.

SAMPLE Nº	Cu	Zn	Pb
NFR 0128 R	200	45	80
" 29 R	70	25	30
" 30 R	190	90	30
" 31 R	220	40	20
" 32 R	430	270	130
" 33 R	40	45	90
NFR 0134 R	10	55	20

LEGEND

Australian Selection copper anomalies

Copper occurrence investigated by Geosurveys

Lines chip sampled for N.F.M. by Consultant Garman

Aerial photo runs with terminal photo numbers

NF { R - regional, M - Mc Leashes, D - O'Donohue } 0131 (sample number) { R - Rock chip, T - Thin section, D - Dry sieve }

A - A' *Mapped section west of Paralana Fault.*

Analysis in ppm.

Scale

0 — 2 miles

2 — 3 kilometres

SHELL MINERALS EXPLORATION (AUST.) PTY. LTD.

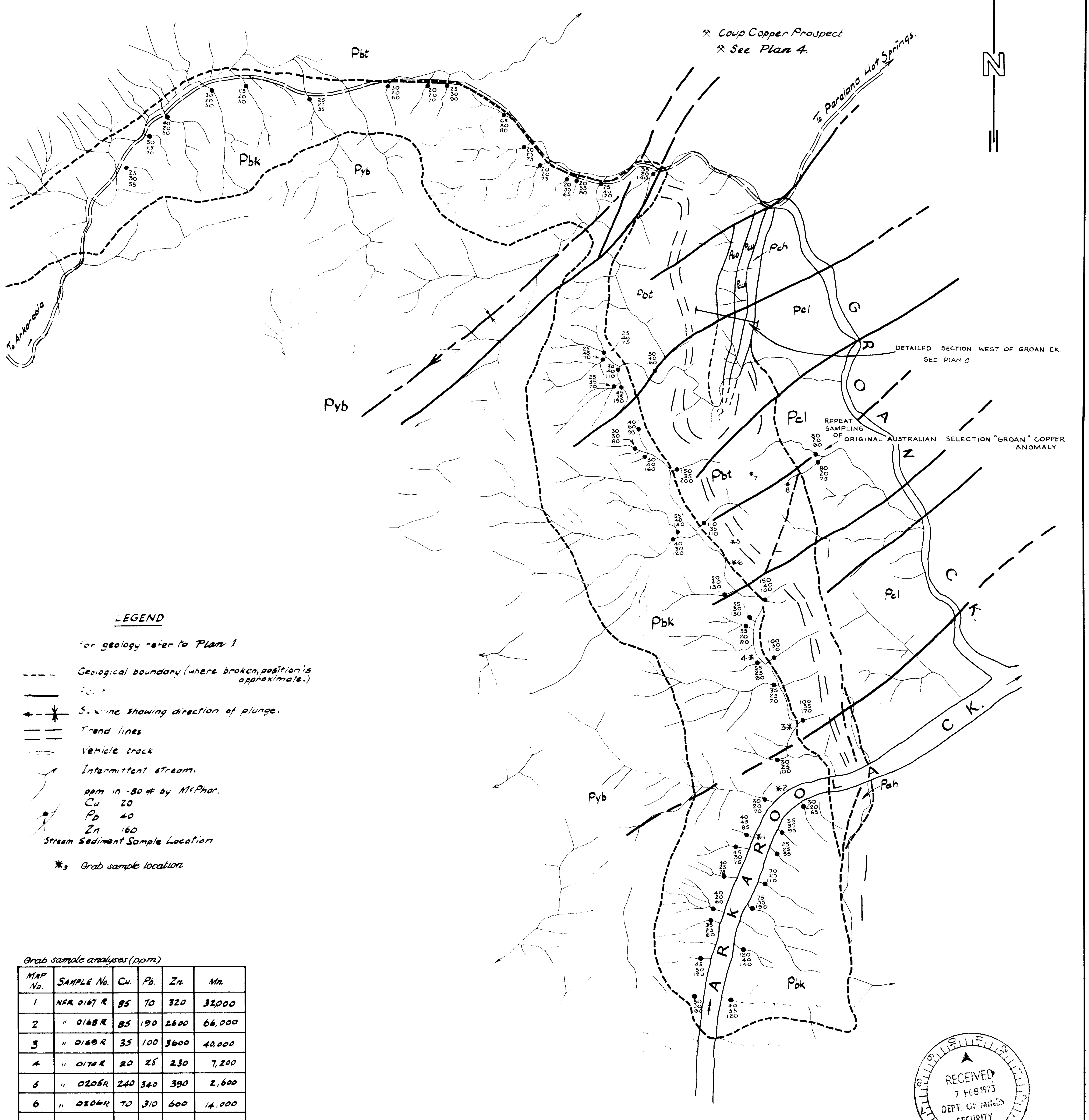
WOOLTANA JOINT VENTURE, SOUTH AUSTRALIA

LOCATION OF CHIP SAMPLING

AND DETAILED WORK AREAS

Scale 1 : 50,000

Author J.R. Sise	Approved
Report No	
Date	Draw. No. 09/009



LEGEND

For geology refer to Plan 1

- Geological boundary (where broken, position is approximate.)
- Fault
- Syncline showing direction of plunge.
- Trend lines
- Vehicle track
- Intermittent stream.
- ppm in -80 # by McPhar.
  - Cu 20
  - Pb 40
  - Zn 160
- Stream Sediment Sample Location
- $*_3$ Grab sample location

Grab sample analyses (ppm)

MAP No.	SAMPLE No.	Cu.	Pb.	Zn.	Mn.
1	NFR 0167 R	85	70	320	32,000
2	" 0168 R	85	190	2600	66,000
3	" 0169 R	35	100	3600	40,000
4	" 0170 R	20	25	230	7,200
5	" 0205 R	240	340	390	2,600
6	" 0206 R	70	310	600	14,000
7	" 0207 R	60	220	30	1,100
8	" 0207 A	3700	220	280	80,000

SHELL MINERALS EXPLORATION (AUST) PTY. LTD.

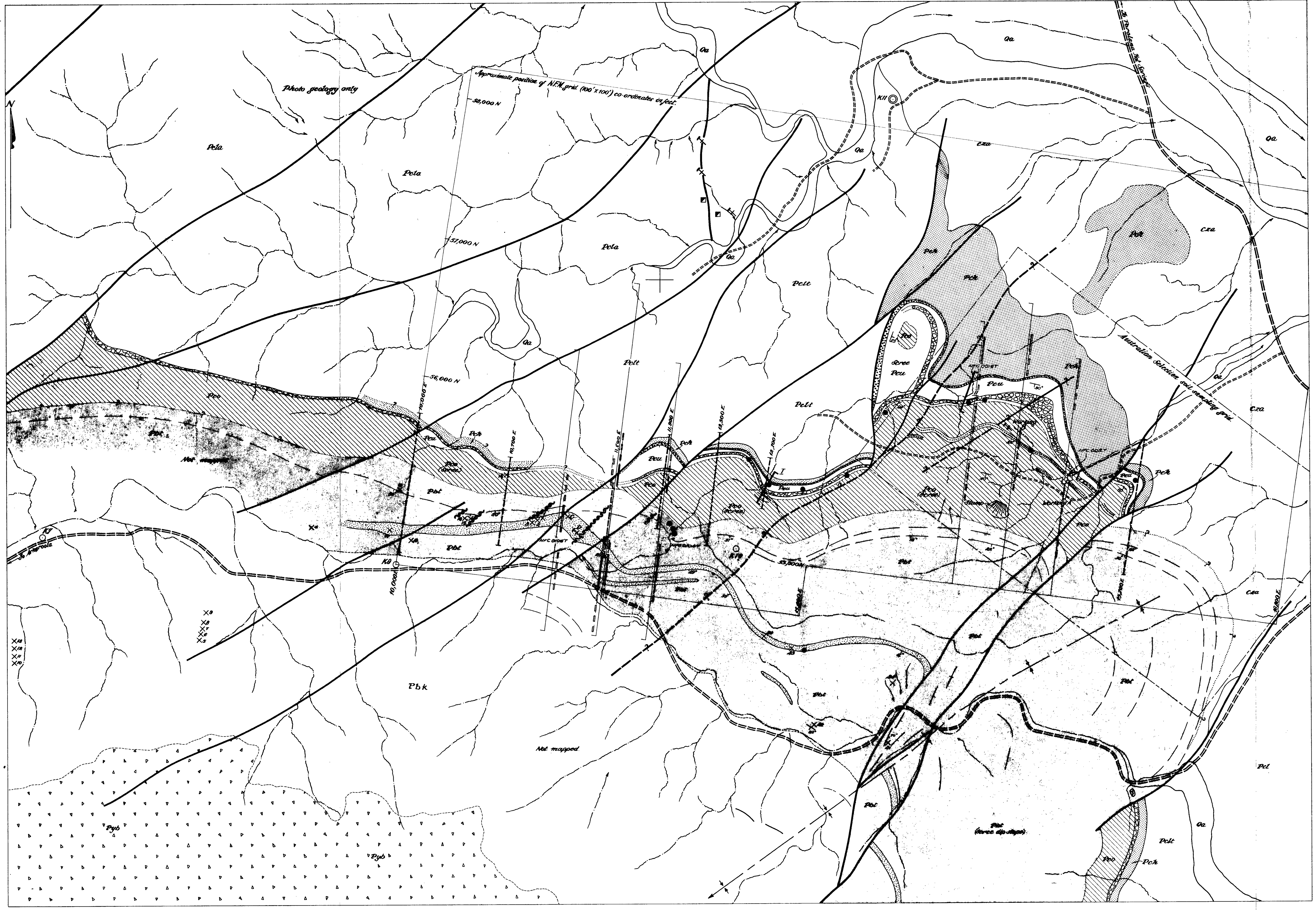
WOOLTANA JOINT VENTURE, SOUTH AUSTRALIA

STREAM SEDIMENT SAMPLING WEST OF GROAN CK. AND SOUTH OF THE COUP Cu. PROSPECT.

SCALE 2,000

Author J. R. Sise	Approved
Report No.	
Date October, 1972	Draw. No.

Plan 4



Legend

CAINOZOIC
- Qa — Alluvium
- Cza — Soil, scree

PRE-CAMBRIAN — ADELAIDEAN

STURTIAN
- Pby — BOLLA BOLLANA FORMATION. Massive tillite. (Yudnamutana Sub-group)

TORRENSIAN — BURRA GROUP
- Pbk — SKILLOGALEE DOLOMITE. Strongly leached multicoloured dolomitic shale. Local ferruginous bands.
- WORTUPA QUARTZITE. Feldspathic medium grained sandstone grading to purple shaly sandstone at top. Abundant ripple marks and mud cracks. Arkosic grits and conglomerate bands.

WILLOURAN — UPPER CALLANA BEDS
- Pcp — OPAMINDA FORMATION. Well bedded multicoloured siltstone. Locally ferruginous; tuffaceous? horizons and grit bands.
- Pcu — BLUE MINE CONGLOMERATE. Undifferentiated. Massive cobble conglomerate marker bed. Basal conglomerate marker bed.

WILLOURAN — LOWER CALLANA BEDS
- Pch — HUMANITY SEAT FORMATION. Dirty purple-grey sandstone. Locally hematitic and strongly manganiferous. Exotic carbonate (dolomite?)
- Pcl — WOOLTANA VOLCANICS. Undifferentiated.
  - a — Andesitic
  - t — Trachitic
  - Brecciated (adjacent to fault).

Geological boundary, Fault — Where line is broken, boundary is approximate; where dotted, concealed; where queried, position is inferred.

Syncline, showing direction of plunge.

70° Dip and strike of strata.

Prevailing dip and strike of strata.

Vertical beds.

Trend lines

Shear

Note: This is a semi-controlled map compiled from aerial photograph enlargements.

Track (two-wheel drive)

Track (four-wheel drive)

Intermittent streams

Shaft-accessible

Shaft-inaccessible.

Prospect-little production

K9 Survey control point

Air-photo centre

4 Grab sample

NFC0011T Petrological description (see Appendix 11)

Secondary Copper occurrence other than old workings

10,700E Approximate position of sections on North Flinders Mines' grid.

I Detailed stratigraphic column. (see plan 9)

I.P. Survey line (McPhar Geophysics)

Anomaly; definite, probable.

Rock Chip Sample Analyses (ppm)

Map No.	Sample No.	Cu	Zn	Pb
1	NFC 0068R	800	1400	30
2	" " 69R	610	1900	20
3	" " 70R	55	100	30
4	" " 71R	80	260	<20
5	" " 72R	150	170	30
6	" " 73R	120	120	25
7	" " 74R	55	70	20
8	" " 75R	90	85	20
9	" " 76R	110	1400	300
10	" " 77R	110	760	60
11	" " 78R	80	920	30
12	" " 79R	140	760	30
13	" " 80R	45	850	50
14	" " 82R	1100	840	40
15	" " 83R	910	210	30
16	" " 84R	850	260	30
17	" " 92R	2100	13500	120
18	" " 93R	550	60	30
19	" " 94R	660	1100	40
20	" 0136R	1700	3000	60
21	" "37R	25	2200	640
22	" "38R	20	2000	160
23	" "39R	270	90	60
24	" "40R	170	5000	150

SHELL MINERALS EXPLORATION (AUST.) PTY. LTD.

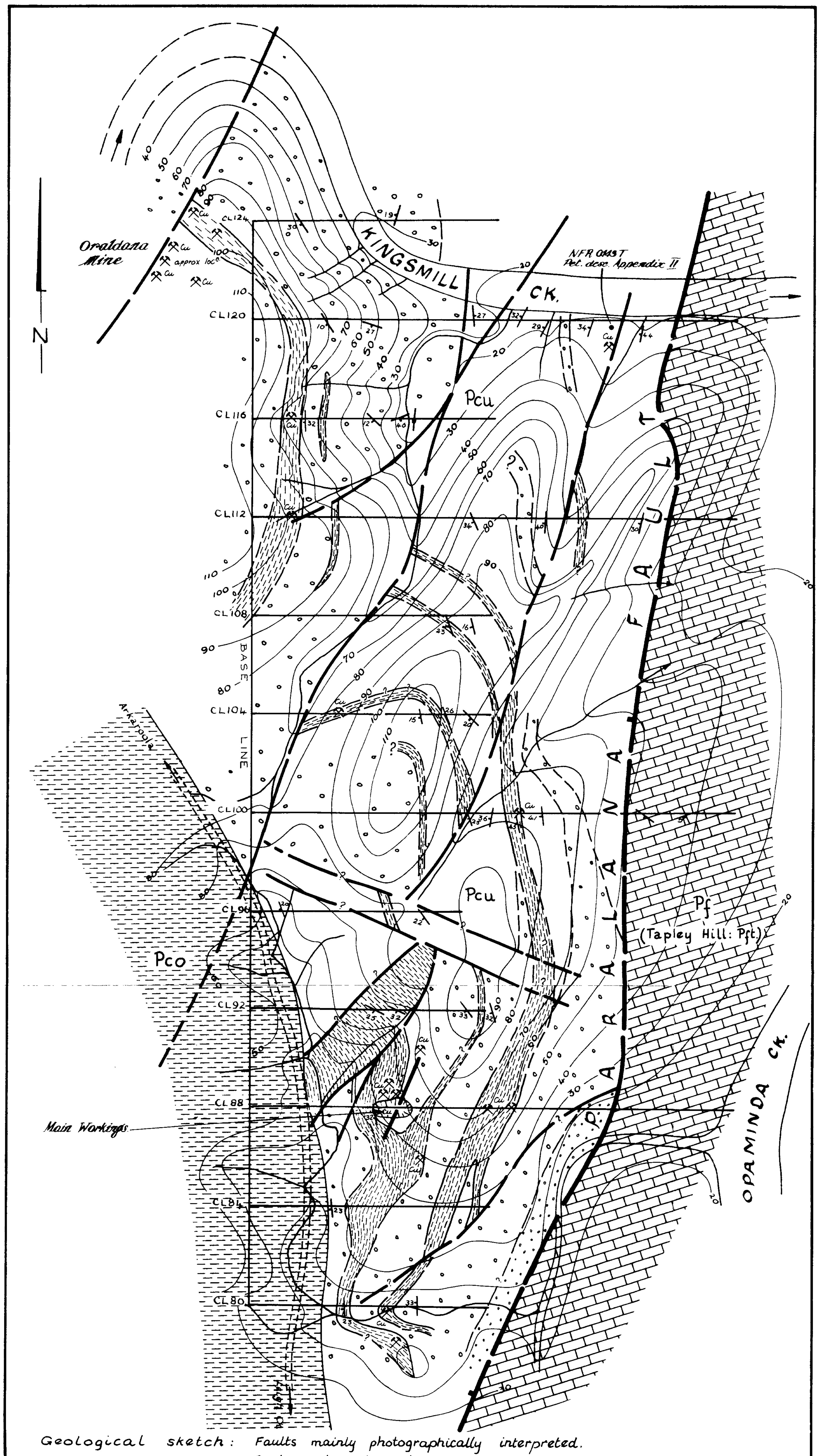
WOOLTANA JOINT VENTURE, SOUTH AUSTRALIA.

GEOLOGICAL PLAN
COUP COPPER PROSPECT

Scale 1:5000

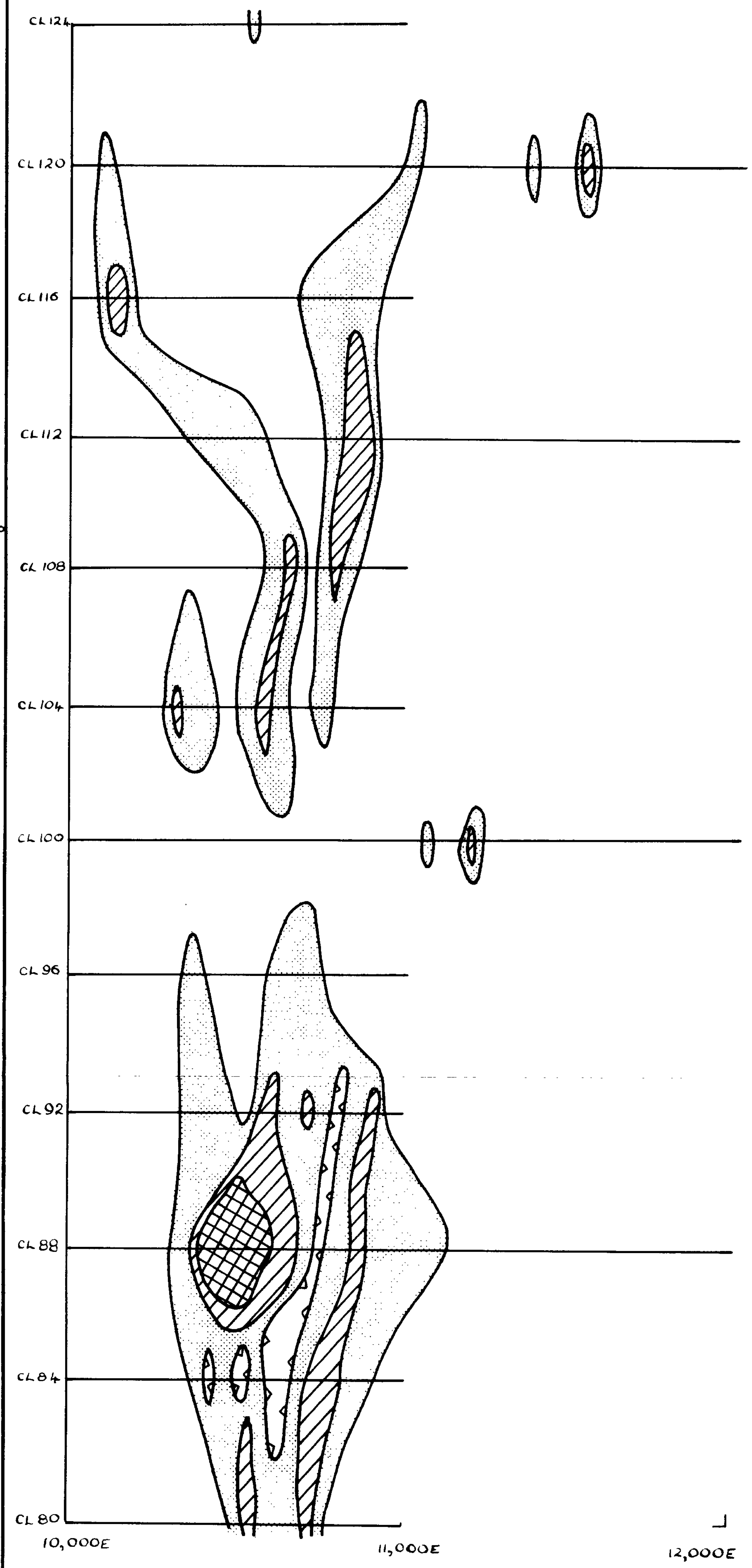
Author: J.R. Sise	Approved:
Report No.:	
Date: November, 1972	Draw. No.:

Plan 5



Geological sketch: Faults mainly photographically interpreted.
Geology based mainly on mapping along grid lines.

Claret grid showing soil geochemical anomalies for copper obtained by Australian Selection.



LEGEND

- \>300 <500 p.p.m.
- \>500 <1000 p.p.m.
- \>1000 p.p.m.
- Geochemical low.

LEGEND

- Pf — Tapley Hill Formation.
- Pco — Opaminda Formation.
- Pcu — Blue Mine Conglomerate
  - sandstone
  - siltstone
  - conglomerate
  - fine, micaceous conglomerate.
- Fault (where line is broken, position is inferred)
- Cu — Malachite showing

Note. Australian Selection grid was re-established.
Survey: Tape and clinometer.
Contour interval 10m.
Datum: Arbitrary.

SHELL MINERALS EXPLORATION (AUST.) PTY. LTD.	
WOOLTANA JOINT VENTURE, SOUTH AUSTRALIA	
CLARET COPPER PROSPECT	
Scale 1:5,000	
Author D.N. Carter	Approved
Report No	
Date November, 1972	Draw. No.

Plan 6

LEGEND

Qa	Alluvium
Czs	Soil; scree
+ + +	Pegmatite (Oligoclase >80%) (Quartz 10%)

Upper Callanna Beds

Pbt	Wortupa Quartzite
Pco	Opaminda Formation (locally strongly scapolitized)
Pcu	Blue Mine Conglomerate
Pcd	Woodnamoka Phyllite

- quartz veining
- Altered: Actinolite - scapolite hornfels.
- Geological boundary
- Fault. Where location of boundaries & faults is approx., line is broken, where inferred, queried.
- Trend lines (air photo interpretation)
- Top of bed
- Mineralisation (Cu copper, Py pyrite)
- o25 Soil sample value for copper in p.p.m. (North Flinders Mines' sampling)
- *C Petrological description
- Intermittent stream
- Australian Selection soil anomaly value >500 p.p.m.
- 30 Strike and dip of strata.

PETROLOGY (N.F.M)

*A Hybrid Alkaline granite - felspathic sandstone

*B Sillimanite - biotite - cordierite felspar schist.

*C Hornfels. Actinolite 30%, Scapolite 40-50%, Biotite 12-15%

•NFW 0221T Petrological description see Appendix II

SHELL MINERALS EXPLORATION (AUST.) PTY. LTD.

WOOLTANA JOINT VENTURE, SOUTH AUSTRALIA

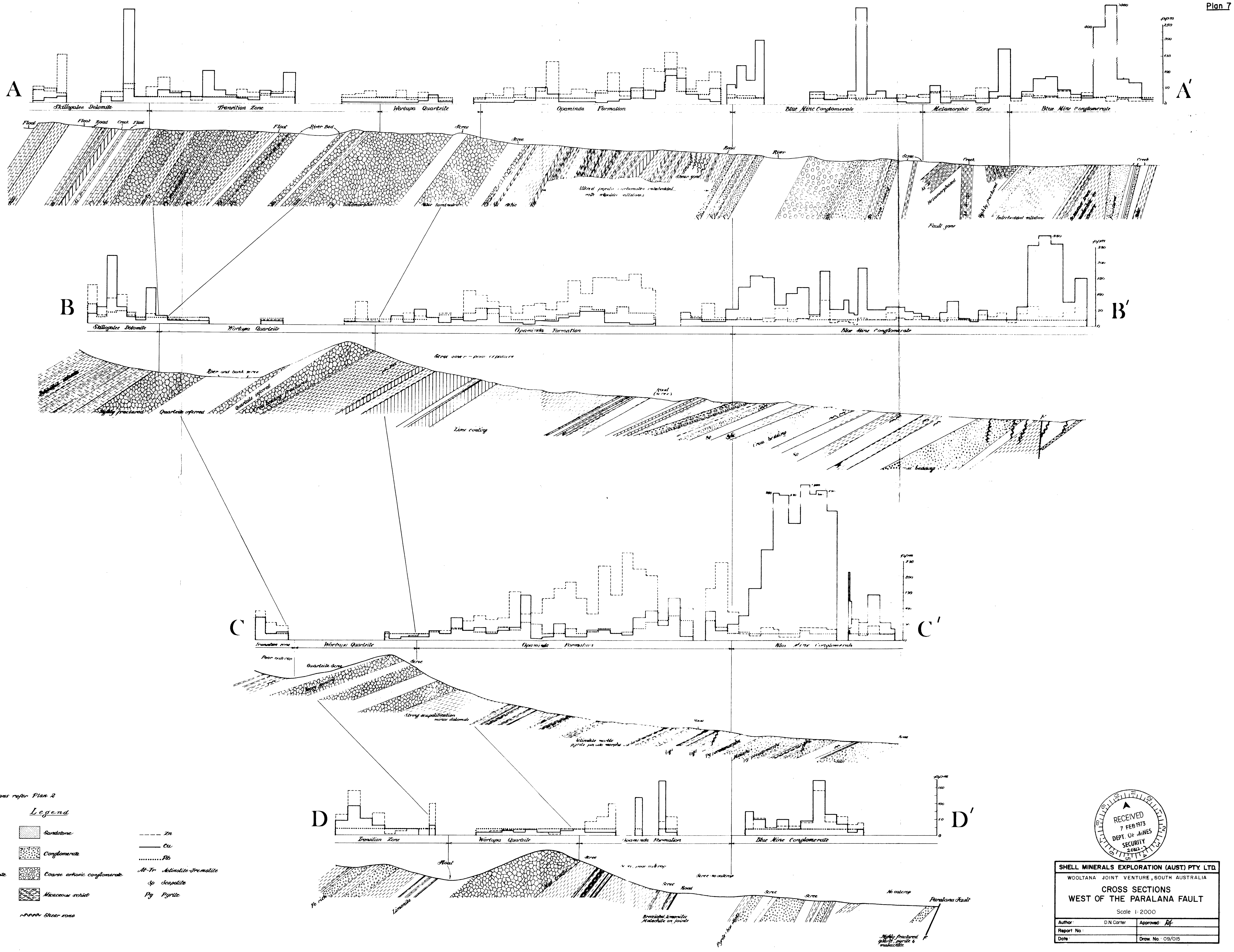
GEOLOGICAL PLAN

WYWHYANA COPPER PROSPECT

Scale 1:5000

Author J.R.Sise	Approved
Report No.	
Date November, 1972	Draw. No.

Plan 7



For location of sections refer Plan 2

Legend

- Dolomite
- Siltstone
- Altered carbonate
- Quartzite
- Sandstone
- Conglomerate
- Coarse arkosic conglomerate
- Micaceous schist
- Mud cracks
- Shear zone
- Zn (dashed line)
- Cu (solid line)
- Pb (dotted line)
- At-Tr Actinolite-Tremolite
- Sp Scapolite
- Py Pyrite

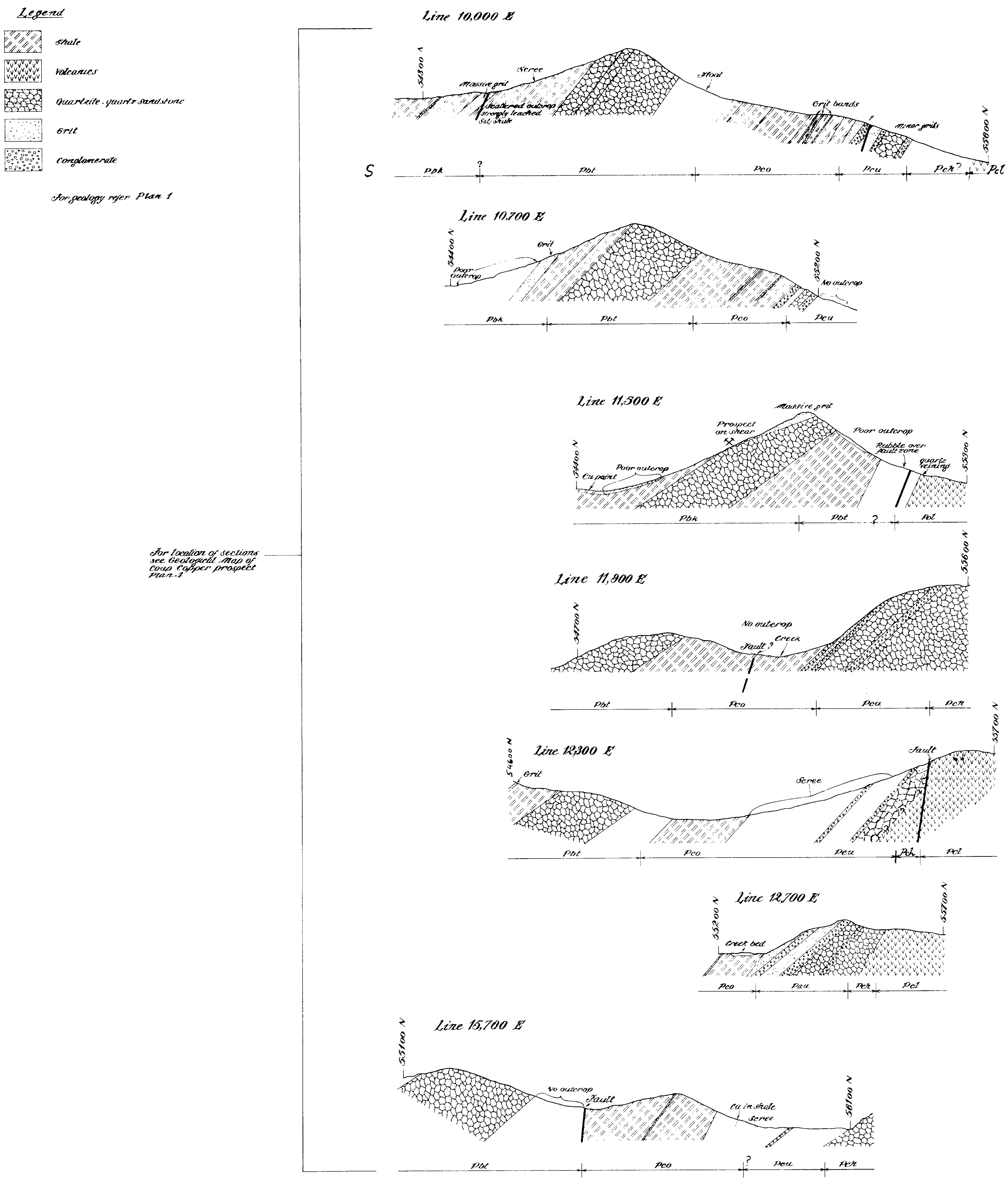
SHELL MINERALS EXPLORATION (AUST.) PTY. LTD.

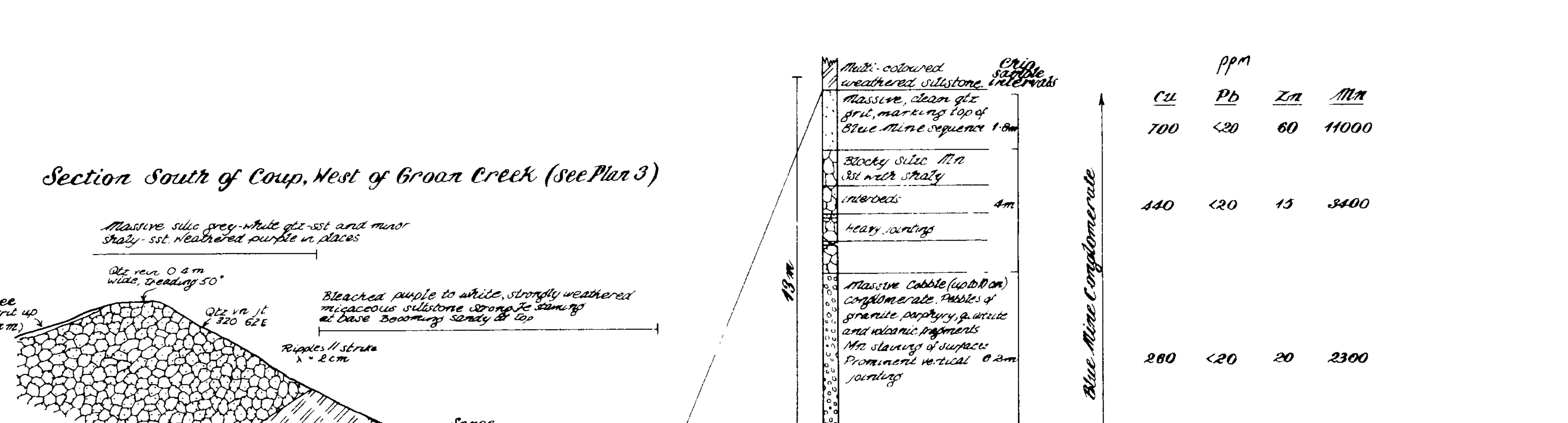
WOOLTANA JOINT VENTURE, SOUTH AUSTRALIA

CROSS SECTIONS WEST OF THE PARALANA FAULT

Scale 1:2000

Author: D.N. Carter	Approved:
Report No.:	
Date:	Draw. No.: 09/015

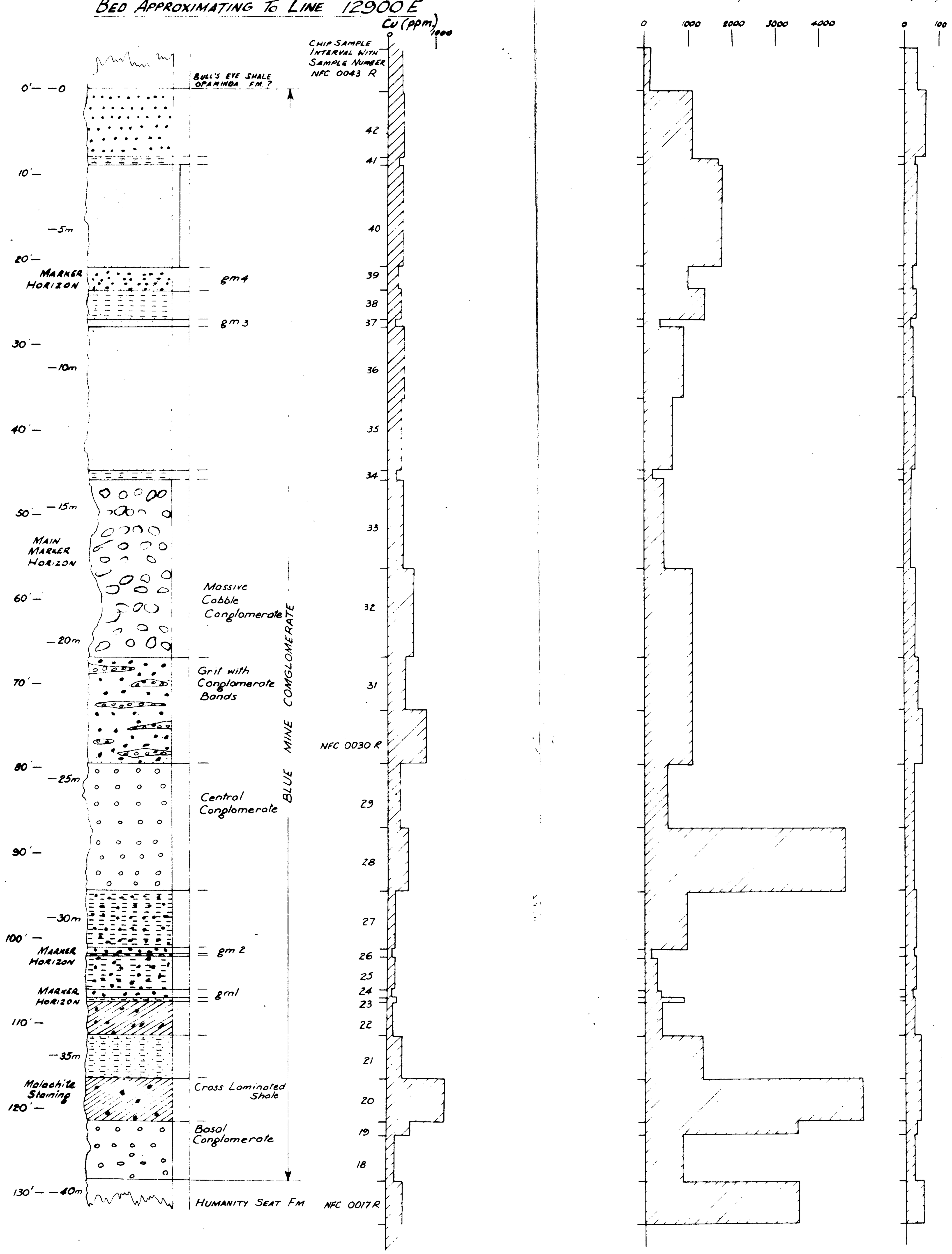




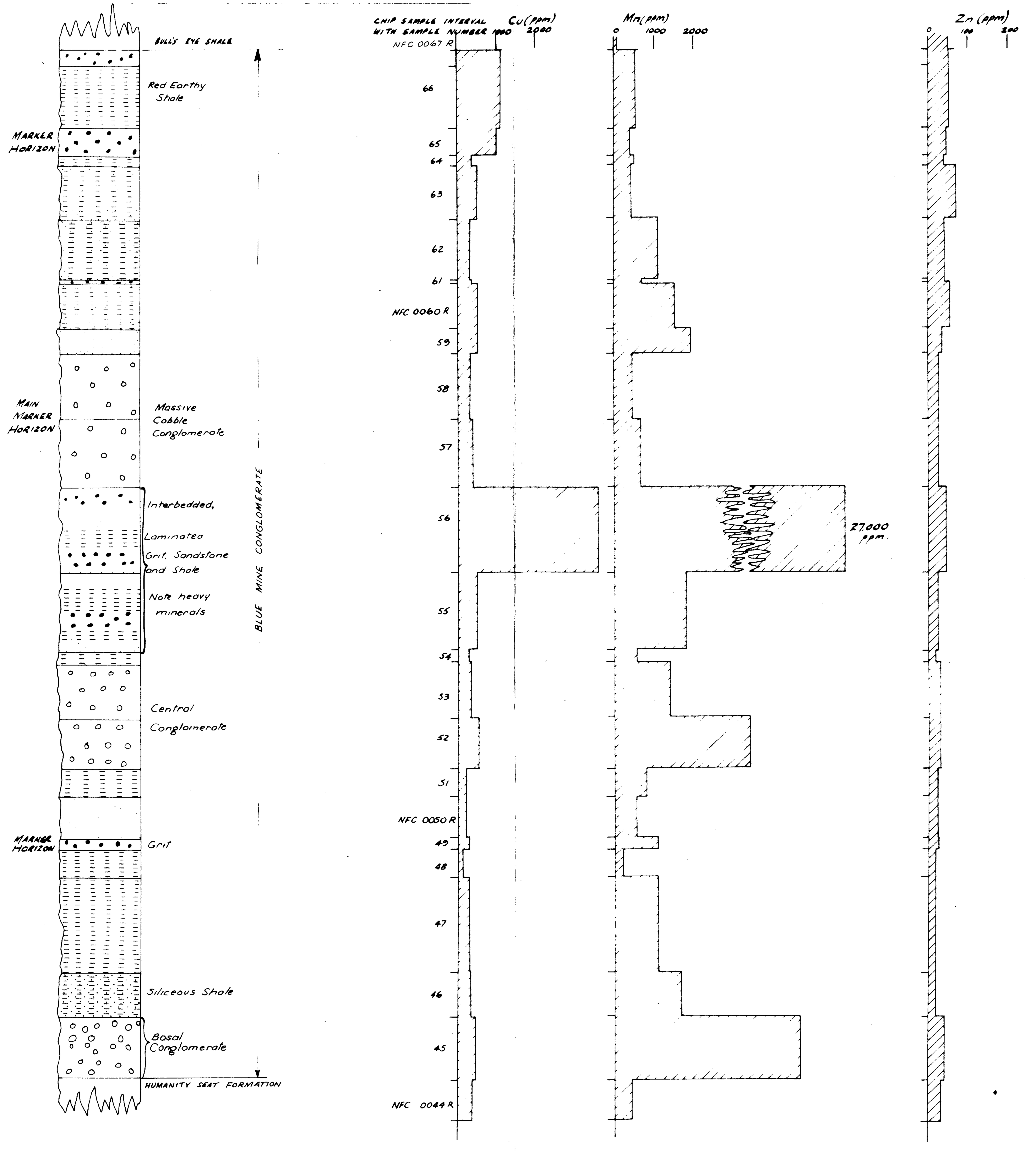
Note: These sections have been reduced and simplified for comparison with the sections west of the Paralana Fault. See Plan 7

SHELL MINERALS EXPLORATION (AUST) PTY LTD.	
WOOLTANA JOINT VENTURE SOUTH AUSTRALIA	
CROSS SECTIONS EAST OF PARALANA FAULT Scale 1:2000	
Author J.R. SISE	Approved
Report No	
Date November, 1972	Draw No.

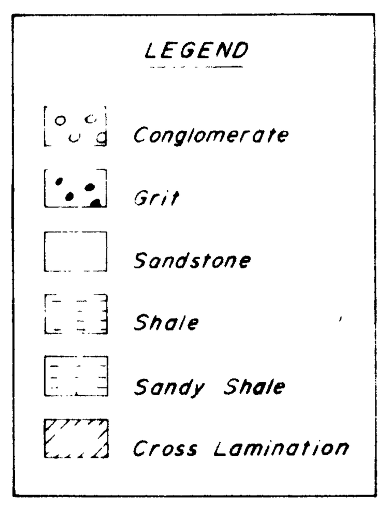
I
SECTION THROUGH BLUE MINE CONGLOMERATE AT THE COUP PROSPECT MEASURED IN CREEK BED APPROXIMATING TO LINE 12900 E



II
SECTION THROUGH BLUE MINE CONGLOMERATE AT THE COUP PROSPECT ALONG LINE 14.300 E.



NOTE:- STRUCTURAL INFORMATION HAS BEEN OMITTED FROM THESE SECTIONS.
FOR LOCATION OF SECTIONS SEE PLAN 4.



SHELL MINERALS EXPLORATION (AUST) PTY LTD.
WOOLTANA JOINT VENTURE, SOUTH AUSTRALIA
SECTIONS THROUGH BLUE MINE CONGLOMERATE AT THE COUP COPPER PROSPECT
Scale 1:100

Author J. R. Sise	Approved D.L.F.
Report No	
Date June, 1972	Draw No

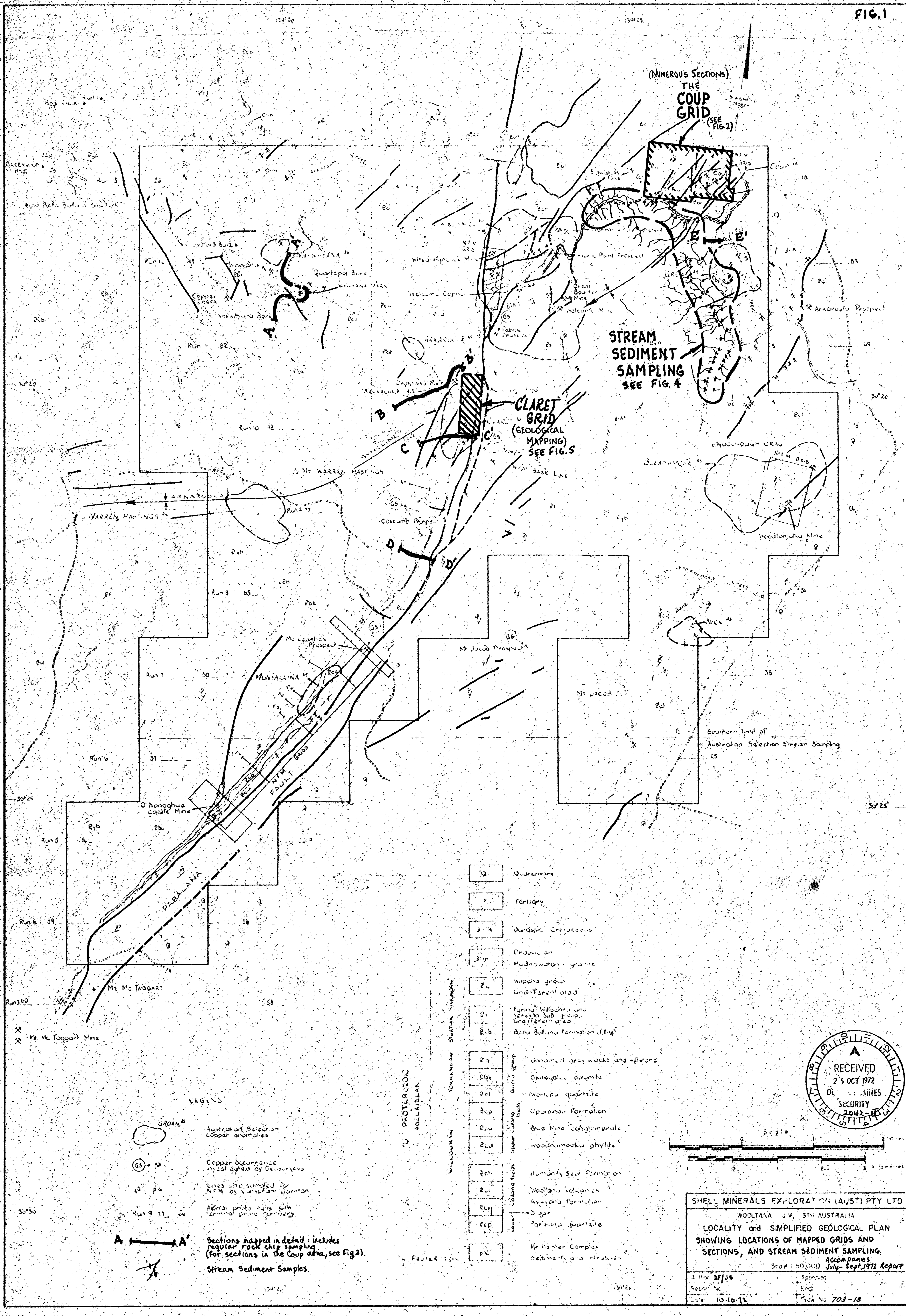
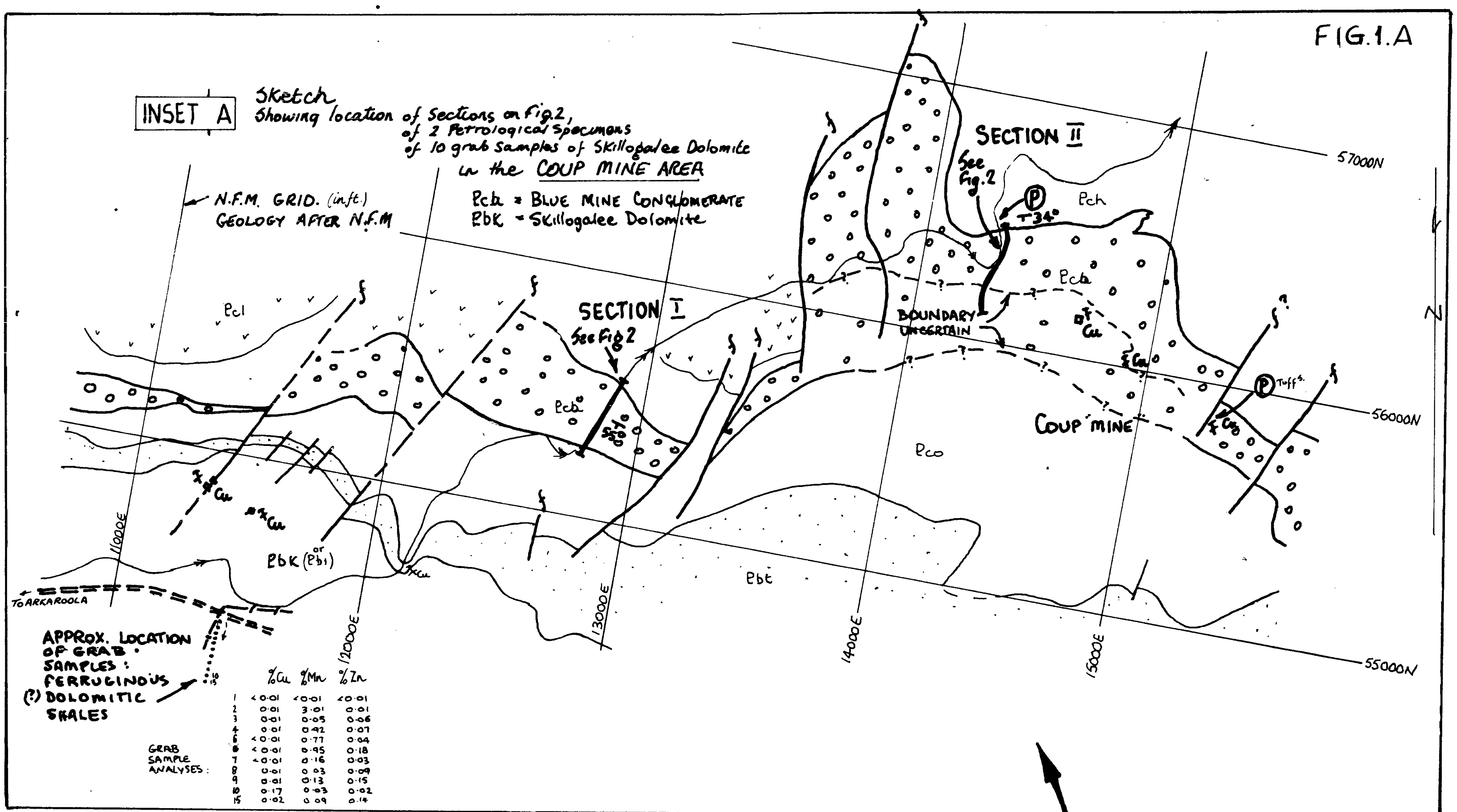
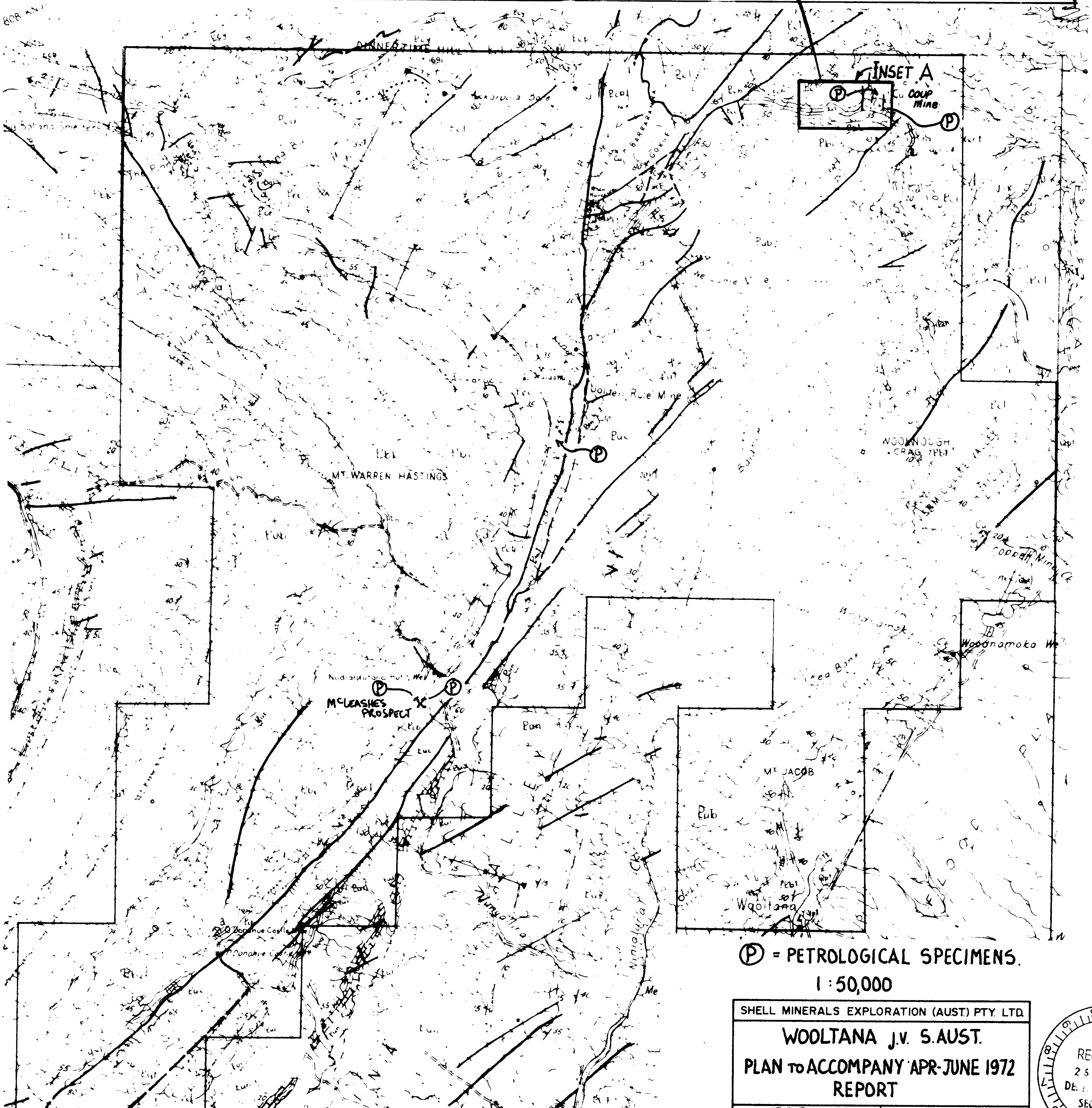


FIG. 1
(NUMEROUS SECTIONS)
THE COUP GRID (SEE FIG. 2)
STREAM SEDIMENT SAMPLING SEE FIG. 4
CLARET GRID (GEOLOGICAL MAPPING) SEE FIG. 5
Quartzpot Bore
Arkaroola Prospect
Mt Warren Hastings
Mt Jacob Prospect
Mt Jacob
Southern limit of Australian Selection Stream Sampling
O'Donoghue Castle Mine
N F M FAULT GRID
PARALANA
Mt Mc Taggart
Mt Mc Taggart Mine
LEGEND
Australian Selection copper anomalies
Copper occurrence investigated by Geosurveys
Aerial photo runs with terminal photo numbering
Sections mapped in detail : includes regular rock chip sampling (For sections in The Coup area, see Fig. 2).
Stream Sediment Samples.
Q Quaternary
T Tertiary
J-K Jurassic Cretaceous
Ordovician
Mudnawatana granite
Wilpena group Undifferentiated
Unnamed grey wacke and siltstone
Woodnamooka phyllite
Blue Mine conglomerate
Wooltana Volcanics
Paralana quartzite
Mt Painter Complex
Sediments and intrusives
PROTEROZOIC
ADELAIDEAN
Scale
SHELL MINERALS EXPLORATION (AUST) PTY LTD
WOOLTANA J.V., STH AUSTRALIA
LOCALITY and SIMPLIFIED GEOLOGICAL PLAN SHOWING LOCATIONS OF MAPPED GRIDS AND SECTIONS, AND STREAM SEDIMENT SAMPLING.
Scale 1:50,000
Accompanies July-Sept., 1972 Report
DF/JS
10-10-72
703-18
RECEIVED
2 5 OCT 1972
SECURITY

FIG.1.A



	%Cu	%Mn	%Zn
1	<0·01	<0·01	<0·01
2	0·01	3·01	0·01
3	0·01	0·05	0·06
4	0·01	0·92	0·07
6	<0·01	0·77	0·04
[illegible]	<0·01	0·95	0·18
7	<0·01	0·16	0·03
8	0·01	0·03	0·09
9	0·01	0·13	0·15
10	0·17	0·03	0·02
15	0·02	0·09	0·14

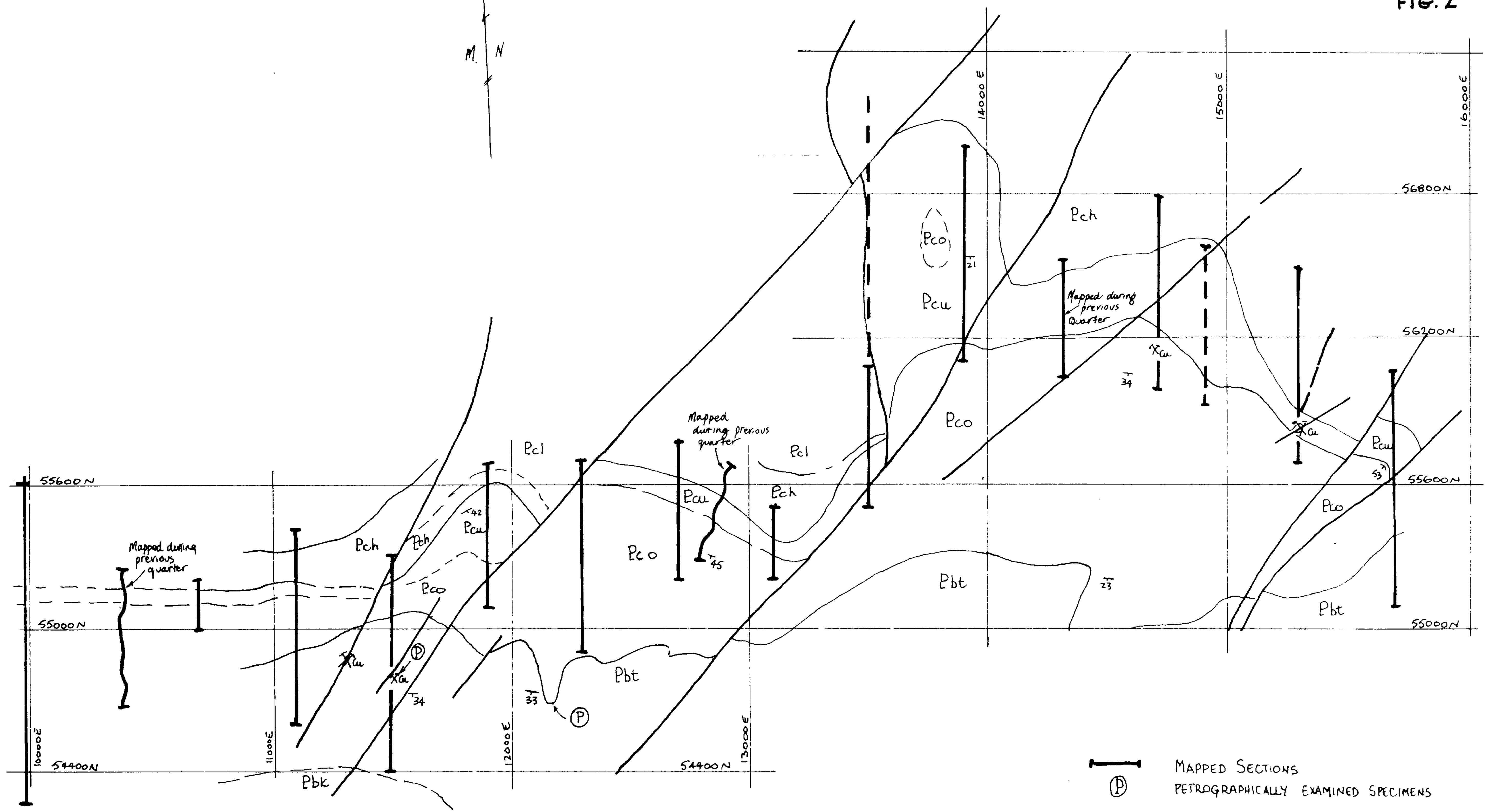


Ⓟ = PETROLOGICAL SPECIMENS.

1 : 50,000

SHELL MINERALS EXPLORATION (AUST.) PTY. LTD.	
WOOLTANA J.V. S.AUST.	
PLAN TO ACCOMPANY APR-JUNE 1972 REPORT	
Author D.L.F.	Approved
Report No	Encl
Date 7.9.72	Drow. No 703-16

FIG. 2



MAPPED SECTIONS

Ⓟ PETROGRAPHICALLY EXAMINED SPECIMENS

approx 1 : 5,000

FOR GEOLOGICAL LEGEND : REFER TO FIG. 1

RECEIVED
26 OCT 1972
DEPT. OF MINES
SECURITY
2042-II

SHELL MINERALS EXPLORATION (AUST.) PTY. LTD.	
WOOLTANA J.V., STH. AUST. THE COUP Cu PROSPECT GRID (PART OF) SKETCH PLAN SHOWING LOCATIONS OF MAPPED SECTIONS To Accompany Report for Quarter July - Sept., 1972	
Author DLF/JRS	Approved
Report No	Encl.
Date 10-10-72	Draw. No. 703-19

RECEIVED
2 5 OCT 1972
DEPT. OF MINES
SECURITY

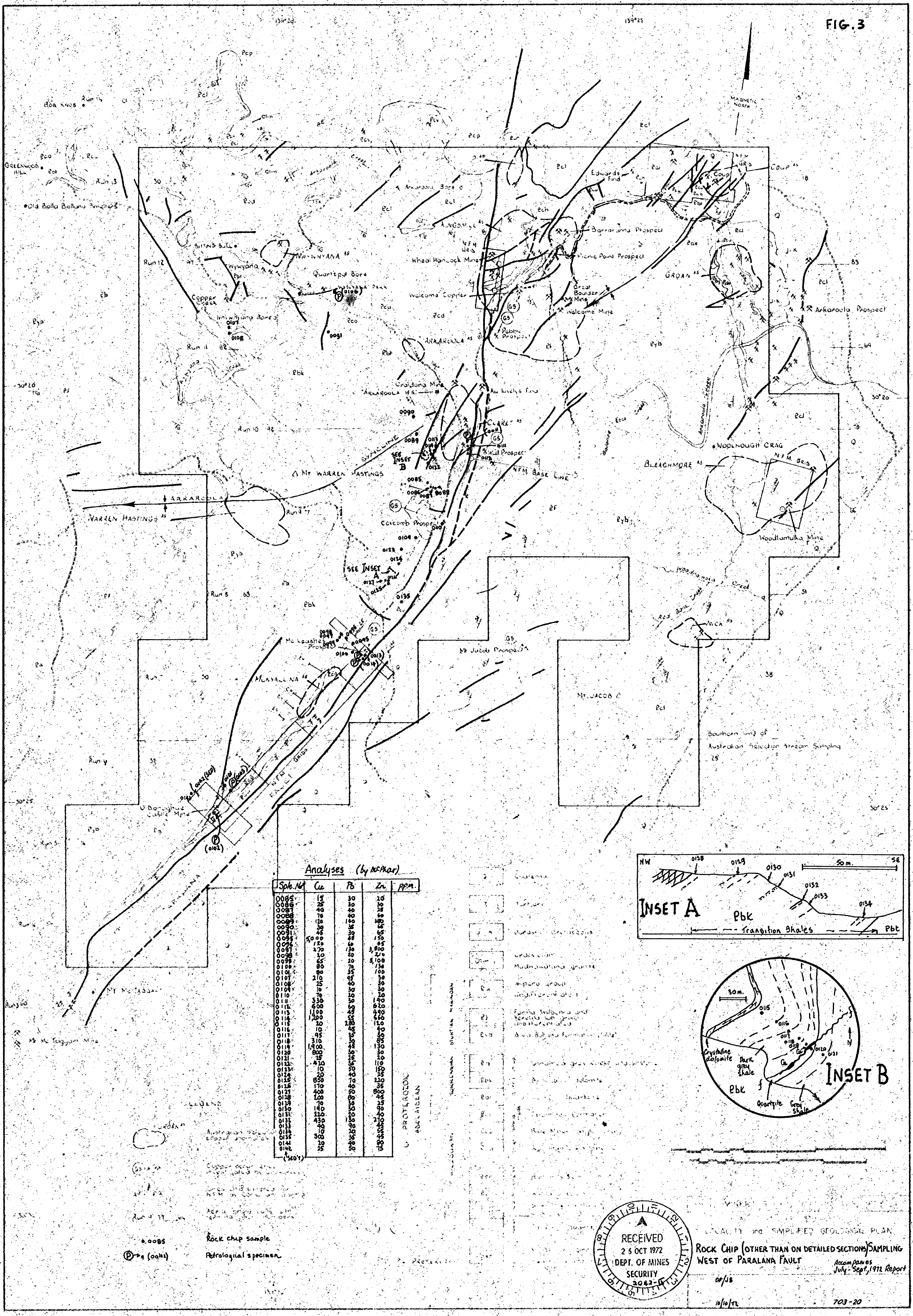
SHELL MINERALS EXPLORATION (AUST) PTY LTD

WOOLTANA J.V.

FIGURE 2

SECTIONS TO ACCOMPANY REPORT FOR QUARTER ENDING 30/6/72

Author J. R. Sise	Approved D.L.F.
Report No	Encl
Date June, 1972	Draw No 703-17



Analyses (by McPhar)

Sple. No.	Cu	Pb	Zn	ppm.
0085	15	30	20	
0086	25	30	30	
0087	40	40	25	
0088	70	40	60	
0089	120	140	380	
0090	30	35	65	
0091	45	30	65	
0095	5,000	45	150	
0096	120	60	45	
0097	270	130	3,800	
0098	20	20	210	
0099	65	20	3,100	
0100	80	70	130	
0101	80	35	100	
0107	210	95	30	
0108	25	40	30	
0109	10	30	30	
0110	70	20	20	
0111	330	30	140	
0112	600	60	620	
0113	1,100	45	490	
0114	1,200	55	660	
0115	20	280	120	
0116	10	45	40	
0117	95	35	30	
0118	310	30	85	
0119	1,900	45	130	
0120	800	30	30	
0121	25	26	20	
0122	420	36	110	
0123	10	50	150	
0124	20	40	25	
0125	850	70	220	
0126	170	40	35	
0127	400	50	800	
0128	200	80	45	
0129	70	30	25	
0130	190	30	90	
0131	220	20	40	
0132	430	130	210	
0133	40	90	45	
0134	10	20	55	
0135	300	35	45	
0141	20	40	80	
0142	25	50	75	

(SED'T)

LOCALITY and SIMPLIFIED GEOLOGICAL PLAN

ROCK CHIP (OTHER THAN ON DETAILED SECTIONS) SAMPLING WEST OF PARALANA FAULT

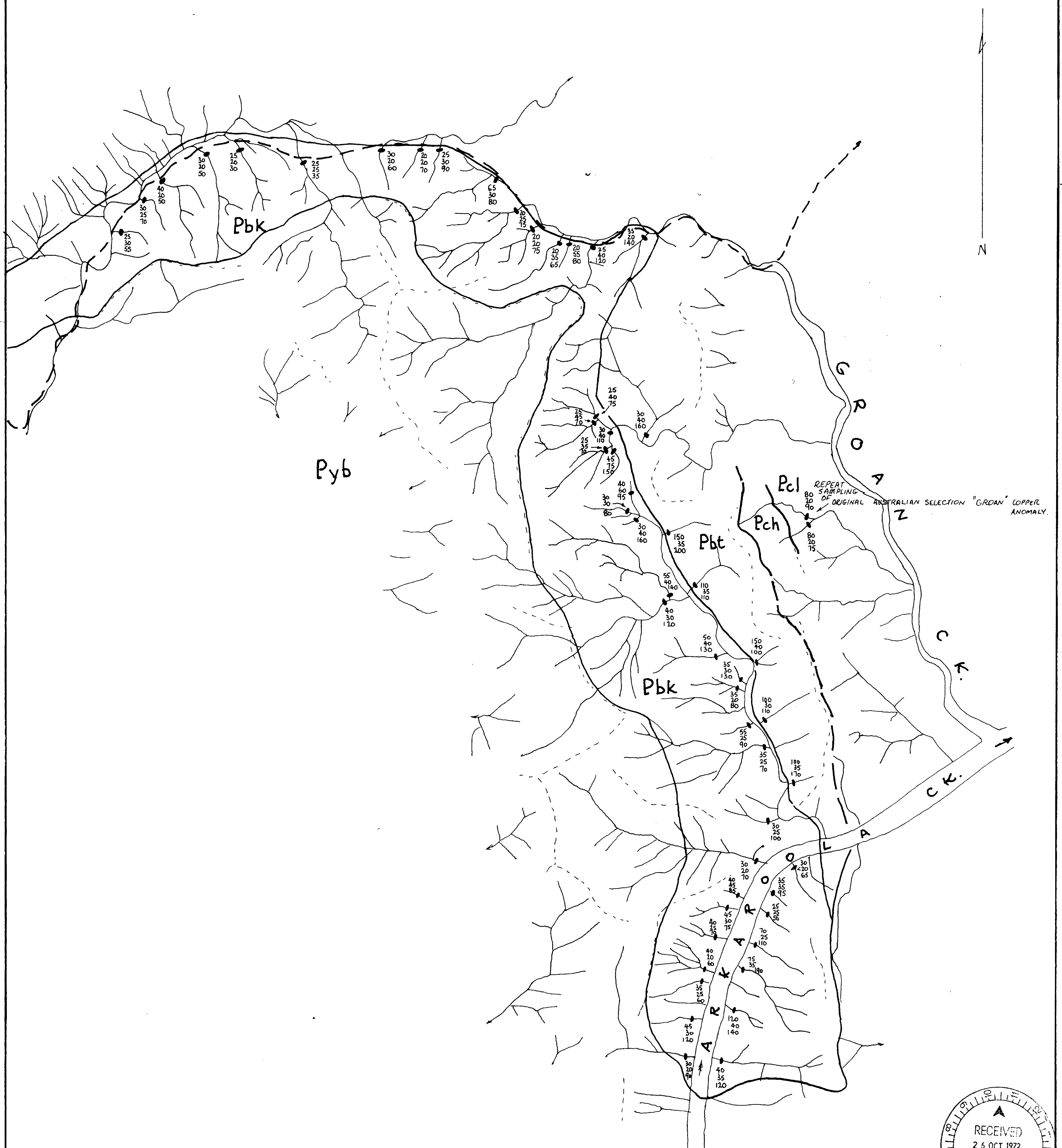
Accompanies July - Sept, 1972 Report

OF/JS

10/10/72

703-20

FIG. 4



Key

ppm in -80# by McPhar.

Cu 20
Pb 40
Zn 160

Stream Sediment Sample Location

FOR GEOLOGICAL LEGEND: REFER TO FIG. 1

1 : 12,000

SHELL MINERALS EXPLORATION (AUST.) PTY. LTD.

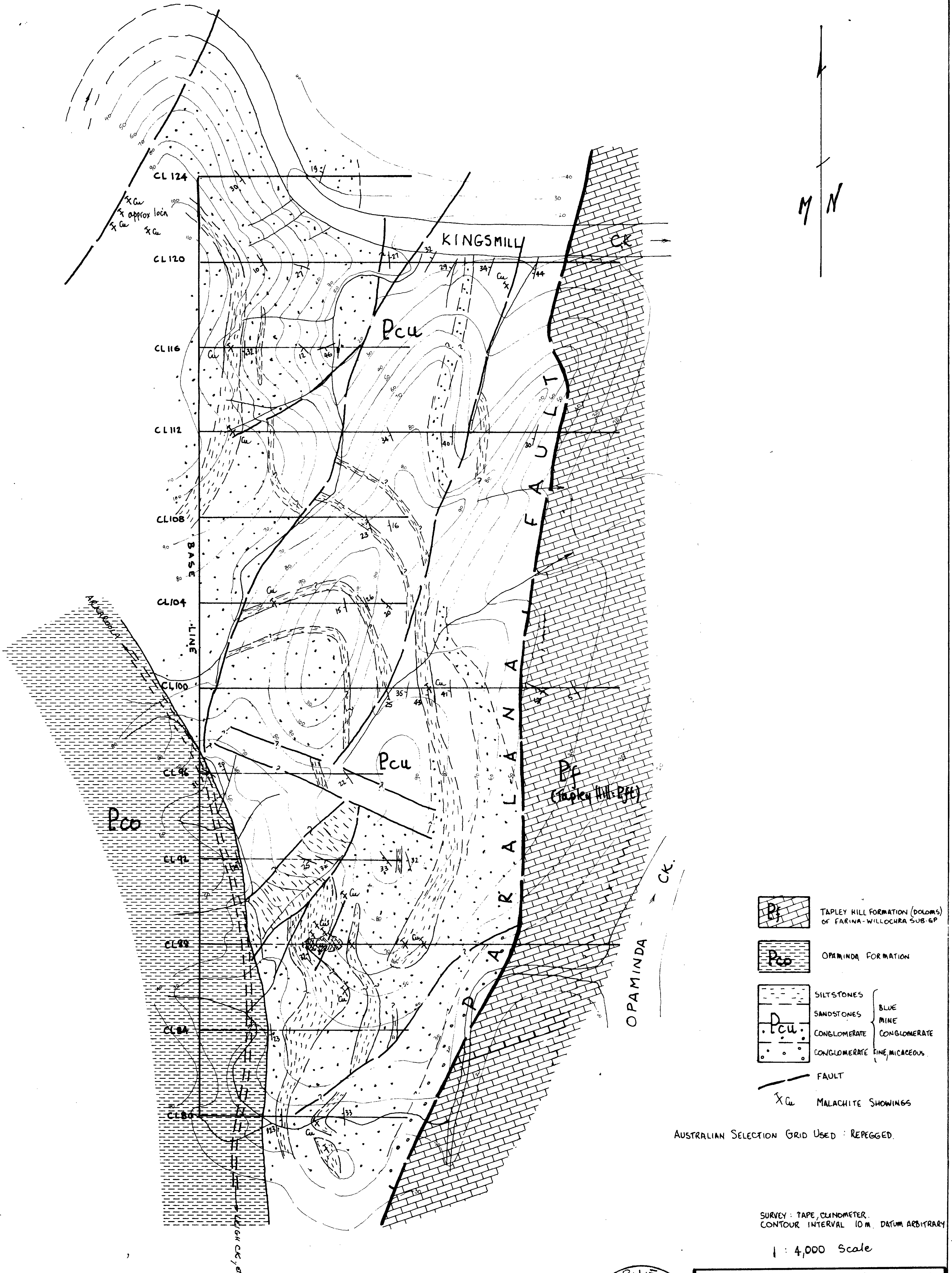
WOOLTANA J.V. SOUTH AUST.

STREAM SEDIMENT SAMPLING WEST OF GROAN CK AND SOUTH OF THE COUP Cu PROSPECT

Accompanies July-Sept, 1972 Report

Author: DF/JS	Approved:
Report No.:	Encl.:
Date: 10.10.72	Draw. No.: 703-21

FIG. 5



SHELL MINERALS EXPLORATION (AUST.) PTY. LTD.	
WOOLTANA J.V. STH. AUST. PRELIMINARY GEOLOGICAL MAP OF "CLARET" Cu PROSPECT NR. ARKAROOLA. Accompanies July-Sept. 1972 REPORT	
Author: DNC/DF	Approved:
Report No.:	Encl.:
Date: 10.10.72	Draw. No.: 703-22