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## EL 351

## MANUNDA CREEK

## FIRST QUARTERLY REPORT TO LICENCE EXPIRY/SURRENDER FOR THE PERIOD 23/8/1977 TO 22/8/1978

Submitted by
Australia – Cities Service, Inc.
1977



**Enquiries:** Customer Services Branch
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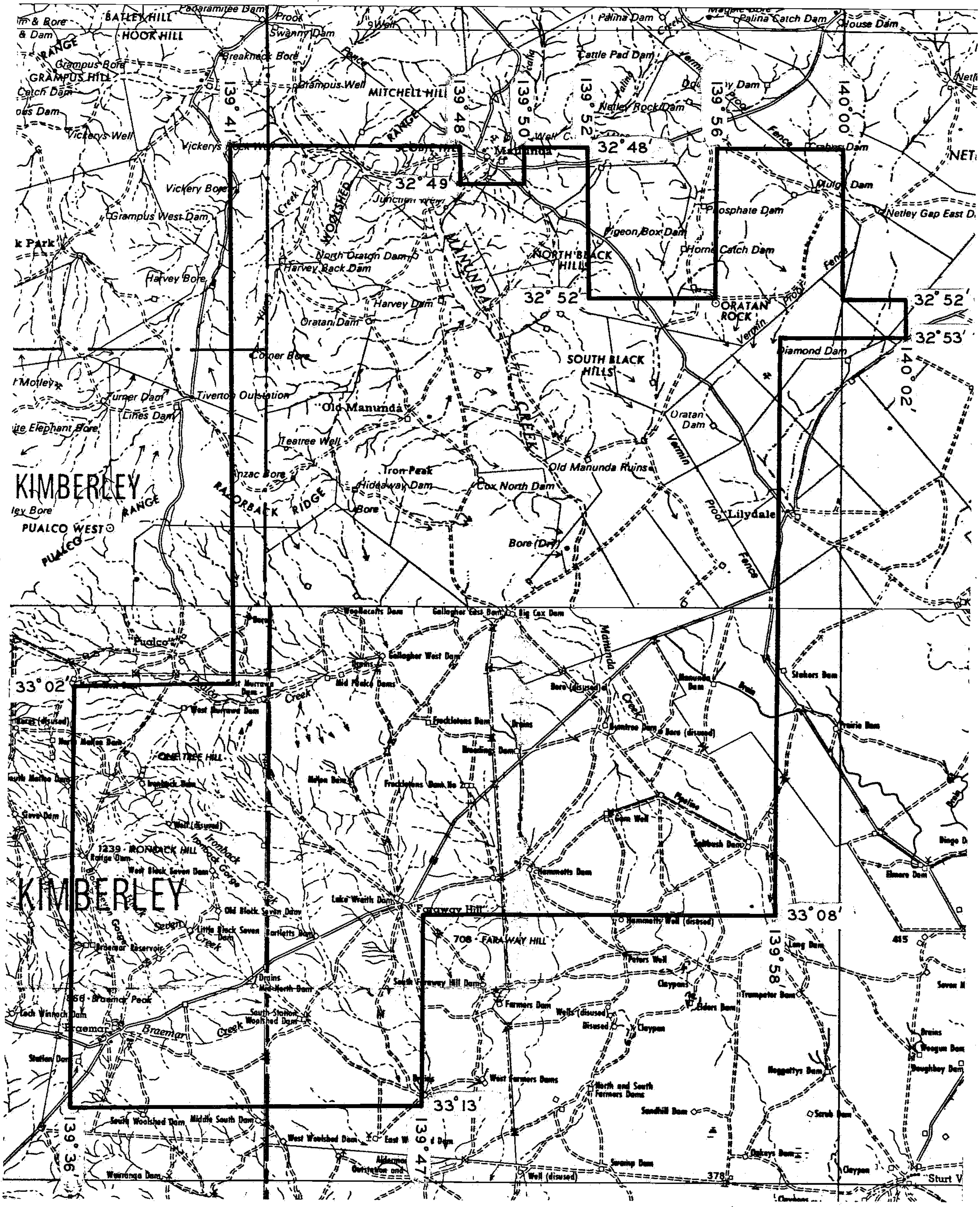
Government of South Australia
Primary Industries and Resources SA

# SCHEDULE A




SCALE 1:250 000

KILOMETRES 5 0 5 10 15 20 25 KILOMETRES

APPLICANT: AUSTRALIA - CITIES SERVICE, INC.

D.M.: 249 / 77 AREA: 1207 Square kilometres

1: 250000 PLANS:

OLARY
CHOWILLA

EXPIRED

LOCALITY: MANUNDA CREEK AREA - APPROX. 100 km EAST OF PETERBOROUGH.

EXPIRY DATE: 22 · 8 · 78 E.L. No.: 351

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**TENEMENT:** EXPLORATION LICENCE NO. 351

**TENEMENT HOLDER:** AUSTRALIAN CITIES SERVICE INCORPORATED

**REPORT:**

DODDS L.R.


| | | | |
|---|---|---|---|
| | | Quarterly Report for Manunda E.L. 351 South Australia | (pgs 3-29) |


**PLANS:**


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QUARTERLY REPORT

for

MANUNDA, E. L. 351,

SOUTH AUSTRALIA


for [signature]

D. H. BUCHHOLZ,

EXPLORATION MANAGER.

[signature]

for: L. R. DODDS,

GEOLOGIST.

AUSTRALIA-CITIES SERVICE, INC.
(INCORPORATED IN THE STATE OF DELAWARE, U.S.A.)
5TH FLR., METROPOLITAN FREEHOLDS BUILDING
151-153 MACQUARIE STREET
SYDNEY, N.S.W. 2000
AUSTRALIA

TELEGRAPHIC ADDRESS:
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December 5, 1977.

The Director of Mines,
P.O. Box 151,
EASTWOOD. 5063.

Dear Sir,

re: Exploration License No. 351 - Manunda

Please find enclosed our first report on exploration in the above License for the first quarterly period ended November 23, 1977.

Our expenditure for the period was:

| | |
|---|---|
| General & Administration | $A33,725.97 |
| Field | 6,236.54 |
| Camp | 1,845.14 |
| Geological | 15,367.04 |
| Geophysical | 965.88 |
| Geochemical | 6,000.97 |
| | $A64,141.50 |

Yours faithfully,

For [signature]

D.H. BUCHHOLZ,
EXPLORATION MANAGER.

kp

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## TOPOGRAPHY AND CLIMATE

Much of the area of E.L. 351, Manunda, consists of the mature dissected slopes of the northeast-southwest trending Mt. Lofty-Olary Ranges. The harder lithologies form fairly prominent hills within the subdued relief of the softer lithologies. To the southeast the Ranges give way to the flat alluvial covered area which is the northern extremity of the Murray Basin.

The climate of the area can be described as arid. An average rainfall of only 6" represents very minor winter rainfall and an unreliable summer rainfall.

The hills generally support only a ground cover of porcupine grass (Triodia irritans) with minor stands of various species of mallee gum, black oak and sandlewood where the water table is nearer the surface. The low flat alluvial and calcrete covered plains and the low undulating hills of the softer lithologies support mainly only the two species of bluebush and saltbush. Larger eucalyptus trees are found along major streams such as Manunda Creek.

## LOCATION AND ACCESS

The 1,207 square kilometre area of E.L. 351, Manunda is located partly on the Olary 1:250,000 map sheet and partly on the Chowilla 1:250,000 in the State of South Australia. The licence area is a rectangular polygon the approximate centre of which lies at 33$^{o}$ 00S, 139$^{o}$ 50'E. The precise area is shown on the Location Map, Figure 1.

Road access to the area is good with the central part of the lease capable of being reached by 4-wheel drive vehicle in about an hour from the township of Yunta on the main Adelaide to Broken Hill Highway. Within the lease, station vehicle tracks of variable quality put all parts of the area within reasonable walking distance.

TENURE

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Australia-Cities Service, Inc., on April 26, 1977 made an initial application for an area of 1,460 square kilometres covering parts of Braemar, Manunda and Lilydale stations on the Olary and Chowilla 1:250,000 map sheets.

The area was subsequently reduced to 1,207 square kilometres because of prior application by Carpentaria Exploration Pty. Ltd. over the portion of the area east of Lilydale HS, and by Sasearch Pty. Ltd. over a small portion in the vicinity of Manunda HS.

The Exploration Licence No. 351 was granted to the company over the 1,207 square kilometres on August 23, 1977 for a period of one year.

PREVIOUS WORK

Previous mapping of the area is available in the form of the Braemar and Manunda 1 mile geological sheets (produced in 1961 and 1960 respectively) and the recently produced (1976, 1977) preliminary editions of the Olary and Chowilla 1:250,000 map sheets produced by the Geological Survey of South Australia.

The available records indicate that although several companies have been active in exploring specific targets there has been no comprehensive mineral exploration carried out throughout the area.

The Mines Department about a quarter of a century ago investigated the economic potential of the ironstone formations particularly on Razorback Ridge where a diamond drilling programme was carried out and an exploratory adit driven. Ore reserves were established as 120 million tons of 26% Fe but the ore was considered too difficult to concentrate economically.

Asarco Australia Pty. Ltd. about 1969 visited and sampled several localities on the Manunda 1 mile map sheet as part of the ground follow up programme of possible hydrothermal zones which they were identifying from air photo interpretations. None were explored in any detail.

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Australian Anglo American carried out a low density stream sediment sampling programme on part of the Braemar 1 mile map sheet including a small portion of the present E.L. in the vicinity of Pualco and Braemar homesteads. The results of the programme gave fairly uniform low values for Cu, Pb, Zn and Mn throughout with no apparent geochemical anomalies.

In 1971 Exoil N.L. held a lease covering a portion of the present E.L. in the vicinity of Faraway Hill and Braemar. Their main activity was to have the aeromagnetic map interpreted as a means to identifing possible alluvial covered intrusions of granite similar to the Anabama Granite. No such structures were identified within the part of the E.L. on the Braemar Map Sheet.

Tricentrol and Mines Exploration spent considerable time and money drilling the Anabama Fault area for uranium. This fault which donwthrows the Adelaidean Sequence to the southeast is associated with a considerable thickening of the Tertiary and Quaternary sequence. The fault cuts across the southeastern corner of E.L. 351 to the south of Faraway Hill.

Rhodes Exploration Pty. Ltd. carried out a stream sediment sampling programme over an area just to the west of E.L. 351 extending into the Orroroo 1:250,000 map sheet. Anomalous copper, lead and zinc (up to 120 ppm, 210 ppm and 200 ppm) were indicated in streams in the vicinity of Grampus Catch Dam and Vickery Well but were apparently not followed up.

## RATIONALE OF SELECTION OF THE MANUNDA AREA

### Structural Consideration

Empirical evidence has accumulated in recent years indicating the importance of the association of major base metal mineralisation with deep persistent crustal fractures, particularly with the intersection zones of two such features. The recognition of such features has been facilitated by the examination of ERTS images of the surface of the earth on which the fractures are visible as linear features which are continuous for a considerable distance. It has also been found that the major crustal fractures are also indicated on regional magnetic maps where they may appear as distinct dislocations and trends in the magnetic structure.

In addition to this evidence there is the further empirical observation that mineral deposits are often closely associated with the justaposition of a magnetic high and magnetic low coupled with such crustal fractures.

It also seems that these relationships hold irrespective of the type of mineralisation or the mode of genesis that has been proposed. Indeed such features may be recognised in association with such diverse types of mineralisation as porphyry coppers, massive sulphide deposits, Mississippi Valley lead-zinc deposits , and with sedimentary copper deposits.

Following the significant discovery of copper at Roxby Downs in South Australia by Western Mining Corporation, the association of this mineralisation with such a justaposed magnetic high/low feature was recognised by our exploration group and a study of such features in South Australia was made. At this time most of the Stuart Shelf, presumably containing the most prospective ground, had already been covered by Exploration Licences by several different companies.

During the study several different linear trends of such structures were observed and considered, but most which had not already been covered by exploration tenure were in the remote northwest of the state and were considered too remote for the initial exploration programme.

A very pronounced and important magnetic structural trend runs from Wallaroo on ~~the~~ Yorke Peninsula east-northeastwards across the state to Broken Hill and beyond. This lineament is associated with known mineralisation: the early copper mines at Wallaroo and Moonta, numerous small copper occurrences within the Burra 1:250,000 map sheet, sub-grade porphyry copper occurrences on the Olary 1:250,000 map sheet, several copper occurrences in Pre-Adelaidean rocks between Mutaroo and Broken Hill and the Broken Hill mineralisation itself.

Another fairly pronounced magnetic structural trend runs north-northwestwards from south of Ballarat in Victoria through the central part of South Australia including the Andamooka 1:250,000 map sheet to the northwestern part of the state.

At the zone of intersection of these two structural trends, lying partly on the Olary 1:250,000 map sheet and partly on the Chowilla 1:250,000 map sheet, there is an association of several justapositioned magnetic highs and magnetic lows of the type described above.

The original application by Australia-Cities Service, Inc. for the Exploration Licence at Manunda was placed so as to cover the area enclosing these structures. The eastern portion of this area was already subject to application by Carpentaria Exploration Pty. Ltd. but the remainder was subsequently granted to this Company and became the Manunda E.L.

## Stratigraphic Considerations

The initial available evidence on the discovery at Roxby Downs suggested that the mineralisation may be of a type similar to the copper mineralisation of the Zambian Copper Belt. A metallogenic analysis of known mineral occurrences in the Torrens, Copley and Parachilna 1:250,000 map sheet areas was made relating known occurrences to their respective stratigraphic units adjusted for equal area of outcrop.

In the Copley and Parachilna areas the most prospective units were parts of the Burra Group and Callanna Beds, while on the Torrens sheet the most prospective units were within the Unberatana Group.

An important feature which Zambian copper deposits have in common with many other sedimentary base metal deposits is their association with a marine marginal sedimentary environment of dolomite, shale and evaporites, very often with the first such sequence in a sedimentary basin. This association with the first marine sequence is thought to be relevant to the differing ages of the most prospective units in different parts of South Australia. Thus it would be suggested that in the Manunda area the Burra Group would be of most interest in respect of exploration for this type of mineralisation.

## OUTLINE OF PROPOSED EXPLORATION PROGRAMME

### Phase I

(a) Reconnaissance Mapping to outline stratigraphy and major structures.

(b) Stratigraphically orientated rock chip sampling programme.

(c) Bio-geochemical orientation programme.

(d) Quartz vein prospecting and geochemical programme.

### Phase II

(a) Detailed mapping of structure and stratigraphic facies changes.

(b) Detailed sampling, gridding and mapping of selected areas.

(c) Detailed mapping of all minor structures including orientation of minor veins in selected areas to identify possible areas of granitic intrusion.

(d) Auger drill programme of rock/soil geochemistry in areas of interest especially those where there is extensive superficial cover or considerable leaching and weathering of the exposed rock.

(e) Ground geophysical surveys in selected areas.

### Phase III

Selection and drilling of targets after consideration of all data.

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## DETAILS OF EXPLORATION PROGRAMME CARRIED OUT

### (a) Reconnaissance Mapping

Previous mapping of the area was already available so the initial part of the programme consisted of several traverses across the stratigraphic sequence in those areas where the structure was less complex and the rock exposure fairly good. This was done to aid identification of units within the less well exposed and more structurally complex parts of the area, to define units within the broad grouping of rock types in mapping units, to check the availability of outcrop and to consider any lithological re-interpretations that might be necessary. A very limited number of rocks were collected and sectioned.

During the initial reconnaissance programme a number of inadequately studied and unmapped minor structural features were observed.

### (b) Stratigraphically Orientated Rock Chip Sampling Programme

This programme was designed to provide chemical parameters to the lithological descriptions of rock units as well as to indicate base metal distribution throughout the sequence.

Samples were collected along two traverses, one to cover the sequence stratigraphically above the Paulco Tillite the other to sample the sequence below the same formation. A sample was collected of each individual distinct rock unit including each thin individual bed or lens of dolomite and ironstone encountered. Interbedded units of greater thickness of apparently uniform lithology were sampled as far as practical at intervals of several hundred metres or so.

The samples were assayed by Semi Quantitative Emission Spectroscopy for 19 elements - potassium, lithium, sodium, cesium, rubidium, magnesium, calcium, barium, strontium, boron, beryllium, manganese, germanium, phosphorus, tellurium, copper, lead, zinc and cadmium.

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(c) Bio-geochemical Orientation Programme

The bio-geochemical samples were collected along the same two traverses used for the rock chip programme. An attempt was made to provide a companion bio-geochemical sample for each rock sample location as well as to cover areas within which rock exposure was lacking.

Preference was given to the larger trees such as Myoporum platycarpum (sandlewood), Casuarina crista (black oak) and several species of mallee gums (Eucalyptus oleosa, E. socialis and E. gracilis) in the minority of locations where these trees were present. The hope was that the root system of the larger trees might penetrate the leached surface material. In most places only either of the two species of bluebush (Kochia pyramidata and K. sedifolia) or saltbush (Atriplex stipitata) were present and these species were sampled.

Samples consisted of several grams of the leaf material of the plant which was packed in a bag, ashed and assayed for copper, lead, zinc and manganese. The washing of the samples was omitted as experience in previous programmes in arid areas had indicated that except for lead there is higher metal concentrations in the plant ash than in the leached top soil and that dilution due to adhering material is a negligible factor.

(d) Quartz Vein Prospecting and Geochemical Programme

A programme of prospecting the often abundant quartz veining throughout the area was undertaken. Samples were collected of all veins which contained vugs or iron oxides which might represent leached base metal mineralisation. The samples were assayed by AAS for copper, lead, zinc, cadmium, manganese and molybdenum.

It has been noted by Mendesohn (1961, P144) that the post mineralisation metamorphic quartz veins which cut the ore formations of the Zambian Copperbelt contain mineralization concentrated into the veins during metamorphism which reflects the mineralisation in the adjacent ore formations. In a highly weathered and leached surface environment such as is present in parts of the Manunda area, mineralization might be better preserved in the quartz veins than in the original ore horizons. Certainly soil and stream sediment geochemical surveys have failed in similar areas in the past and might be expected on chemical grounds to be unsuccessful in a deep leached weathered calcareous environment.

While many of the quartz veins in the Manunda area, especially those that form enechelon sets, are of metamorphic origin; at least some are due to underlying intrusive or crypo-volcanic activity and others may be due to late hydrothermal filling of fracture zones. The precise nature of most of the veins remains to be determined.

(e) Phase II Programme

Two areas were selected on the basis of the results obtained in Phase I of the programme for gridding and rock chip sampling. Samples were collected from the two areas at 50 metre intervals across strike along lines 200 metres apart. Outcrop was sampled where it was available and this was supplemented by auger drill rock sampling at the other locations.

RESULTS OF PHASE II PROGRAMME

Area I - Manunda Copper Mine area - (P. Shinton)

An area 1,400 x 800 metres several kilometers west of Manunda Homestead to cover the Burra Group lithologies and the small copper showing in this area.

The Manunda Copper Mine is situated close to the centre of the Manunda Anticline and within the fairly prospective Burra Group lithologies.

Mineralisation within the area consists of dominantly chrysocolla with minor chalcopyrite and pyrite within quartz veins, which have intruded along the tectonic cleavage. Mineralisation has also invaded the surrounding siltstones to a small degree.

The tectonic strike (shearing) direction is around 045$^{\circ}$ and ranges from fairly subtle generally, to strong near the boulder tillites in the west of the area and around the copper mine.

The Burra Group lithologies from east to west range from:

i. black dolomite (5-10m),

ii. black siltstone (10-15m),

iii. dolomite (20m),

iv. limonite pseudomorphed pyritic siltstone with occasional quartzite and dolomite bands (5-25% limonite cubes)(1.2km),

v. boulder tillites (western margin).

Bedding measurements taken in the area show a strike direction closely parallel to the shearing direction and dipping to the east, generally, on the eastern margin ($45^{o}$-$80^{o}$) and to the west, generally on the western margin ($65^{o}$-$85^{o}$).

Strong jointing directions strike at $305^{o}$ and $325^{o}$.

The geochemical results for the copper mine grid showed that the background results for copper are much higher in the Burra Group sediments than in the Willyerpa Formation sediments whilst lead and zinc appear generally lower. The results also revealed that mineralisation is definitely associated with quartz veining.

A narrow zone of anomalous results occurs north and south of the main shafts (200S 200W) for a total distance of 400 metres. The anomalous copper results range in magnitude from 130ppm-700ppm and lay in an area of outcropping mineralised quartz veins.

The smaller anomalies occurring probably reflect mineralised quartz veins at a shallow depth.

This quartz vein associated mineralisation is of no significance.

<u>Area II - Iron Peak Grid area</u> - (P. Shinton)

An area 1,000 x 4,000 metres just to the south of Old Manunda Homestead to cover base metal mineralisation associated with the Benda Siltstones.

Regional work around the Iron Peak area suggests that a smaller synclinal body occurs to the east of the Harvey Syncline and that a tightly folded anticline occurs between the two. It is assumed that the anticline is faulted since a strong photo lineament occupies the general area.

The limited number of bedding measurements (4) within the area indicate the presence of the anticline. Two measurements on the Harvey Syncline side dip west at $80^{o}$ and $65^{o}$ and two on the Iron Peak Syncline side dip east at $47^{o}$ and $30^{o}$.

The tectonic strike (shearing) within the area is fairly strong and at $045^{o}$, generally.

The lithologies within the area, are the fairly unprospective Willyerpa Formation and are represented by siltstones (limonite pseudomorphed pyrite in part) and hematite magnetite rich siltstone beds. Boulder tillites and finer grained tillites occur in the south of the grid area.

The geochemical results from the Iron Peak grid showed nothing of significance. The results revealed the low and variable copper background of the Willyerpa Formation lithologies along with several 'spot highs'.

The 'spot highs' range in value for copper from 74ppm to 240ppm; well above the background of 25ppm, and always come from samples taken close to quartz veins.

It appears then that the anomalous results reflect mineralisation derived from the numerous quartz veins.

## RESULTS OF PHASE I PROGRAMME

### STRATIGRAPHY

The area consists of folded and lightly metamorphosed sediments of Adelaidean (Late Proterozoic) age. The sequence is divided naturally by unconformable relationships into three groups of rocks; the Burra Group, the Yudnamutana Sub-Group of the Umberatana Group and a sequence which has been correlated with the Willyerpa Formation.

The lowest group, the Burra Group, consists of a littoral association of sediments--siltstones, sandstones, shales, dolomites, black dolomites and an assemblage of evaporitic siltstones and shales many of which are readily identifiable by the numerous pseudomorphs after halite. It is considered that in the Manunda E.L. area a subdivision of the Burra Group into formations would be misleading because of the presence of lateral facies changes, and that this matter should be further investigated.

The Burra Group is overlain unconformably by sediments of the Yudnamutana Sub-Group of the Umberatana Group. This has been subdivided into two formations the Pualco Tillite and the Benda Siltstone. The Pualco Tillite consists of lower and upper tillites and an intermediate coarse sandstone (quartzite) member. The Benda Siltstone consists predominantly of siltstones but is characterised by numerous distinct beds of haematite and magnetite ironstone and ferruginous siltstone. Some of the siltstone is of glacial origin while most is probably of glaciofluvial origin.

The overlying Willyerpa Formation could be divided in this area into two members. The lower part of the formation consists predominantly of siltstones with several thin impure dolomite units and minor sandstone of glacial origin. The upper part of the sequence consists of a fairly uniform sequence of fine grained siltstones and shales. The lower part of the sequence was probably deposited in a shallow marine shelf during fluctuating sea level changes at the end of glaciation, the upper part deposited in a fairly stable shallow basin.

## SUMMARY OF GEOCHEMICAL STRATIGRAPHY

The following is a summary of the geochemical stratigraphy based on an analysis of the stratigraphically orientated rock chip sampling programme and geological information. Further details of the geochemical results is given in the section 'Geochemical Notes - Manunda Rock Sampling'.

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(A) BURRA GROUP

The Burra Group as sampled consists of a sequence of dolomite lenses in a sequence of siltstone, evaporitic siltstones and shales and minor sandstones. The sediments were deposited along the margin of a stable coastal shelf where small evaporitic basins became excluded from the sea by the formation of calcareous reefs probably of biological origin. There is some evidence that indicates that contemporaneous volcanic activity was absent during the deposition of these sediments.

Some minor zinc, lead, copper and cadmium mineralisation is associated with the distinct dolomite lenses and to a lesser extent with some of the evaporitic siltstones.

It is suggested that this minor mineralisation may be similar to that of the Mississippi Valley Lead-Zinc deposits and Zambian Copper deposits in respect of the hypothesis that the precipitation of metal sulphides is due to the organic reduction of sulphates derived from evaporites.

(B) BENDA SILTSTONE

The Benda Siltstone consists predominantly of siltstones but is characterised by numerous distinct beds of hematite and magnetite ironstones and siltstones.

Many of the siltstones are feldspathic and are probably derived from the rapid erosion of granites. A few could be described as tillites while most are probably of glaciofluvial origin. The ironstones were probably formed in small restricted esturine basins within large glaciofluvial outwash deltas.

A distinct zone of higher base metal values is indicated within part of the formation. Several hypotheses could be advanced to account for this, but further work is required to test the continuity along strike.

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(C) WILLYERPA FORMATION

The lower Willyerpa Formation consists of siltstones, several interbedded impure dolomite units and minor sandstone. The upper part of the formation consists of a fairly uniform sequence of fine grained siltstones and shale.

It is suggested that the dolomite units were deposited in shallow water on a marine shelf interrupted by periods of deeper water siltstone deposition due to fluctuating sea level and increased detrital material.

There is also evidence of contemporaneous acid to intermediate volcanism which has contributed to the composition of the sediments.

Higher base metal values are associated with the Willyerpa dolomite units; but, whereas the lead and cadmium contents of some of these dolomites are comparable with those in the Burra Group, the zinc content and particularly the copper content are considerably lower.

GEOCHEMICAL NOTES - MANUNDA ROCK SAMPLING

I - BORON

Geochemistry

In the igneous environment boron is fractionated towards the acid igneous rocks particularly the residual fluids of acid intrusive rocks.

In the mature sedimentary environment boron is transported as the soluble borate ion to the sea where it tends to be adsorbed onto the clay fractions of sediments. The content of boron within the clay fraction of sediments has been observed to increase with increasing distance seaward from a shoreline probably due to the increased adsorption by the clay minerals as their grain size is reduced.

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The clay content of most of the sediment is probably made up of hydrated micas such as illite. In the absence of precise estimations of the total clay content the ratio $^{B}/K$ in argillaceous sediments should also be expected to increase with increasing distance from the shore line.

Boron would also be expected to occur as detrital tourmaline in immature sediments derived from greisens, and as sodium borate in the most soluble portion of evaporite deposits.

### Boron in the Manunda Sequence

The higher boron content (up to 100 ppm B) in the Burra Group, the Lowermost Benda Siltstone and in the Upper Willyerpa (siltstone) Formation corresponds with high potassium in these rocks.

However in the Lower Willyerpa Formation (siltstone and dolomite) several of the siltstones contain up to 100 ppm B with no corresponding increase in Potassium. It is tentatively suggested that this increase in the $^{B}/K$ ratio may reflect fluctuating sea level changes between the deposition of the shallow water dolomites and the deeper water siltstones.

## II - CESIUM AND RUBIDIUM

### Geochemistry

Cesium and rubidium are concentrated in the igneous environment towards rocks of acid character particularly the potassium rich late stage intrusives. The two elements might be expected to accompany potassium metasomatism.

In the sedimentary environment the two elements show strong adsorption onto the clay fraction of argillaceous sediments similar to the behaviour of potassium.

A high cesium or rubidium content of a sediment would indicate the proximity of the environment to the weathering of an acid igneous or hydrothermal source. The Ce/K and Rb/K ratios should also be highest in the vicinity of sediments derived from such a source.

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Cesium and Rubidium in the Manunda Sequence

The results indicate increasing rubidium and cesium (up to 500 ppm compared with a background of 50-100 ppm lower in the sequence) within the siltstones in the Willyerpa Formation. This increase may indicate increasing acid to intermediate volcanism taking place near the source of these sediments or could indicate potassium metasomatism.

The former hypothesis is supported by the few thin sections that have been examined by M. G. Maxwell to date - TSM1, TSM4, TSM6 which were taken from the Willyerpa Formation sediments contain evidence of accompanying volcanism while TSM2, TSM3 taken from the Burra Group sediments do not.

III - LITHIUM

Geochemistry

In the igneous environment lithium is fractionated towards the acid igneous rocks particularly the residual fluids of acid intrusive rocks.

In the sedimentary environment lithium tends to be adsorbed onto the clay fraction of the sediment but not as strongly as sodium or potassium. The small ionic radius of the lithium ion causes a strong polar attraction with water, high solubility and a consequential association with sodium and magnesium such as in evaporites.

Lithium in the Manunda Sequence

The lithium in the Willyerpa Formation shows strong correlation with potassium, cesium and rubidium confirming the proximity of a volcanic source during the deposition of these sediments.

In the Burra Group the lithium has strong correlation with the sodium and in general the association of lithium and sodium strongly correlates with evaporitic siltstones and shales containing pseudomorphs after halite.

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In the Benda Siltstone sequence part of the higher lithium can be correlated with higher potassium while another part can be correlated with the higher sodium, indicating probable variable sources of derivation for the siltstones in this sequence. The former are probably granite derived feldspathic siltstones the latter may have been formed during evaporitic conditions.

## IV - PHOSPHORUS

### Geochemistry

In the igneous environment phosphorus is concentrated in the calc alkaline rocks.

In the sedimentary environment phosphorus is found in higher concentrations in deep water shales, in iron sediments and in biological detritus especially that formed from chitinous shells and bones.

### Phosphorus in the Manunda Sequence

In the Burra Group there is an increase in phosphorus (up to 5,000 ppm) in many of the evaporitic sediments. The dolomites generally contain less than 1,000 ppm P.

Within the Benda Siltstone the siltstones contain about 200 ppm P, while an increased content (up to 2,000 ppm) is recorded in many of the ironstones.

A low background (500 ppm and less) is found throughout the Willyerpa Formation.

## V - MANGANESE

The manganese content of the Benda Siltstone and Willyerpa Formation is very low throughout (100 ppm Mn and less).

In the Burra Group the manganese content is generally higher (200-300 ppm) with two samples containing 1,000 ppm Mn.

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## VI - CALCIUM AND MAGNESIUM

Calcium and magnesium constitute a large portion of the total composition of the dolomites and the dolomitic siltstones within the area. Re-calculation of the two elements as the carbonates, indicates that the dolomites sampled from the Willyerpa Formation are fairly impure containing from 40% to 60% carbonate while those in the Burra Group are generally more pure containing up to 85% carbonate material.

Most of the results show an almost molar equality of magnesium and calcium confirming that dolomite is the principal carbonate present. A slight excess of magnesium over calcium is usual throughout the sequence, but there is a more pronounced excess of magnesium in the evaporites within the Burra Group. Sporadic samples containing an excess of calcium over magnesium are very often found to be due to late stage calcite veining.

A more complete study should be done to determine how much of these elements is present as the carbonate and how much is present as the sulphate. This would be of considerable value especially as regards the evaporite and associated sediments in the Burra Group.

## VII - MERCURY

The mercury content of the rock chip samples is very low probably because of the ease of vapour pressure leaching of mercury in surface layers. There is one dolomite sample (MR 101) from within the Burra Group which contains several times the general background. This higher mercury content does not correspond with any of those samples which contain higher base metal contents.

## VIII - BASE METALS

### Burra Group

Zinc - A general background of zinc up to 300 ppm

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is in sharp contrast to the distinctly zinc mineralised dolomite units and some of the dolomitic siltstones which contain up to 5,000 ppm zinc.

Cadmium - In general cadmium shows sympathetic behavious with zinc in the dolomite units but also increases in the evaporitic siltstones. The ratio ($\frac{Cd}{Zn} \times 10^4$) which has a value of between 20 and 100 in the lower dolomite units increases to the range 100 to 3000 in the evaporitic sequences and some of the adjacent dolomites.

Lead - Several of the dolomite units and a few of the evaporitic siltstones contain up to 300 ppm Pb compared with a general background of less than 50 ppm Pb. The lead results have a general but not precise correlation with the zinc and cadmium results.

Copper - Several units contain up to 500 ppm Cu compared with a background of below 50 ppm Cu. Copper would appear to be correlated best with cadmium rather than with lead or zinc.

The observed characteristic of the mineralisation in the Burra Group suggests a Mississippi Valley type environment with the precipitation of metal sulphides due to the organic reduction of sulphates in the evaporites.

Several of the dolomites contain distinct cubes of diagenetic or epigenetic pyrite and hematite after pyrite. Free elemental sulphur was observed in some of the small vuggy quartz veins.

Benda Siltstone (Braemar Iron Formation)

Zinc - A general background of up to 500 ppm Zn was recorded within the ironstone and argillaceous ironstones. The interbedded siltstones contain more variable amounts of zinc,

. . ./21

ranging from below 300 ppm in the upper and lower parts of the formation to a distinctly anomalous zone containing up to 5000 ppm zinc.

Cadmium - The cadmium results shows a general sympathy with zinc throughout the sequence except that unlike the zinc it prevails in the ironstones rather than the siltstones.

Lead - The lead content in both rock types varies from a background of less than 100 ppm to a high of 1,000 ppm in the siltstones and 500 ppm in the ironstones. The highest values are displaced upwards stratigraphically from the highest zinc values.

Copper - A general background of about 50 ppm copper is present throughout the sequence except for a zone which contains up to 1,000 ppm Cu in the siltstones. This is almost coincident with the highest zinc values except for being displaced slightly lower stratigraphically.

The general overall parallelism of the results for these four metals but the distinctly difference behaviour of each metal with respect to rock type suggests that the four metals were originally precipitated together and perhaps re-distributed during diagenesis or metamorphism.

Several hypotheses could be advancedto explain the presence of this mineralisation but further work is required to examine these units along strike to see whether the mineralisation is stratigraphically continuous or restructed to a zone of increased fracturing and veining.

Willyerpa Formation

There are several of the dolomites which contain increased base metal contents ( up to 200 ppm Cu, 500 ppm Pb, 3,000 ppm Zn and 50 ppm Cd) compared with a general background of 50-100 ppm Cu, 100 ppm Pb, 50 ppm Zn and less the 10 ppm Cd).

It is noteworthy that while the lead and cadmium results of some of these units are comparable with those in the Burra Group the zinc content and particularly the copper content is considerably lower. The iron content (by observation) and the manganese by assay within the dolomites are also much lower in the Willyerpa Formation.

## BIO-GEOCHMISTRY

Initial comparisons of the orientation bio-geochemical sample results with the rock chip samples collected over the same traverses shows little correlation. A more thorough analysis taking into account the species type, soil and water table conditions should be done and might yield useful information.

## QUARTZ VEIN PROGRAMME

The quartz vein sampling and prospecting programme has indicated several areas of quartz veining which contain significant base metal values (see Figure 4 , Manunda, South Australia; Quartz Vein Sample Assay Results). Two of these areas were selected for follow up rock chip and auger rock chip sampling programmes and this is discussed in a later section.

It remains to be determined whether most of these veins are of metamorphic or hydrothermal origin, and precise structural mapping might be required to determine this.

The larger copper mineralised vein discernible for some several hundred metres which lies several kilometres west of Manunda HS is a late stage, low temperature vein occupying a shear zone. The mineralisation probably represents re-distribution from a deeper primary source the nature of which has not been determined.

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## METAMORPHISM

Most of the Proterozoic rocks in the Manunda area have been subjected in varying degrees to low grade metamorphism.

In general the more chemically stable components of the rock, such as quartz and feldspar are not affected by metamorphism but there is widespread re-crystallisation of the clay minerals to sericite and muscovite, often with a distinct preferred metamorphic orientation. Minor amounts of metamorphic biotite and chlorite are present in some of the rocks and re-crystallisation of carbonates is general. Magnetite and minor stilpnomelane are metamorphic components of the ironstones. Some of the rocks have been more completely metamorphosed: the feldspars have been sericitized and the quartz grains re-crystallised.

The metamorphic minerals present indicate that most of the area has experienced low grade greenschist facies metamorphism. Not enough work has been done to determine whether mappable zones of different metamorphic grades can be recognised, but the presence of stilpnomelane is indicative of the quartz-albite-muscovite-chlorite subfacies, while the presence of biotite is indicative of the quartz-albite-epidote-biotite subfacies of the greenschist facies.

## GRANITIC ROCKS

A number of small granitoid masses have been found within various parts of the Adelaidean sequence at Manunda. Their formation predates at least the last phase of metamorphism as they exhibit greenschist facies alteration and reflect the fabric of the enclosing rocks.

An apparently intrusive mass some 10 metres in diameter was found within the meta-siltstone of the Willyerpa Formation in the Harvey Syncline. The granite shows a distinct tectonic foliation parallel to the schistosity of the meta-siltstones and is cut by barren quartz veins younger than the principal foliation.

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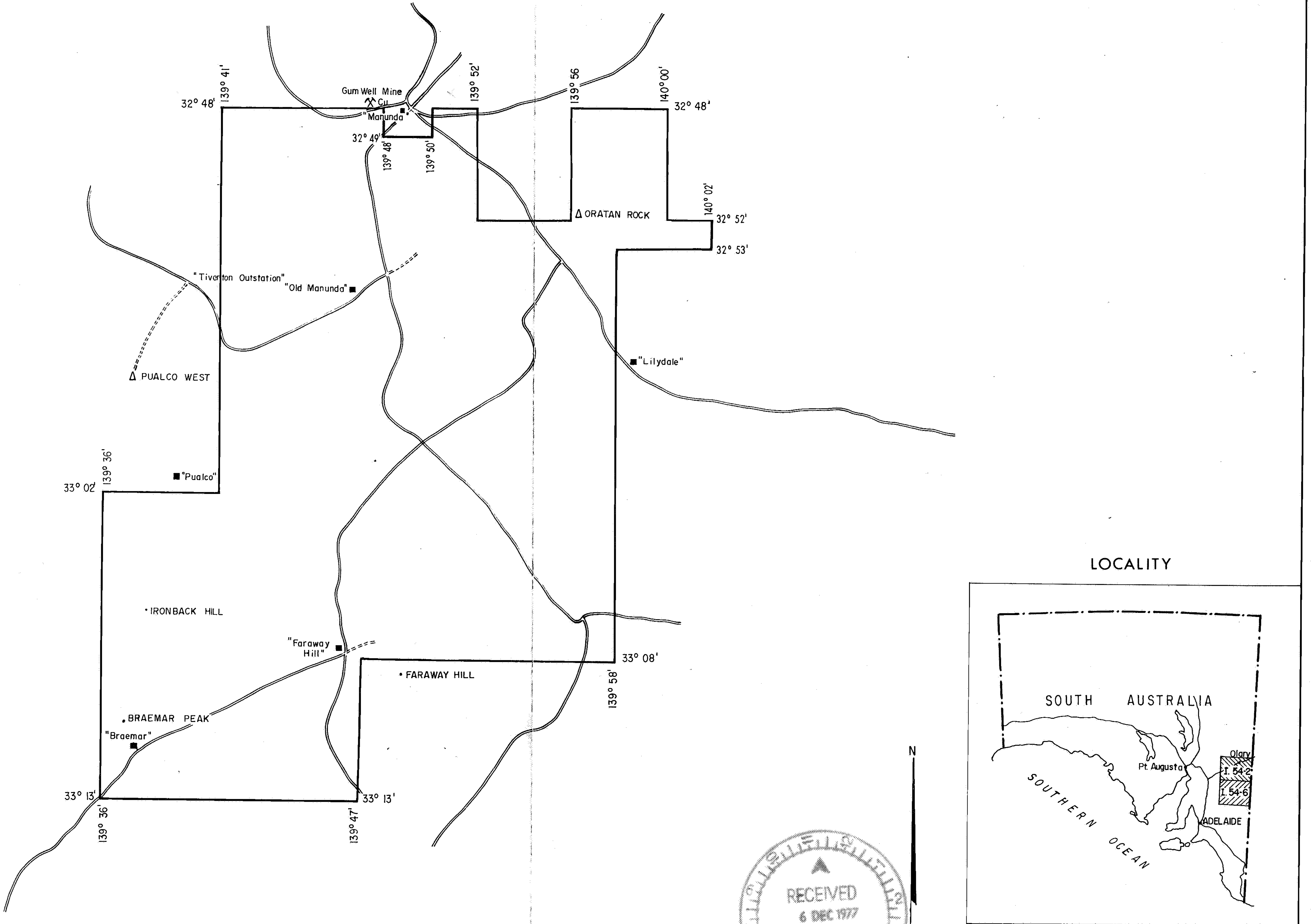
The immediate wall rock sediments are not well exposed but little effect due to any contact metamorphism could be discovered adjacent to the granite mass. The mass is probably of intrusive origin, though the possibility of it being a lone glacial erratic cannot be completely ruled out.

Another interesting locality is close to the nose of the syncline on South Black Hills where a number of small, apparently isolated outcrops of granite occur within highly sheared and poorly exposed Benda Siltstone, a short distance stratigraphically above tillite and ironstone units. One might initially expect that these were glacial erratics except for their unusual distribution. Following from one granite outcrop to the next one can trace out an S shaped structure elongated across the schistosity and across bedding with the hinges axis approximately parallel to the schistosity. A search was also made in the surrounding area confirming that granite outcrops or boulders were absent elsewhere in this part of the sequence. The most likely explanation is that the granite which was subsequently folded and disrupted by tectonic movement during regional folding.

Another area of interest lies between Rasorback Ridge and Teatree Well. Here, within a small concentrated area, the Adelaidean sequence is highly folded, shearing and dislocated to an extent that might be almost described as tectonic brecciation. Several small masses of granite which might originally have been glacial erratics are present.

However of most interest is an outcrop where granite and dolomite are found in contact. Here the granite, a fairly fine grained uniform textured rock consisting of quartz, feldspar and muscovite, extends into the fabric of the dolomite indicating an intrusive relationship. Though the more argillaceous dolomite has not been substantially changed parts of the more pure dolomite have been re-crystallised to a coarse marble fabric. Minor limonite probably after pyrite is present within both rock types as well as along the contact.

LRD/cah






NOTE — Area = 1460 sq. kms.

3104-1

Fig I.

AUSTRALIA-CITIES SERVICE INC.
MINERALS EXPLORATION DEPARTMENT

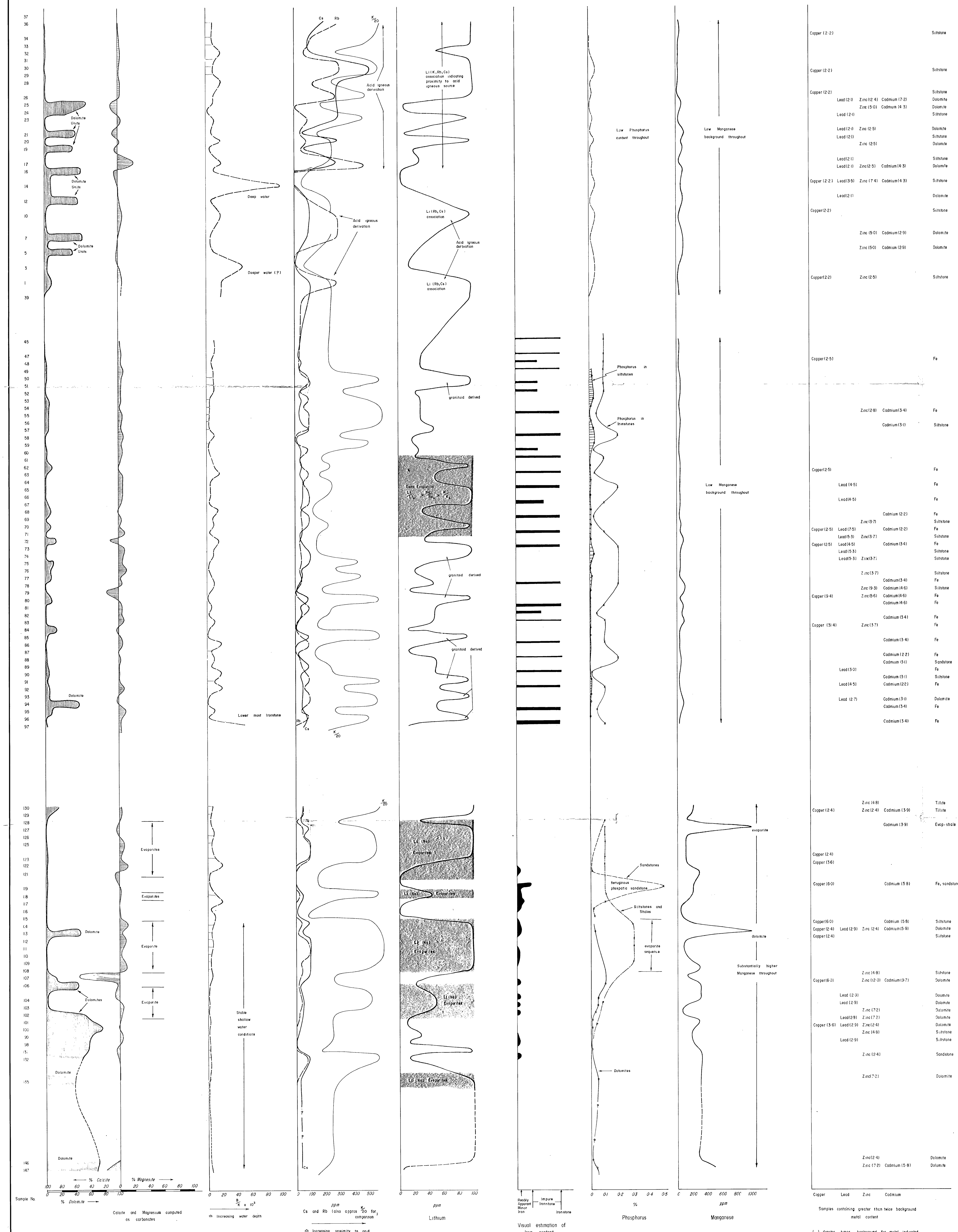
LEASE No. 2
OLARY/CHOWILLA SHEETS
BRAEMAR, MANUNDA AREA

| | | |
|---|---|---|
| SCALE: 250,000 | C.I. | REVISIONS |
| | DATA BY: R. Dodds | |
| DATE: April 1977 | SHEET OF | |
| DRAWN BY: JMR | DRAWING NO. SA. 26 | FILE NO. |




3104-2 Fig 2.

| AUSTRALIA-CITIES SERVICE INC. | | |
|---|---|---|
| MINERALS EXPLORATION DEPARTMENT | | |
| E.L. 351 MANUNDA S.A. MULTIELEMENT STRATIGRAPHIC ORIENTATION SAMPLING PROGRAMME | | |
| SCALE | C.S. | REVISIONS |
| | DATA BY R. DODDS | |
| DATE November 1977 | SHEET OF | |
| DRAWN BY R. GEORGE | DRAWING NO. SA 33 | FILE NO. |




3104-3



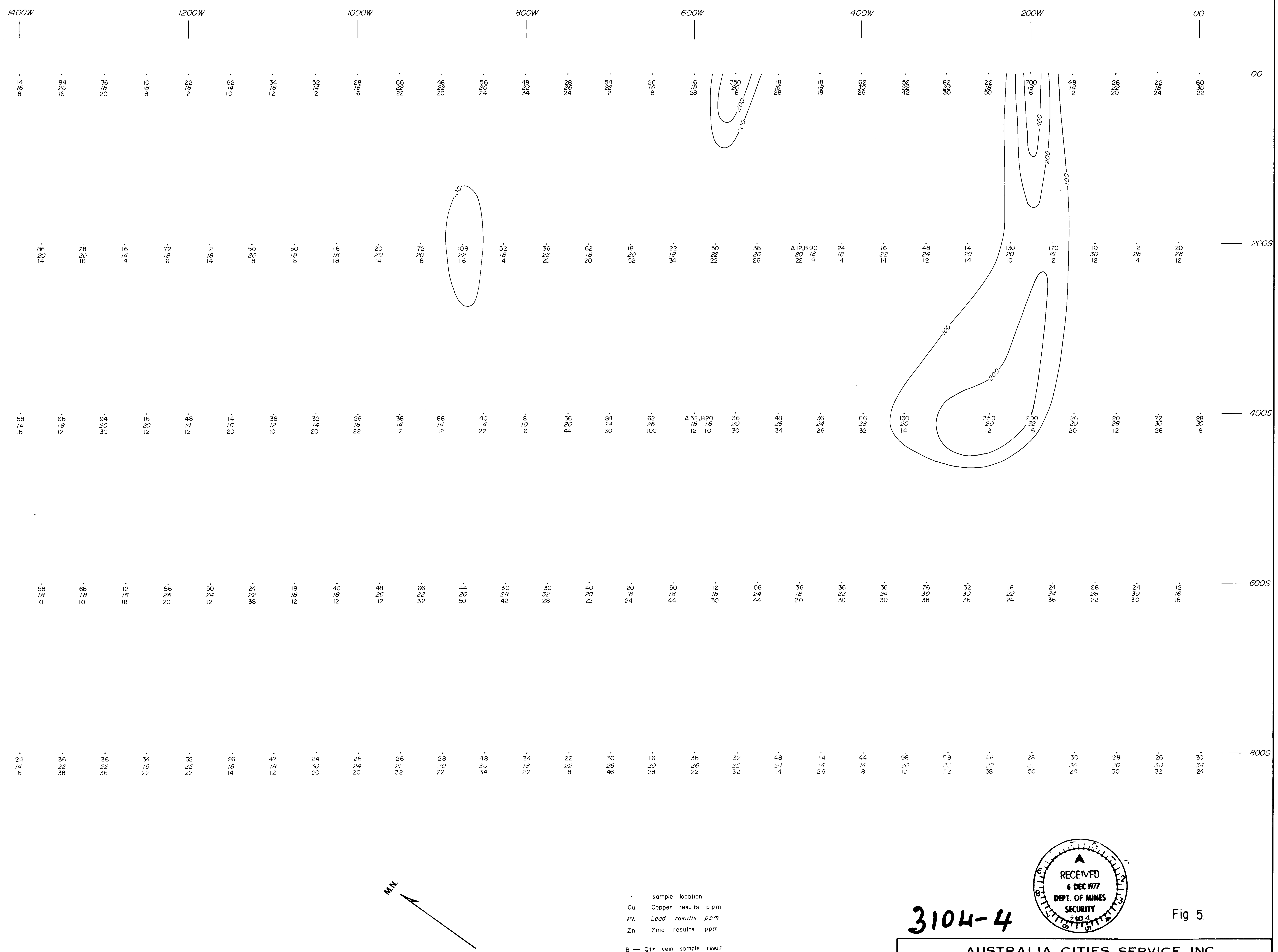
Fig 3.

AUSTRALIA-CITIES SERVICE INC.

MINERALS EXPLORATION DEPARTMENT

## E.L. 351 MANUNDA S.A.
## ILLUSTRATION OF FEATURES OF THE MULTIELEMENT STRATIGRAPHIC SAMPLING PROGRAMME

| | | |
|---|---|---|
| SCALE | C.I. | REVISIONS |
| | DATA BY R DODDS | |
| DATE November 1977 | SHEET OF | |
| DRAWN BY R. GEORGE | DRAWING NO. S.A. 34 | FILE NO. |




3104-4



Fig 5.

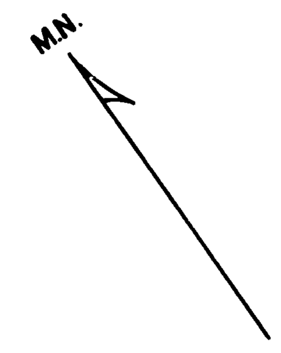
**AUSTRALIA-CITIES SERVICE INC.**

MINERALS EXPLORATION DEPARTMENT

# E.L. 351 MANUNDA S.A.
# COPPER MINE GRID
# AUGER ROCK CHIP GEOCHEMISTRY

| | | |
|---|---|---|
| SCALE 1 : 25,000 | C.I. 100, 200, 400 ppm | REVISIONS |
| | DATA BY D McGraw, R Shinton, D Couchman | |
| DATE SEPTEMBER 1977 | SHEET OF | |
| DRAWN B R GEORGE | DRAWING NO. SA 30 | FILE NO. |


· Sample location
12 Copper results in ppm
28 Lead results in ppm
86 Zinc results in ppm






3104-5

Fig 6

AUSTRALIA-CITIES SERVICE INC

E.L. 351 MANUNDA S.A.
IRON PEAK GRID
AUGER ROCK CHIP GEOCHEMISTRY

| | |
|---|---|
| SCALE 1:5000 | DATA BY P Shinton |
| 1cm = 50m | |
| DATE NOV. 1977 | SHEET OF |
| DRAWN BY R. GEORGE | DRAWING NO S.A. 31 |