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DEPARTMENT OF NATIONAL DEVELOPMENT.

BUREAU OF MINERAL RESOURCES GEOLOGY AND GEOPHYSICS.

RECORDS:

1964/99

REPORT OF THE 1961-62 GEOLOGICAL AND GEOCHEMICAL SURVEY OF THE CAPTAIN'S FLAT AREA, NEW SOUTH WALES

By

W. Oldershaw

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RECORDS 1964/99

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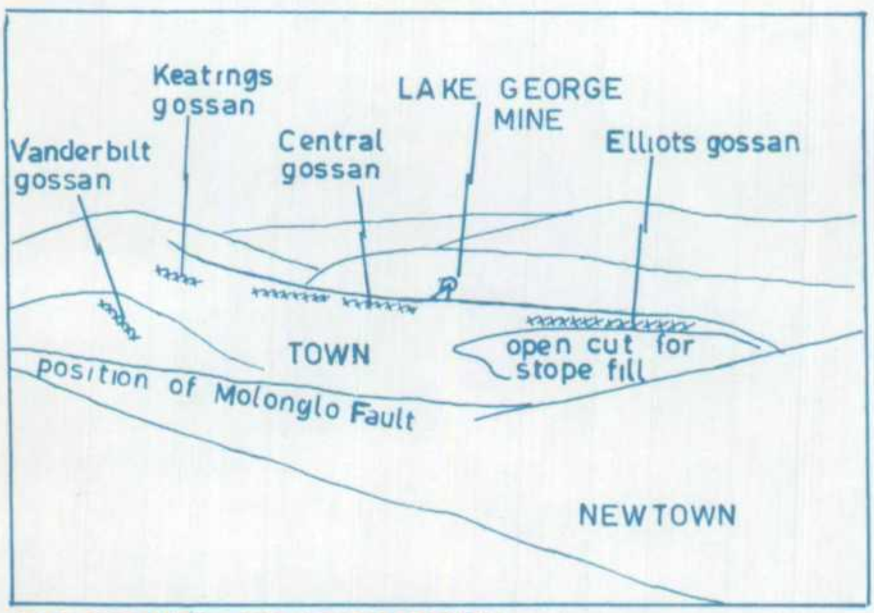
ILLUSTRATIONS

FIG. 1.

G5008

CAPTAINS FLAT, 1961.

THE LINE OF LODE KEATINGS CENTRAL AND ELLIOTS TRENDS 010 DEGREES. VANDERBILTS GOSSAN TRENDS 020 DEGREES.



DESCRIPTION OF PHOTOGRAPH

REPORT OF THE 1961-62 GEOLOGICAL AND GEOCHEMICAL SURVEY OF THE CAPTAINS FLAT AREA, NEW SOUTH WALES.

SUMMARY

In 1961, the zinc-lead-copper orebodies then being worked at Captains Flat by Lake George Mines Pty Ltd were almost exhausted. The New South Wales Geological Survey and the Bureau of Mineral Resources were requested to undertake a search for new orebodies near the Mine. The New South Wales Geological Survey mapped the area south of Captains Flat to Jerangle; their map and report will appear separately. The Bureau of Mineral Resources mapped the area north of Captains Flat to Hoskinstown. This report describes the results of the Bureau of Mineral Resources mapping and the geochemical survey over the area from Hoskinstown to Jerangle.

The worked-out orebodies were localized on the overturned, contorted western limb of a north-plunging synclinorium in Silurian shale, siltstone, and volcanics. The synclinorium extends twelve miles north and six miles south of the Mine, and is one and a half miles wide. It lies in a graben bounded by the Narongo Fault to the west and the Ballallaba Fault to the east. East and west of the graben are horsts of tightly folded Ordovician greywacke and shale intruded by granite.

A geochemical survey was carried out over the Silurian synclinorium and its outliers to the south. Five thousand soil samples were collected at intervals of 600 feet from the "B" horizon of the residual soils. The numerous erosion gullies and creeks of the trellised drainage pattern of the area were used as a natural grid for sampling. One hundred and ten geochemical anomalies were found, ninety three of which overlay one formation - the Copper Creek Shale. Twenty of these anomalies had previously been found, tested, and abandoned by Lake George Mines Pty Ltd.

The sulphide mineralization in the Captains Flat area is mainly confined to three shale beds - the Ordovician Bullongong Shale Member of the Foxlow Beds and the Silurian Copper Creek Shale and Keatings Shale Member of the Kohinoor Volcanics. The Bullongong Shale Member and the Copper Creek Shale contain disseminated sulphides, but the major orebodies are in the Keatings Shale Member. Keatings, Central, and Elliots orebodies occur where the north-trending Main Lode Shear is intersected within Keatings Shale Member by a series of shears trending 020° - the Narongo Shears. Small sulphide masses, with associated

geochemical anomalies, occur where the Copper Creek Shale is sheared or folded. There appears to be a strong structural and stratigraphical control of the sulphide mineralization, and it is possible that the sulphide masses were formed by 'lateral accretion' of disseminated syngenetic sulphides which became mobilized in areas of structural disturbance.

Further work is recommended on the Vanderbilt and Bollard Prospects and on three of the new geochemical anomalies.

INTRODUCTION

Mineralization was discovered at Captains Flat, 35 miles south-east of Canberra, in 1874 and mining began in 1882 (Glasson, 1957). The separate orebodies were mined by different companies until 1928, when mining virtually ceased. Lake George Mines Pty Ltd took over the leases in 1937 and amalgamated the separate mines into one operation (see Fig.1). 3,946,650 tons of ore averaging 6.24% Pb, 10.70% Zn, 18.57% Fe, 0.63% Cu, 1.63 oz Ag and 1.11 dwt Au were mined before the mine closed in March 1962.

In 1961 the Bureau of Mineral Resources and the Geological Survey of New South Wales were requested by Lake George Mines Pty Ltd to undertake a geological survey of the Captains Flat Synclinorium with the object of finding new ore-bodies. An area 34 miles long and 8 miles wide trending 182° * and centred on Captains Flat was mapped (see Fig.2). The Bureau of Mineral Resources mapped the northern part extending from Hoskinstown to a line three miles south of Captains Flat, and the Geological Survey of New South Wales mapped the rest to Jerangle. The Bureau subsequently undertook a geochemical survey of the Captains Flat Synclinorium in both areas.

This Report was compiled from the results of the Bureau surveys, from a study of the available literature, and from information provided by Lake George Mines Pty Ltd. Further details of Lake George Mine and its environs can be found in reports written by the Mine Staff (1953) and K. R. Glasson (1957). The mineragraphy of the orebodies has been described by Edwards (1943) and Edwards & Baker (1953). The search for new orebodies has been described by Debnam (1957), Glasson & Paine (1959), and Paine (1961).

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* Compass Bearings in this Record are True bearings.

PHYSIOGRAPHY

The Captains Flat area is part of the Southern Highlands of New South Wales, and lies on the western slopes of the Great Dividing Range. In general it is an area of rugged relief except for the alluvial flats in the northern part of the Molonglo Valley. The Ordovician horsts to the east and west of the Molonglo valley comprise rugged, deeply dissected, bush-covered country, whereas the Captains Flat Synclinorium consists of low undulating country with mature valleys.

North of Captains Flat the relief is approximately 1600 feet - from 2400 feet above sea level at Carwoola Homestead to 4003 feet above sea level on Foxlow Mountain. South of Captains Flat, in the area mapped by the Geological Survey of New South Wales, the land is higher and more rugged - ranging from 3000 feet above sea level at Narongo Homestead to 4839 feet above sea level on Tumanong Mountain.

The area mapped by both field parties comprises the upper parts of the Molonglo and Queanbeyan river systems. The drainage is structurally controlled. It is influenced in different places and to various degrees by the north-trending Narongo, Lake George, and Ballallaba Faults; north-trending bedding and cleavage; and north-west-trending faults.

GEOLOGICAL MAPPING

Field mapping by Bureau personnel occupied 18 man-months. Those who took part were W. Oldershaw (Party Leader), G.R. Pearson, E.G. Wilson, C.M. Gregory, D.O. Zimmerman, and C.D. Branch. E.K. Carter and D.A. White supervised the mapping and also took part in the field work. Detailed outcrop mapping at 700 feet to the inch (photo-scale) was carried out over the Silurian Synclinorium, but the Ordovician horsts and the granites were only mapped in reconnaissance detail (see Fig.2). The geological map of the area south of Lake George Mine was compiled from detailed mapping and surveys previously made by geologists of Lake George Mine Pty Ltd and from reconnaissance surveys by the Bureau. Some areas were re-mapped in detail by the Bureau.

GEOCHEMICAL SURVEY

Minalization was also sought by reconnaissance geochemical sampling of the residual soils developed on the Captains Flat Synclinorium and outliers of Silurian strata to the south. The residual soil above an orebody, or through which water from an orebody was seeping, would be expected to contain anomalously large amounts of metals such as copper and zinc. The trellised

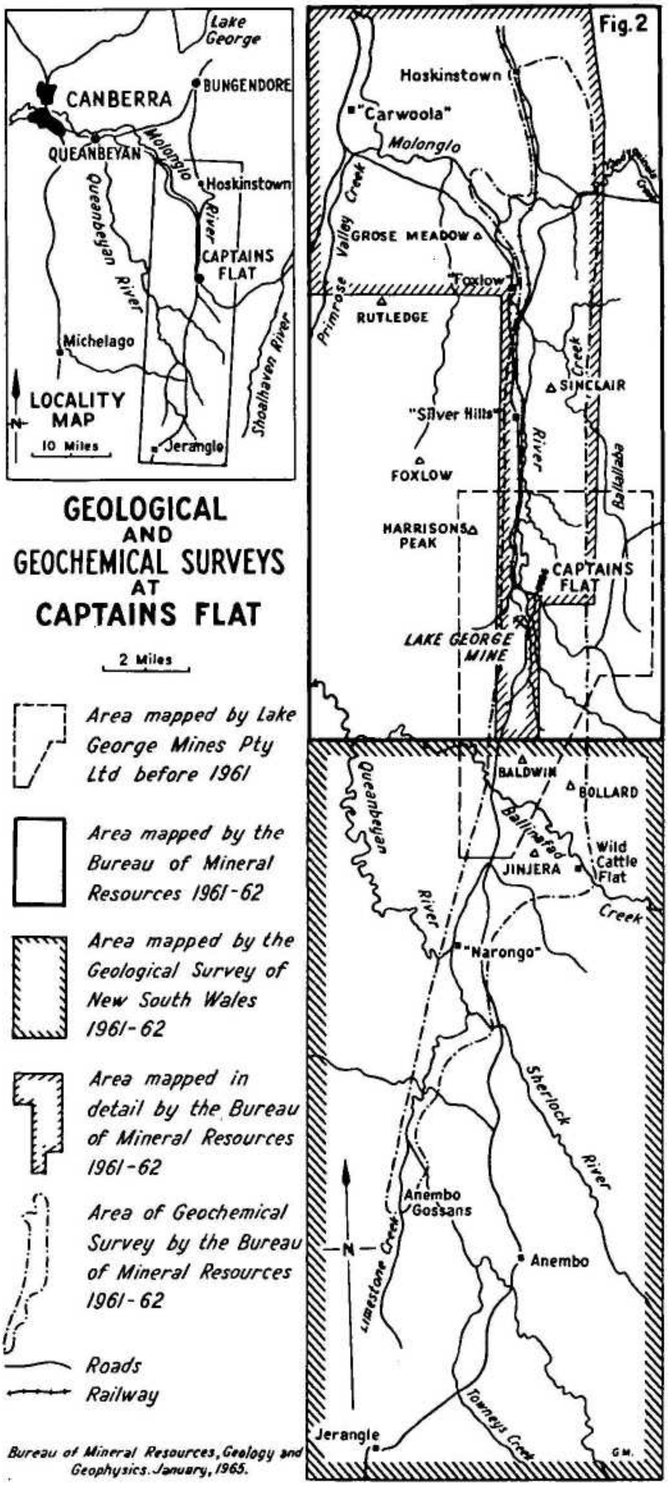
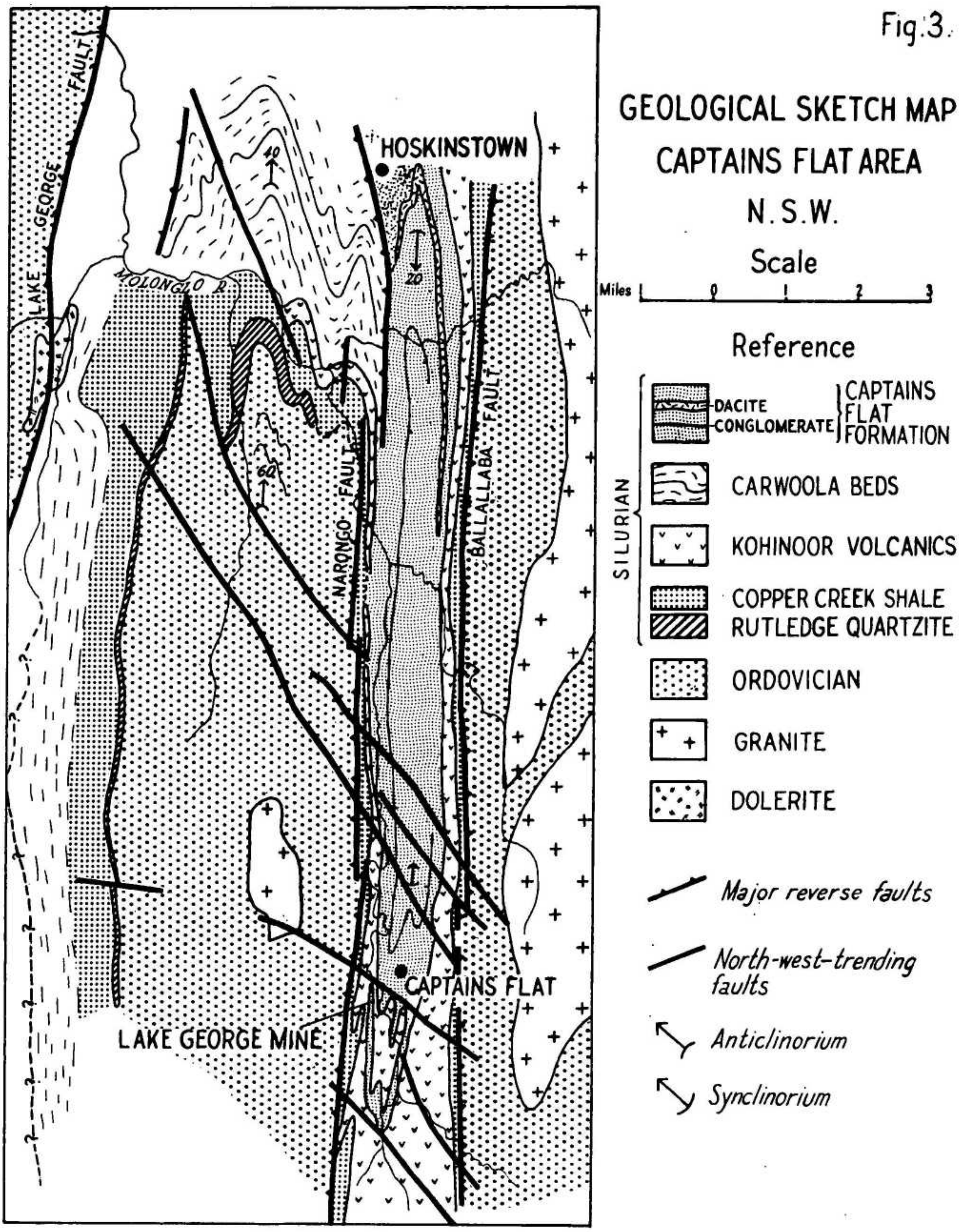
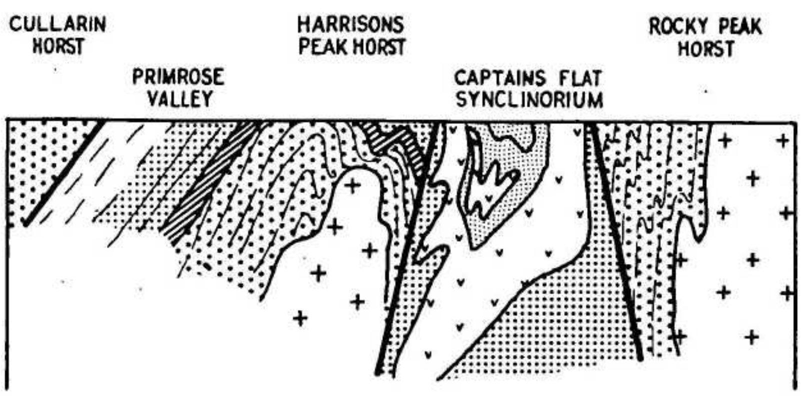


Fig. 2
Lake George
BUNGENDORE
CANBERRA
QUEANBEYAN
Molonglo
Hoskinstown
River
Queanbeyan River
CAPTAINS FLAT
Michelago
Shoalhaven River
LOCALITY MAP
10 Miles
Jerangle
GEOLOGICAL AND GEOCHEMICAL SURVEYS AT CAPTAINS FLAT
2 Miles
Area mapped by Lake George Mines Pty Ltd before 1961
Area mapped by the Bureau of Mineral Resources 1961-62
Area mapped by the Geological Survey of New South Wales 1961-62
Area mapped in detail by the Bureau of Mineral Resources 1961-62
Area of Geochemical Survey by the Bureau of Mineral Resources 1961-62
Roads
Railway
Hoskinstown
"Carwoola"
Molonglo
Primrose Valley Creek
GROSE MEADOW
"Foxlow"
RUTLEDGE
Creek
SINCLAIR
"Silver Hills"
River
Ballallaba
FOXLOW
HARRISONS PEAK
CAPTAINS FLAT
LAKE GEORGE MINE
Queanbeyan River
BALDWIN
BOLLARD
Ballinafad
JINJERA
Wild Cattle Flat
Creek
"Narongo"
Sherlock River
Anembo Gossans
Limestone Creek
N
Anembo
Towneys Creek
Jerangle
G.M.
Bureau of Mineral Resources, Geology and Geophysics. January, 1965.

Fig.3.

GEOLOGICAL SKETCH MAP CAPTAINS FLAT AREA N.S.W.





DIAGRAMMATIC CROSS-SECTION

Bureau of Mineral Resources, Geology and Geophysics *To accompany Record No. 1964/99* 155/16/45 drainage pattern of the area was used as a natural grid pattern for sampling and soil samples were collected at 200-yard intervals with a 3" auger from the "B" horizon of the residual soils along the valley bottoms. Water samples were collected from springs and seepages wherever the water was discoloured, or acid, or contained sulphate, or tasted unusual. Salt encrustations were scraped off and collected, and gossans were sampled.

The geochemical survey began in May 1961 and 5,000 samples were collected. The samples were analysed in the Bureau Laboratory by S. Baker, E.J. Howard, N. Le Roux, and J.R. Beevers.

GENERAL GEOLOGY

INTRODUCTION

The following description of the lithology and distribution of the sediments and intrusives is a brief account of regional characteristics compiled from observations made during the survey and from mine records. More detailed description of lithologies and structures within the mine lease and underground workings can be found in the 'Geology of Australian Ore Deposits' (1953, p.910-920), Edwards & Baker (1954), and Glasson (1957).

ORDOVICIAN

FOXLOW BEDS

The oldest rocks in the Captains Flat Area are the Foxlow Beds, a 7000-foot series of greywacke and shale (see stratigraphic column, Fig.5). The Foxlow Beds crop out in two areas: the Rocky Peak Horst (Fig. 3), where they crop out in a long, narrow strip along the contact of the Rocky Peak Granite; and the Harrisons Peak Horst where they crop out in a north plunging anticlinorium. The lower part is a sequence of alternating greywacke and shale. The beds of greywacke are from 1 to 6 feet thick and decrease in both thickness and frequency upwards. They are dark grey and consist of rounded and subrounded grains of quartz, feldspar, and fragments of shale and siltstone 0.5 to 2 mm. across set in a fine-grained matrix of chlorite, biotite, sericite, quartz, and black iron oxide. The interbedded shales range from dark to light grey and are well cleaved. The middle part of the Foxlow Beds consists of alternating shale and siltstone with a few thin beds of greywacke. The upper part is mainly shale with a few thin siltstone beds. The shale beds range from dark to light grey and from red to yellow. Some are well cleaved. They are mostly from 20 to 100 feet thick, but some are as thin as ⅛th inch. There is some slight metamorphism: many grains of quartz in the greywackes show marginal intergrowth with the groundmass and some shale beds show extensive sericitization.

The upper part of the Foxlow Beds contains a distinctive and extensive marker bed - the Bullongong Shale Member. This is a 200 feet thick graphitic black shale containing disseminated pyrite and chalcopyrite. In places it is highly contorted, sheared, and silicified. Graptolites found in unsheared parts of the shale were identified by Dr. Öpik as Mesograptus multidens, Nemagraptus tricornis, Dicranograptus glingani, Climacograptus bicornis, Leptograptus sp., and Dicellograptus sp. These date the shale as Upper Ordovician, Zones 10 to 12 (Gisbornian). It appears to be the local equivalent of the Acton Shale in Canberra described by Öpik (1958). A similar graptolitic black shale occurring over large parts of New South Wales consists of quartz dust and carbonaceous material and is thought to be a widespread deep-water acid-volcanic dust (Joplin, 1945). The shale is well exposed at Captains Flat Railway Station.

Thin beds of fine-grained white quartzite from 1 - 3 feet thick were found in the Upper Ordovician on the Cullarin Horst in the north-eastern part of the area.

SILURIAN

RUTLEDGE QUARTZITE

The Rutledge Quartzite, maximum thickness 300 feet, consists of beds of white quartzite and conglomeratic quartzite, two to six feet thick, interbedded with thin siltstone. The conglomerate quartzite beds contain rounded cobbles, up to six inches across, of white quartzite, silicified black slate, and silicified grey slate. These were probably derived from the local Upper Ordovician. The quartzite consists of poorly sorted, rounded grains of quartz set in a sparse fine-grained silicified matrix. Many of the quartz grains have sutured margins and irregular outlines suggestive of some resorption and metamorphism. Very few bedding planes, and no current or graded bedding, were found. The quartzite has been tightly folded, extensively sheared, and invaded by veins of white quartz two to six inches wide. Some of the cobbles in the conglomerate have been tectonically elongated parallel to the minor folds. In places the quartzite contains disseminated cubes and irregularly shaped masses of pyrite up to a quarter of an inch across.

During the folding of the Captains Flat Synclinorium the Rutledge Quartzite was broken up into numerous sheared lenses from 150 to 1500 feet long and 3 to 300 feet thick which now crop out along both limbs of the synclinorium and round the nose of the north plunging anticline on Harrisons Peak Horst (Fig.3). The quartzite crops out as narrow rocky ridges and thus forms a useful marker bed. The best exposure is near the Grose Meadow Trig. station.

COPPER CREEK SHALE

The Copper Creek Shale is a 200-300 foot sequence of thin-bedded grey shale, black shale, argillaceous siltstone and thin beds of tuff. The shale beds contain thin lenses, small pods, and disseminated crystals of pyrite and chalcopyrite. Small lenses of limestone less than 100 feet thick and 500 feet long occur near the middle of the formation. Dr. Öpik identified the following fossils from the limestone: *Hercophyllum shearsbyi*, *Entelophyllum yassensis*, *Atrypa* sp., bryozoa, gastropods and crinoid ossicles.

The Copper Creek Shale conformably overlies the Rutledge Quartzite. It is an incompetent formation and was contorted and sheared out into lenses during the folding of the Captains Flat Synclinorium. It now crops out as discontinuous lenses along both limbs of the synclinorium and in two small anticlines south-west of the mine. The best exposures are in Copper Creek at Captains Flat and in a road cutting near Captains Flat Railway Station.

KOHINOOR VOLCANICS

The Kohinoor Volcanics are a well exposed series, 1000-3000 feet thick, of strongly foliated dacite, andesite, and rhyolite flows, beds of tuff, agglomerate, probable ignimbrite, and a few beds of shale. The individual flows and beds are from 30 to 100 feet thick and can rarely be traced for more than a mile. The Kohinoor Volcanics near the mine have been described in great detail by Lyon (1949), and Glasson (1957).

The dacite and rhyolite flows are fine-grained, hard, blue-grey rocks with a well-marked foliation. Most contain corroded phenocrysts (average $\frac{1}{8}$" across) of quartz (some bi-pyramidal), orthoclase, and oligoclase, set in a foliated, fine-grained granular matrix of quartz and plagioclase studded with flakes and felted masses of sericite and chlorite. In places the matrix has a trachytic texture, but mainly it consists of minute interpenetrant granules of quartz and feld-spar - probably devitrified glass. The feldspar phenocrysts and the groundmass are generally quite fresh except along shear-zones, where the feldspars are highly altered and masses of sericite and chlorite have developed.

The crystal tuff consists of granular aggregates of broken crystals of quartz and oligoclase with a sparse interstitial matrix of fine-grained granular quartz and plagioclase - probably a devitrified glass. Some tuff contains fragments of black shale and fine-grained volcanics up to two inches long. One unusual rock, a medium-grained granular quartz-feldspar tuff cropping out near Ballinafad Creek, contains rounded, corroded ovoids of white vein quartz half an inch across.

The agglomerate and ignimbrite are the most striking members of the formation, and constitute the major part of it. They contain twelve-inch bombs (commonly with chilled margins) of pale grey, fine-grained, porphyritic dacite set in a matrix of dark grey, well-foliated porphyritic dacite. The degree of flattening or elongation of these bombs varies with the degree of shearing of the rock. On Mount Baldwin the bombs are rounded and ellipsoidal and are only slightly flattened (see Fig.4). In the road cuttings half a mile north of Lake George Mine the bombs are markedly flattened and elongated parallel to the pronounced vertical north-south shearing.

The Kohinoor Volcanics contain a few minor lenses of shale. The most important, the Keatings Shale Member, 20 to 40 feet thick, is a sheared silicified brown shale near the top of the formation. It has been traced for a mile south of the Mine. The orebodies worked at the Mine occur where mineralized shears trending 020° intersect this sheared and contorted shale.

Disseminated pyrite cubes occur in the marginal zones of the shales in contact with, and within, the Kohinoor Volcanics.

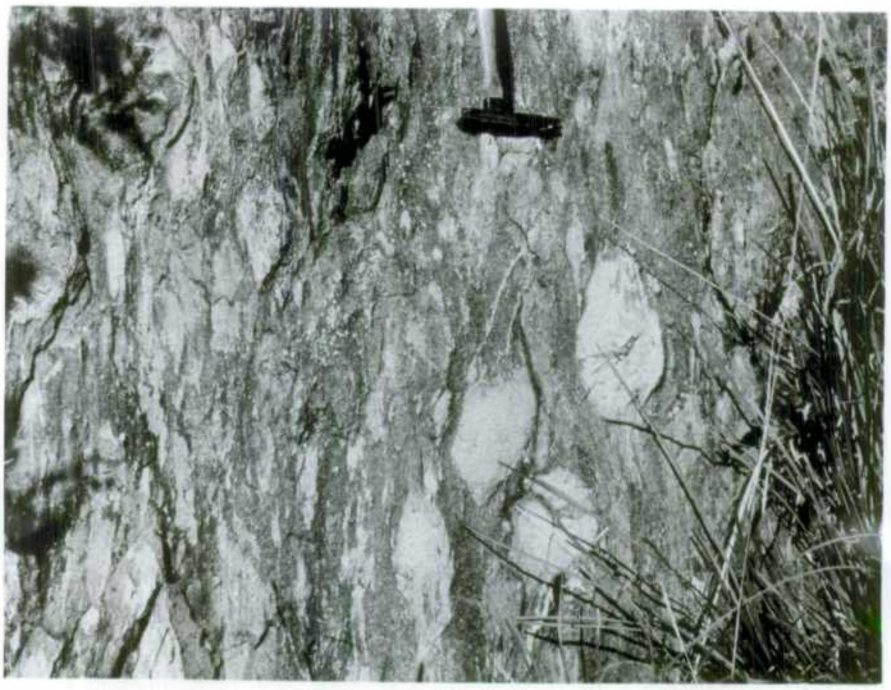
Lenses of red jasper, with a maximum thickness of 40 feet, occur along the contact of the Kohinoor Volcanics and the overlying Captains Flat Formation. They also occur along the contact of the Keatings Shale Member with underlying volcanics. The jasper could be a primary deposit at the base of each major shale sequence, or could be due to secondary silicification of shales underlain by volcanics.

The Kohinoor Volcanics conformably overlie the Copper Creek Shale (Fig.5). They acted as a competent bed during the folding of the Captains Flat Synclinorium. They crop out along both limbs of the synclinorium and extend 15 miles from Mount Baldwin northwards to Hoskinstown (Fig.3). Outliers occur as far south as Jerangle, 20 miles from Captains Flat. However,

Fig. 4.

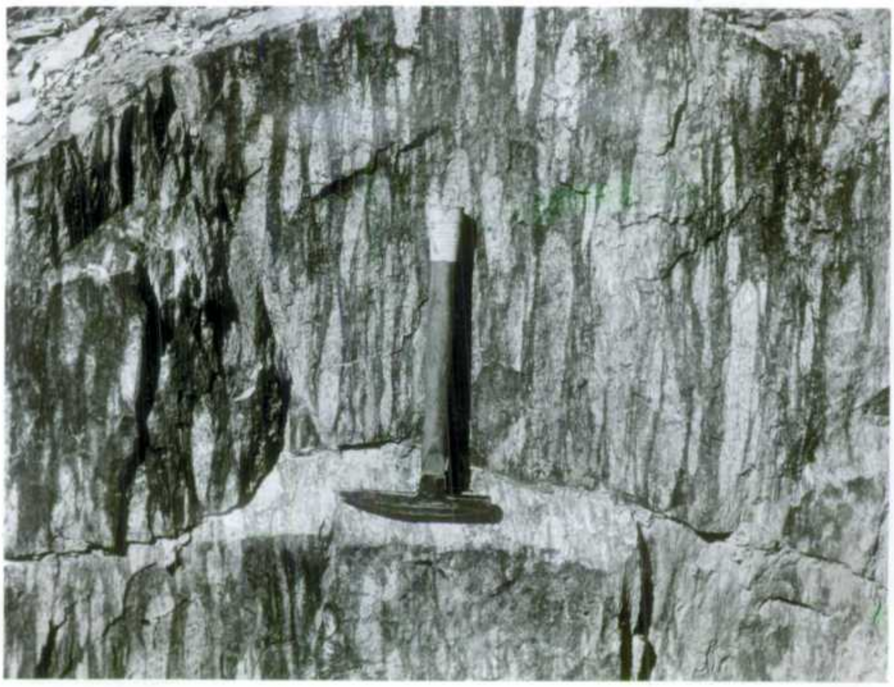
A. 9/5004

Kohinoor Volcanics. Baldwin Mountain. The rock consists of spindle shaped "bombs" of fine-grained dacite set in a matrix of foliated porphyritic dacite.



B. 9/5006

Sheared Kohinoor Volcanics in road cutting half a mile north of Lake George Mine.



C. 9/5005

Highly sheared Kohinoor Volcanics one and a half miles south of Lake George Mine.

the Kohinoor Volcanics above the Keatings Shale Member appear to be restricted to the keel of the synclinorium and crop out only around Vanderbilt Hill and Molonglo Dam.

The marked foliation was thought to be a primary flow or bedding foliation. It is commonly vertical and trends northwards parallel to the axial plane of the synclinorium, even in the keel of the synclinorium where one would expect it to curve around the keel or follow the plunge of the synclinorium. The foliation varies in intensity from place to place, as is shown by the flattening of the bombs (see Fig.4), and is possibly an axial plane foliation or shear.

CARWOOLA BEDS

The Carwoola Beds crop out over an area of 10 square miles around Carwoola Trig. Station, two miles west of Hoskinstown, and extend southwards along Primrose Valley. Exposure is very good around Carwoola Trig. Station where the beds appear to rest directly and conformably on the Kohinoor Volcanics.

The Carwoola Beds consist of over 4,000 feet of well cleaved brown shale, grey siltstone, and rhythmically bedded argillaceous brown sandstone. There are no volcanics. The argillaceous sandstones occur in rhythmically interbedded groups, separated by 300 to 500 feet of shale. Within each group the thin beds of sandstone (two to six inches thick) interbedded with shale increase in thickness upwards to a maximum of three feet in the middle of the group and then decrease upwards (see stratigraphic column Fig.5). Graded bedding was found in the sandstones.

CAPTAINS FLAT FORMATION

The Captains Flat Formation forming the core of the Captains Flat Synclinorium was formerly referred to as the Captains Flat Beds (Glasson, 1957; Paine 1961). It is well exposed on Town Hill at Captains Flat and consists of 2,500 - 4000 feet of well cleaved dark grey shale, reworked lithic tuff, acid crystal tuff, dacite flows, and basalt flows (see stratigraphic column, Fig.5).

The Yandyguinula Member, near the bottom of the formation, is a 200 foot sequence of alternating beds ⅛th inch to 4 inches thick, of grey siltstone and shale. The thicker beds of siltstone contain worm tubes. The member is well exposed along the eastern limb and round the southern keel of the Captains Flat Synclinorium.

The beds of reworked lithic tuff are dark grey coarse-grained rocks consisting of fragments of shale, siltstone, sandstone, fine-grained volcanics and rounded grains of quartz and feldspar set in a matrix of shale and minute grains of quartz and flakes of sericite. Some of the thinner and finer-grained beds show graded bedding. Derived crinoid ossicles and fragments of brachiopods have been found in the fragments of shale and in the matrix.

The middle of the formation contains beds of crystal tuff, a light grey, granular rock composed of grains or crystals of quartz and plagioclase set in a matrix of minute grains of quartz, plagioclase, sericite, epidote, and calcite. Some consist of broken and angular crystals set in a sparse matrix, and are probably direct-fall crystal tuffs. Others consist of rounded crystals set in an abundant matrix, and contain crinoid ossicles; they are probably reworked crystal tuffs.

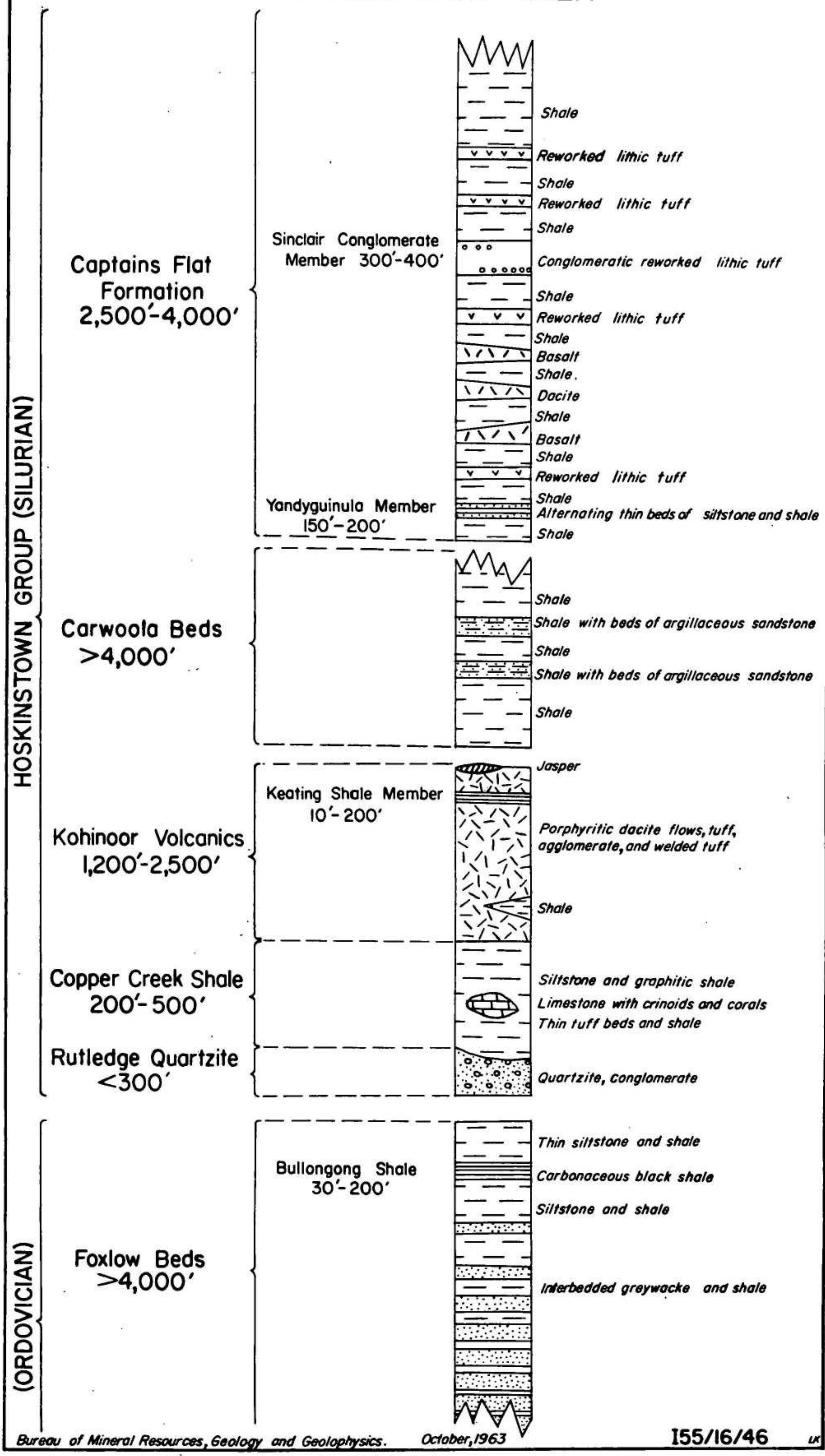
Dacitic flows and tuffs occur in the middle of the Captains Flat Formation and crop out in the northern keel of the Captains Flat Synclinorium (Fig.3). Basalt flows also occur in the middle of the formation and crop out both in the northern and southern keels. A few of the basalt flows have vesicular tops, but none show pillow structures nor are they spilitic. Under the microscope the basalt is seen to consist of a fine-grained mosaic of irregularly-shaped crystals of poorly-twinned plagioclase, actinolite, biotite, minute flakes of sericite and biotite, needles of actinolite and grains of epidote. Small aggregates of calcite crystals may be vesicle fillings.

The Sinclair Conglomerate Member, near the top of the formation, is a 400-foot sequence of interbedded shale and reworked lithic tuff (see stratigraphic column, Fig.5). Some of the beds of reworked lithic tuff contain rounded boulders nearly 18 inches across of white quartzite, dark grey slate, black slate, white dacite, and granite. No current bedding or flute casts, indicative of the direction of deposition, were found. This distinctive member has been traced eight miles along the western limb of the synclinorium and round the northern keel to the eastern limb. It has not been found in the southern keel.

The Captains Flat Formation conformably overlies the Carwoola Beds north of Hoskinstown, but transgresses them to rest on the underlying Kohinoor Volcanics in the Captains Flat Synclinorium. The Captains Flat Formation contains indigenous and derived Silurian brachiopods, corals and crinoids. Dr. Öpik identified the following forms - Favosites gothlandicus, Alveolites, Rugosa, Bryzoa, Lingula, and Rhynchonellids.

STRATIGRAPHIC SUCCESSION IN THE CAPTAINS FLAT AREA

Fig. 5.



To accompany Record. Nº 1964/99

PERMIAN?

Coarse river gravels occur in the upper part of the Molonglo Valley at approximately 3200 feet above sea level around the foot of Mount Bollard. The gravels consist of rounded and sub-rounded cobbles of quartz and quartzite up to six inches across set in a sandy matrix.

A similar gravel, probably of the same age, caps the low hills along the southern side of Yandyguinula Creek, a tributary of the Molonglo. The gravel contains angular blocks of white quartz up to four feet across. The surface layer of the gravel has been cemented to a hard compact billy by secondary silica. The gravels occur about 100 feet above the present floodplain of the Yandyguinula and Molonglo and may be high-level terrace gravels. They are similar to the Fyshwick gravels in the Australian Capital Territory, which have been interpreted as Permian glacials by Öpik (1958).

QUATERNARY

The Molonglo floodplain is covered by gravel, sand, and silt, laid down during the last phase of aggradation. This alluvium was contaminated by lead and zinc and copper bearing tailings swept down from Lake George Mine during a flood in 1942.

The undifferentiated alluvium shown on the map consists of uncontaminated silt, sand, and gravel deposited by the upper Molonglo and by other streams.

IGNEOUS INTRUSIONS

ROCKY PEAK GRANITE

The Rocky Peak Granite occurs on the eastern margin of the Captains Flat area and crops out over an area of at least 50 square miles along the crest of the Great Dividing Range (Fig.3). It was not mapped in detail.

The main rock type is a coarse-grained biotite-oligoclase - microcline granite containing feldspar crystals up to half an inch across. The microcline percentage decreases towards the western contact, where the marginal rock is a medium-grained granodiorite. There is a well marked marginal foliation; the xenoliths, biotite flakes, and hornblende crystals are streaked out into vertical planes trending parallel to the contact.

Numerous small pods of medium-grained hornblende-diorite (mapped as amphibolite) composed of interlocking crystals of plagioclase and actinolite crop out along the western margin of the granite. It is possible that they are a contaminated marginal phase of the granite.

HARRISONS PEAK GRANITE

The Harrisons Peak Granite crops out over an oval area of two square miles, two miles north-west of Lake George Mine. It is generally a homogeneous, non-foliated, medium-grained, grey granite with one eighth to one quarter inch feldspar phenocrysts. There are no veins of pegmatite, aplite, greisen, or quartz.

AMPHIBOLITE

Most of the amphibolite masses occur along the western margin of the Rocky Peak Granite, and have already been mentioned. However, one small amphibolite mass occurs in the Captains Flat Formation on the banks of Ballallaba Creek. It is a concordant, lenticular intrusion 2700 feet long from north to south and 300 feet wide. It is medium-grained, granular, greenish rock, pegmatitic in places, with crystals of hornblende a quarter inch long. The overlying soils contain anomalous amounts of copper ranging up to 160 ppm (eight times background), and a specimen of the amphibolite contains 200 ppm. Further sampling showed the anomaly to be restricted to a small area, and to have no values over 200 ppm.

DOLERITE

Several dykes and one big lens of dolerite occur in the area. The dolerite dykes were found cutting the Kohinoor Volcanics near Captains Flat. Most of them trend north and were emplaced along the strike of the foliation; one near the Foxlow gold mines contains disseminated pyrite.

One dyke near the mine has an anomalous north-westerly trend parallel to the Molonglo Fault. This dyke has been intersected in the mine workings, where it was found to be displaced by the shearing along the lode channel and to be partly mineralized (Glasson, 1957, p.35).

A north-trending lens of dolerite, ranging to gabbro in places, crops out over an area of two miles by one quarter mile in Primrose Valley. It occurs along the Lake George Fault and has been cut by numerous shear zones.

Under the microscope the dolerites are seen to consist of lath-shaped plagioclase set in irregularly shaped crystals of augite. The minerals are highly altered. The plagioclase has been saussuritized, and fringes of actinolite occur along the margins and in the cracks in the augite. Skeletal crystals of ilmenite and granular epidote are abundant.

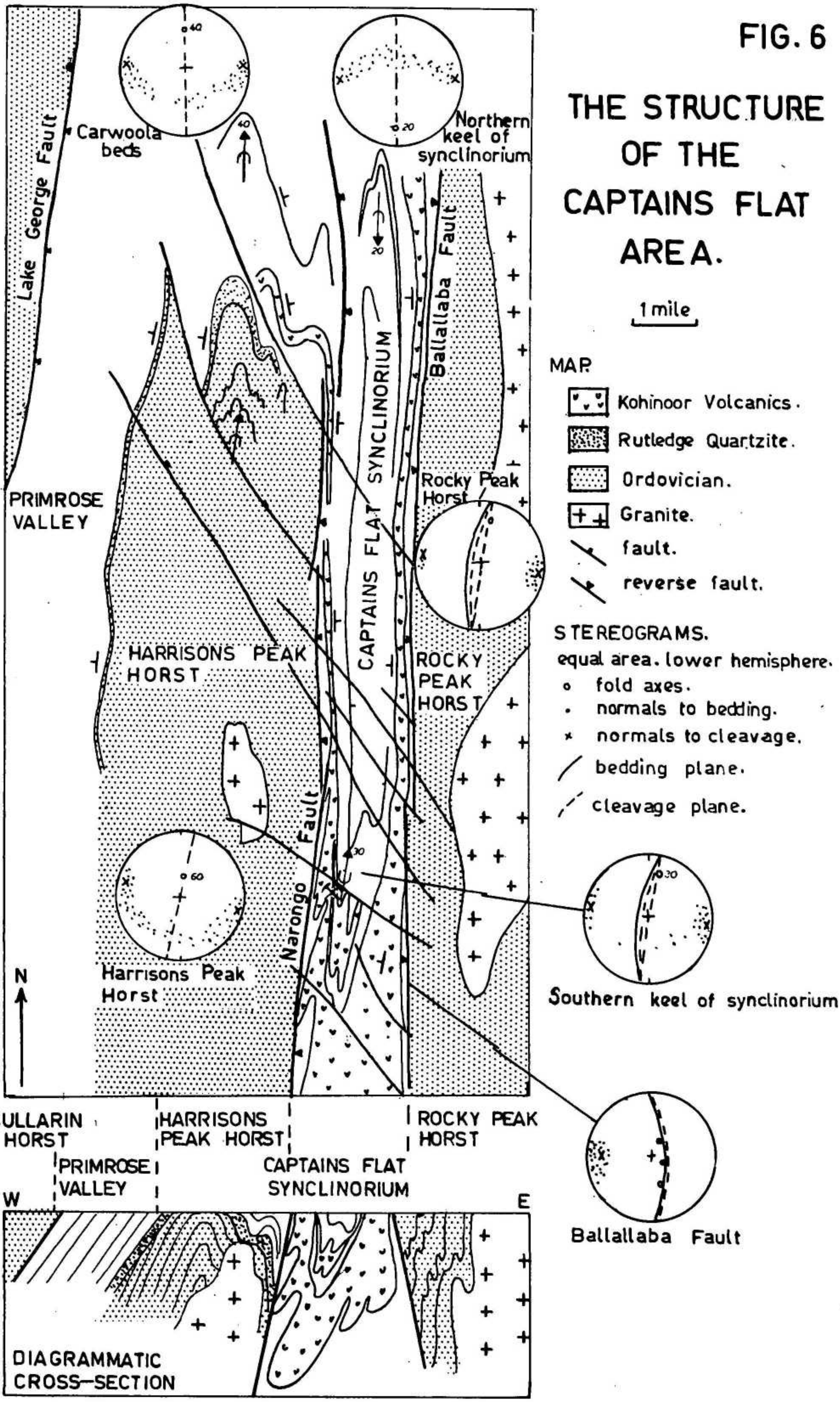


FIG. 6

THE STRUCTURE OF THE CAPTAINS FLAT AREA.

Bureau of Mineral Resources, Geology and Geophysics To accompany Record Nº 1964/99

STRUCTURE

INTRODUCTION

The Captains Flat Area consists of a north-trending synclinorium of Silurian strata in a narrow graben bounded to the east and west by two horsts of contorted Ordovician meta-sediments invaded by granite (see Fig. 3 and 6).

The major structural elements - faults, shear zones, fold axes, and cleavage - trend north. The area was folded around north-trending axes at the end of the Ordovician (Benambran Orogeny). At the end of the Silurian the area was again folded around north-trending axes (Bowning Orogeny) which almost coincide with the earlier fold axes. During this later and more intense period of deformation, the area was broken up by north-trending reverse faults. Still later movements disrupted the area along northwest-trending faults.

BENAMBRAN FOLDING

The Ordovician strata on the Rocky Peak and Harrisons Peak horsts were not mapped in detail. They contain few marker horizons and therefore little of the structure could be deciphered.

The evidence for Benambran folding in the area consists of (a), the slight difference in trend between the fold axes in the Ordovician strata and those in the Silurian strata in the northern part of the Harrisons Peak Horst, (b), the period of non-deposition, or erosion, in Lower Silurian times, and (c), the presence of cobbles of Ordovician slate and quartzite in the conglomerate at the base of the Wenlockian strata.

There are a few marker horizons in the Upper Ordovician strata in the northern part of the Harrisons Peak Horst. The Bullongong Shale Member and several greywacke beds can be traced for a mile or so and some of the structure can be deciphered. The fold axes plunge at 60° to 010° and the cleavage trends 010°; whereas the fold axes in the overlying Silurian to the north plunge at 40° to 360° and the cleavage trends 360° (see stereograms on Fig.6).

BOWNING OROGENY

At the end of the Silurian, the previously folded Ordovician and the overlying Silurian were folded around north-trending axes and were faulted into horsts and graben.

The major structure in the area is the Captains Flat Synclinorium, 20 miles long and two miles wide. It plunges gently northwards, but there are a few minor reversals in plunge and changes in trend. Near Lake George Mine the synclinorium plunges at 20-30° to 010°, north of the mine it is sub-horizontal and trends 360°, the plunge reverses to 20° to 180° south of Hoskinstown and reverses again to 20° to 340° to the north. The synclinorium is bounded to the east by the Rocky Peak Horst and to the west by the Harrisons Peak Horst.

The Rocky Peak Horst

The Rocky Peak Horst consists of isoclinally folded Ordovician micaceous siltstone and shale invaded by a large granite mass. The bedding, cleavage and fold axes trend north parallel to the contact of the Rocky Peak Granite which forms the core of the horst. There are two sets of isoclinal folds (see stereogram on Fig.6) one set plunging north at 60°, the other plunging south at 40°. In places an early cleavage foliation, probably Benambran, has been isoclinally folded. Crinkle jointing (herringbone or chevron structures) with north-westerly "S" planes parallel to the north-west faults occurs in places.

Harrisons Peak Horst

The northern part of the Harrisons Peak Horst consists of an anticlinorium of Ordovician greywacke and shale plunging at 60° to 010°, overlain by folded Rutledge Quartzite, Kohinoor Volcanics and Carwoola Beds plunging at 40° to 360°, (see Fig.6). No refolding of the Benambran folds was found; only the slight difference in trend was noted.

The Captains Flat Synclinorium

The synclinorium was folded twice, and owing to the different competencies of the different strata, it folded disharmonically.

The Kohinoor Volcanics and the Carwoola Beds were gently folded and in places the Carwoola Beds were stripped off by erosion before the Captains Flat Formation was deposited. There was some differential slip along the Keatings Shale Member during the final folding. The strata above Keatings Shale were folded into a simple twin-keel structure, whereas the strata below were folded into one major asymmetric keel with numerous minor folds and dragfolds on both limbs (see Figs. 7a and 7d).

The twin-keel structure consists of the contiguous Dam and Newtown Hill synclines separated by the Vanderbilt Anticline (see Fig. 7a). North of the mine the strata trend north and there are minor reversals of plunge. The twin keels re-appear south of Hoskinstown, where they plunge south at 20° to 180°. North of Hoskinstown they plunge north at 20° to 340°.

The Kohinoor Volcanics below Keatings Shale were folded and thickened into one major keel which, on the golf course four miles south of Captains Flat, plunges at 20° to 010°. This syncline is flanked to the west by numerous smaller folds and dragfolds which plunge north at 20° to 010° (see Hickey, Wilkins, and Yorkdale anticlines on Fig. 7a). The Hickey Anticline contains a core of probable Ordovician black slate overlain by sheared remnants of the Rutledge Quartzite. The keel of Kohinoor Volcanics is margined to the east by a complex of north-plunging folds containing Copper Creek Shale, Rutledge Quartzite, and probable Ordovician black slate, which are exposed on Bollard Mountain.

During the later stages of the folding, the disharmonically folded sequence of incompetent shales and competent volcanics and quartzites was broken up along north-trending faults and shears which developed along the shale beds and the axial planes (Fig.7b). The western limb was overturned to the east; the axial planes and the strata dip steeply westwards at 70 - 80°.

Possibly the first shear to develop was the Main Lode Shear within the Keatings Shale Member. The disharmonic folding of the overlying and underlying competent volcanics resulted in extensive slipping and shearing along the shale bed between them. There has been a displacement of 120 feet east block north along this shear-zone.

Glasson (1957) regards the Waterfall Fault along the western margin of the east limb of the synclinorium as the most important fault in the area (Fig.7b). This fault has little surface expression in the form of breccias, shearing, or quartz veins, except in its southern part, but it forms a zone of weakness which has been etched out by erosion. The whole of the western limb of this part of the synclinorium appears to have been thrust upwards and eastwards along this fault. Later overthrusting affected only the western limb, which over-rode the eastern limb. The eastern limb is relatively little sheared, and is not plicated like the western limb; it does not appear to be a favourable locus for mineralization, except farther south in the contorted quartzites of the Bollard area.

The Dam Shear is a mineralized shear along the axial plane of the Vanderbilt Anticline. It is well exposed in the Molonglo at the foot of the dam wall, but to the south it is covered by tailings.

Forsters and Vanderbilts shears are two prominent members of a series of shears - the Narongo Shears - which diverge eastwards from the Narongo Fault. Close to the fault they trend 040°, but farther eastwards, near the Main Lode Shear, their trend changes to 020°. The Vanderbilt Shear trends to the Vanderbilt orebody and Forsters Shear follows Forsters Gully. These are only two of numerous shears which diverge from the Narongo Fault, and apparently form favourable loci for the development of orebodies where they intersect the Main Lode Shear. The Narongo Shears dip westwards at 70° to 80°; they may be slightly convex eastwards, and probably formed in response to local eastward overthrusting.

Major Faults

The Captains Flat area was broken up into horsts and graben by movement along major reverse faults trending north.

The Narongo Fault, forming the western margin of the Captains Flat Synclinorium, has been traced 37 miles from Jerangle to Hoskinstown. The Fault is actually a zone of contiguous, parallel high-angle reverse faults which dip westwards at 70° to 80°. The outcrop of the fault zone is marked by breccias (some of which are mineralized) and quartz veins. Harrisons Peak Horst was moved upwards towards the east along the Narongo Fault and tilted down to the north. The fold axes in the horst plunge steeply north, whereas the plunge of the folds in the synclinorium ranges from 20° to the south to 20° to the north (Fig.6).

The Ballallaba Fault forming the eastern margin of the Captains Flat Synclinorium has been traced for 16 miles. It is a high-angle reverse fault along which the Ordovician sediments to the east have been thrust up a few thousand feet into contact with the Silurian strata. The fault appears to have developed mainly within the Bullongong Shale Member of the Foxlow Beds. Its outcrop is marked by zones of contorted slate and veins of quartz.

These major faults were formed towards the end of the Bowning Orogeny, when, after a period of intense folding, the rocks yielded to further stress by fracturing along faults and broke up into horsts and graben.

The movement along the major fault-zones appears to have been so intense as to have destroyed many of the previous structures in the contiguous rocks and to have imposed a planar foliation parallel to the fault plane (see stereogram of Ballallaba Fault-zone in Fig.6). This is an example of metamorphic convergence. Close to the fault-zones the twice-folded Ordovician sediments cannot be distinguished from the once-folded Silurian sediments.

The Northwest-trending Faults

The final episode in the tectonic history of the Captains Flat Synclinorium was its disruption by north-west-trending faults (e.g. the Molonglo, Golfcourse, and Tiger Cat Creek Faults, Fig.7c). These faults offset the folding, the north-trending shears, and the orebodies. Some can be traced as far as nine miles from the Rocky Peak Horst, across the Captains Flat Synclinorium, and across the Harrisons Peak Horst.

The Molonglo Fault is probably the most important fault in the area for it cuts off the northern extensions of Elliots and Vanderbilts orebodies. Its north-block-down (over 1500 feet) and west (240 feet) movement has apparently carried the orebodies beyond the limits of exploration and economic mining, for they have not yet been found in spite of extensive drilling. The fault extends westwards into the Harrisons Peak Granite.

The Golf Course Fault has a large but unmeasured north-block-down movement combined with a probable north-block-east movement. The fault obscures the closure of the Kohinoor Volcanics round the nose of the Hickey anticline, and has displaced the axis of the anticline an unknown distance to the east. This makes it difficult to predict the position of the Hickey anticline under the mine.

A late structural deformation associated with the faulting was the development of three sets of crenulation cleavages, crinkle joints, or "S" planes. Their late development is indicated by their deformation of intensely sheared and foliated volcanics and shales in different parts of the synclinorium. Two sets are vertical and trend 320° and 030°, and a third dips 50° to 160°. According to Rickard (1961) these "S" planes are developed only in previously foliated rocks in response to local minor stresses. Here they may be associated with local movement along the north-west-trending faults or with the regional forces imposing the faults.

FIG. 7.

A
MN
MINE GRID
10,000 N
OW OE
YORKDALE
NEWTOWN HILL SYNCLINE
DAM SYNCLINE
0 N
0 S
MESS
WILKINS
VANDERBILT ANTICLINE
10,000 S
HICKEY
STAGE 1
folding
B
NARONGO FAULT
MAIN LODE SHEAR
FORSTERS SHEAR
VANDERBILT SHEAR
DAM SHEAR
WATERFALL FAULT
BALLALLABA FAULT
STAGE 2
thrusting
C
HARRISONS PEAK
MOLONGLO FAULT
NARONGO FAULT
KANGA FAULT
TIGER CAT CREEK FAULT
CAPTAINS FLAT
Elliots orebody
Vanderbilts orebody
Keatings orebody
DAM
BALLALLABA FAULT
GOLFCOURSE FAULT
ROCKY PEAK GRANITE
T N
MN
STAGE 3
faulting
D
WEST
EAST
Elliots orebody
Vanderbilts orebody
3000 ft
2000
1000
SEA LEVEL
0
HARRISONS PEAK GRANITE
ROCKY PEAK GRANITE
1000ft
This cross-section was derived from a geometrical projection of the outcrop plan of the synclinorium and diamond drill hole data.
Diagrammatic cross-section of the Captains Flat Synclinorium (EAST-WEST THROUGH ELLIOTS OREBODY AND OMITTING THE NORTHWEST TRENDING MOLONGLO FAULT).
THE DEVELOPMENT OF THE MAJOR STRUCTURES AT CAPTAINS FLAT, N.S.W.
basalt
CAPTAINS FLAT FORMATION
Keatings Shale
KOHINOOR VOLCANICS
COPPER CREEK SHALE
RUTLEDGE QUARTZITE
ORDOVICIAN
GRANITE
ANTICLINE
SYNCLINE
FAULT
REVERSE FAULT
ORE
MINE
1 MILE
Bureau of Mineral Resources, Geology and Geophysics. To accompany Record Nº 1964/99
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GEOLOGICAL HISTORY

The oldest rocks exposed in the Captains Flat area are the greywackes at the base of the Foxlow Beds. No current bedding, flute casts or fossils were found; so the source of the greywackes remains unknown. The Bullongong Shale Member has been dated as Gisbornian and extends over a wide area. It is thought to be a deep-water acid volcanic dust (Joplin, 1945). The overlying beds in the Cullarin Horst consist of thin quartzites and suggest a shallowing of the sea.

There is a gap in the stratigraphic column in the Captains Flat area between the Upper Ordovician and the Wenlockian. During this period, the Ordovician strata were folded around north-trending axes (Benambran orogeny) and various members of the Upper Ordovician were stripped off by erosion before the basal Silurian conglomerate - the Rutledge Quartzite - was laid down unconformably across the area (Fig.8). The Rutledge Quartzite contains rounded cobbles of quartzite and silicified shale derived from the underlying Ordovician.

The Rutledge Quartzite was followed by the Copper Creek Shale, which contains lenses of Wenlockian coral reef limestone. This was followed by a period of extensive volcanic activity which resulted in the deposition of nearly 3000 feet of dacite tuff, agglomerate, and lava - the Kohinoor Volcanics, over an area extending from Hoskinstown to Jerangle.

No volcanic activity marked the deposition of the succeeding Carwoola Beds, a 4000-foot sequence of shale and argillaceous sandstone. No current bedding, flute casts, or fossils were found in these beds; so little could be learnt of their origin.

The area was folded slightly and somewhat eroded before the Captains Flat Formation was laid down with a slight unconformity over the area. It rests on Carwoola Beds at Hoskinstown and on Kohinoor Volcanics at Captains Flat. This slight earth movement was followed by a renewal of volcanic activity and both acid and basic flows and tuffs were deposited in the Captains Flat Formation. The formation was laid down in a shallow-water near-shore environment, for some of the reworked lithic tuffs contain beds of conglomerate with well rounded cobbles of slate, quartzite, dacite, and granite. The presence of granite boulders is of interest because no pre-Bowning granites are known from the area.

After the deposition of the Captains Flat Formation, the area was subjected to its most intense deformation - the

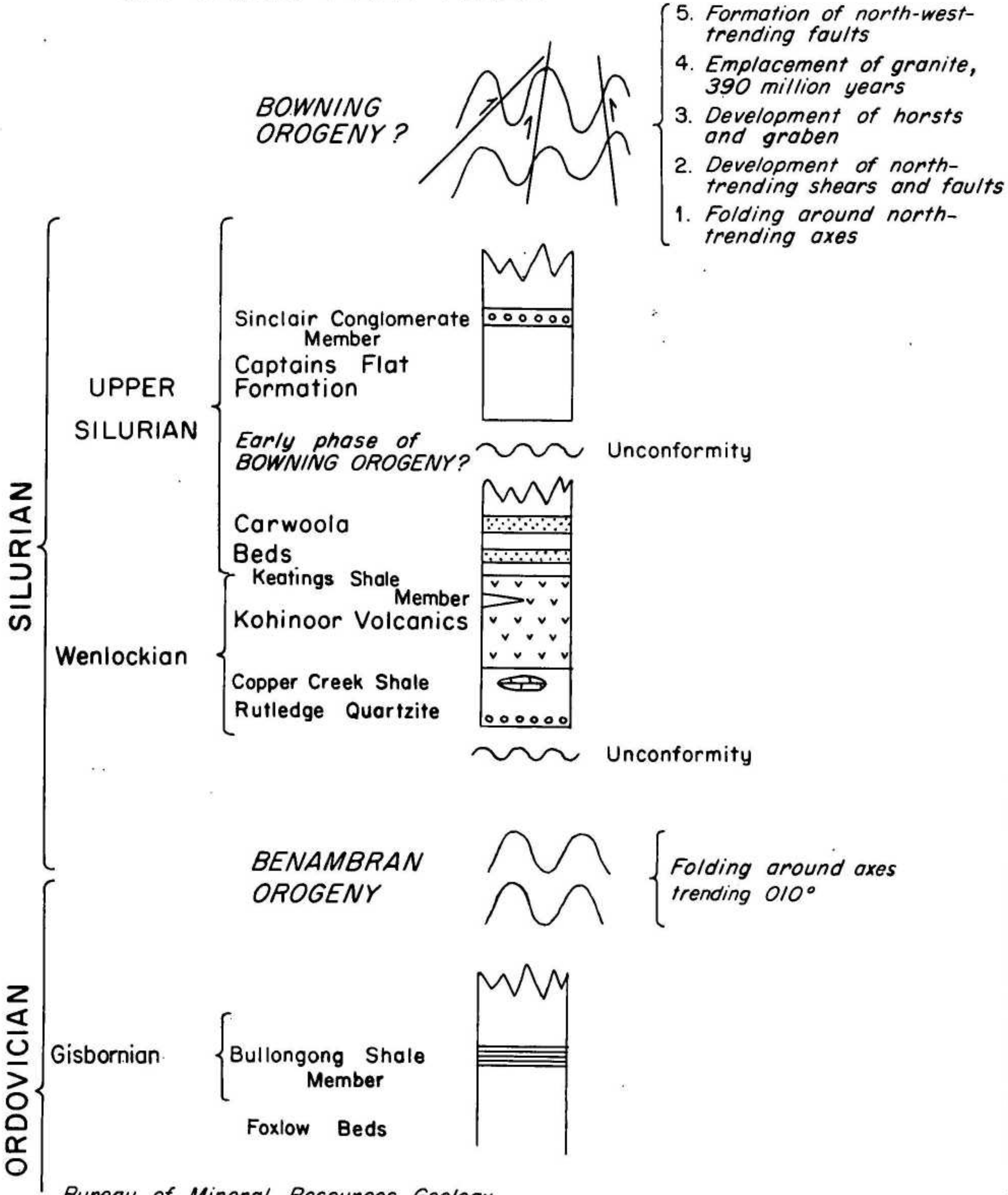
Bowning Orogeny - and was folded around north-trending axes which in places trend slightly across the earlier Benambran axes. As folding continued, slippage occurred along incompetent strata, and the rocks parted along north-trending faults. During the final stages of the orogeny, movement took place along reverse faults dipping steeply eastwards and westwards, and the area broke up into north-trending graben and horsts. The Harrisons Peak Granite and the Rocky Peak Granite were probably emplaced during these final stages. The adjacent Tinderry, Boro, and Shannons Flat Granites have been dated as 390 million years old (Everndon & Richards, 1962). The final phase of movement was the disruption of the area along north-west-trending faults. One of these, the Molonglo Fault, cuts the Harrisons Peak Granite, and so post-dates it. Some basic intrusives were emplaced during the orogeny.

The sulphide minerals at Captains Flat were emplaced during the Bowning orogeny. The later and quite distinct gold-quartz mineralization appears to be associated with the last phases of the Bowning granites at the end of the orogeny.

The only post-Silurian deposits in the area are the silicified gravels along the terraces of the Molonglo and the alluvium on the floodplain. Some of the gravel resembles the Fyshwyck Gravel in Canberra, which Öpik (1958) identified as a Permian fluvioglacial gravel. If this is correct, then most of the features of the present landscape date from the Permian.

STRUCTURAL DEVELOPMENT OF THE CAPTAINS FLAT AREA

Fig. 8.



Bureau of Mineral Resources, Geology and Geophysics. Canberra, A.C.T.

I 55/16/47 F.J.R.

To accompany Record No 1964/99

GEOCHEMICAL SURVEY

INTRODUCTION

Between 1949 and 1960 the staff of Lake George Mine made several detailed geochemical surveys over prospects which they had found (Fig.12). Samples of soil, bedrock, and gossans were collected at intervals of fifty feet along north-south lines 200 feet apart. Some of these surveys detected areas of anomalously high zinc, lead, and copper. These anomalies were drilled and some were found to be associated with narrow lodes of chalcopyrite, sphalerite, and galena.

In view of the successful use of geochemical surveys in the area, the Bureau of Mineral Resources made a reconnaissance geochemical survey over the whole of the Captains Flat Synclinorium and its southern outliers in an attempt to find new lead-zinc-copper orebodies.

Five thousand samples of soil, water, salt encrustations and gossans were collected over an area 27 miles from north to south and two miles from east to west centred on Captains Flat (Fig.9). Owing to limitations of time and laboratory facilities the samples were analysed for two metals only: zinc, because of its mobility and long dispersion trains, and copper, in preference to lead, because of its higher value at the time.

One hundred and ten anomalies were found, most of them associated with small gossans and mineralized shear-zones. Ninety three overlay one shale bed - the Copper Creek Shale. Only four anomalies warrant further investigation.

THEORETICAL BASIS OF THE SURVEY

The basis of the survey was the search for anomalously high concentrations of zinc and copper in the residual soil. These could be due to two causes:-

1. The soil could contain fragments of metal-rich rock mechanically derived from an orebody or zone of mineralization exposed nearby.
2. The clay particles in the soil could adsorb zinc or copper from metal-rich groundwater draining nearby orebodies or zones of mineralization.

The area has a highland Temperate climate and a uniform annual rainfall of 23 inches. The main springs and streams are perennial. There is a good cover of residual humid podsols which supports extensive dry schlerophyll forest and savannah woodland. The rocks in the area are being broken down by a combination of mechanical and chemical weathering. A permanent downward-percolating flow of groundwater attacks the bedrock, dissolving some of its constituents, percolating through the soils, and depositing alkalis, salts, colloids and metals in favourable horizons.

Thus, as water is the main transporting medium, the water in all springs and seepages was examined for copper, zinc, sulphate, and acidity. Numerous salt encrustations found where seepage-water had evaporated were scraped off and tested for copper and zinc. It was thought that the clay minerals in the soil would adsorb metal from percolating groundwater, especially in zones of concentrated flow such as the bottoms of depressions, gullies and valleys. Therefore soil samples were taken with a three-inch post-hole auger from the "B" horizon of the residual soils developed at such localities. A trellised drainage pattern had developed on the Silurian strata. This was used as a natural grid pattern, and the soil samples were taken along it at every confluence and at intervals of 600 feet. Every sample which contained anomalous values of copper or zinc was checked, and the area was revisited and resampled at closer intervals until the anomaly was delineated.

The complete soil profile can develop within six inches or may extend over six feet in the residual soils in the Captains Flat area. The "A" horizon (see Fig.10) usually consists of a leached grey silt. This is underlain by a 'stone line', a layer of fragments of white quartz accumulated after sinking through the soil which was being activated by burrowing organisms. This stone line gave great difficulties in sampling, for it was so compact in places that it resisted the augers and even broke some of them. The "B" horizon is the horizon of secondary enrichment in metals, colloids, alkalis, etc., derived from the leaching of the "A" horizon and also of adjacent rocks. Here, minerals are broken down to clay minerals, and thus the horizon consists of red, orange, yellow, or brown clay with varying amounts of sand and silt.

The weather had a marked effect on the geochemical survey. In wet weather the silts of the "A" horizon were hard to distinguish from the residual clays of the "B" horizon. The extra water percolating through the subsoil diluted the metal content of spring water. Salt encrustations were washed off rock and soil surfaces during rain (but reappeared thicker than before as the extra water percolating through the rocks evaporated).

In 1959 the staff of Lake George Mine sampled the active sediments being transported by the streams on the golfcourse and on Bollard Mountain (Fig.12). The sediments carried by the streams flowing off Bollard Mountain had a high metal content which could be traced back to the Bollard Anomalies. No active stream sediments were sampled during the 1961 survey because the whole of the Molonglo Valley was contaminated by tailings swept down the river in 1942, and the other streams were probably contaminated by drainage from small mines, prospects, homesteads, eucalyptus stills, and rubbish dumps. Furthermore, the local property owners treat damp and swampy areas with copper sulphate to kill the fluke snail parasite.

DETERMINATION OF COPPER AND ZINC

Standard methods of colorimetric determination were used (Sandell, 1959). 500 mg of the ground soil sample was digested in a crucible with 2 ml. of concentrated sulphuric acid plus 0.5 ml. of concentrated nitric acid, and heated until most of the acid had evaporated. The residue and solution were transferred to a 50 ml. measuring cylinder and made up to volume with distilled water. After mixing and settling of the residue, suitable aliquots were taken and the copper and zinc estimated colorimetrically by visual comparison with suitable standards. The copper was estimated by using biquinoline in amyl alcohol and the zinc by using dithizone in carbon tetrachloride.

RESULTS

The results of the reconnaissance geochemical survey are shown on Fig.9 and on the 40-chain geochemical contour maps Plates 2 to 5. The major geochemical anomalies will be discussed in the section on mineralization. An indication of the accuracy of the geochemical survey is that all prospects discovered by the Mine Staff were detected independently by this reconnaissance survey, and about 80 new anomalies were discovered. Where Bureau sample sites coincided with Lake George Mine sample sites, the analyses were very similar.

It may be appropriate here to discuss the general size and extent of the anomalies in comparison with the background values, and to correlate the anomalies with the orebodies at the mine and with known mineralization intersected by diamond drill holes.

Analysis of Results

The analyses of the 5000 samples were plotted on a histogram (Fig.11). The histogram shows that 94 percent of the samples contained less than 40 ppm cu, and only 2 percent contained 100 ppm or more; 90 percent of the samples contained less than 40 ppm Zn, but nearly 6 percent contained 100 ppm or more. The regional background was taken as 0 to 30 ppm with a modal value of 10 ppm. Zinc is apparently more abundant than copper and any value of 100 ppm or over was regarded as significant. The regional background for water was found to be 0.02 ppm. and any value over 0.2 was regarded as significant.

If the analyses of the samples taken over the different formations are plotted separately, there is a significant variation. Only one percent of the samples collected over the Captains Flat Formation and over the Kohinoor Volcanics contain 100 ppm Zn or more, whereas eleven percent of those collected over the Copper Creek Shale contain 100 ppm Zn or more. The modal value of the samples collected over Keatings Shale Member was 30 ppm and 18 percent of the samples contained more than 100 ppm Zn.

Correlation of Geochemical Anomalies with adjacent Mineralization

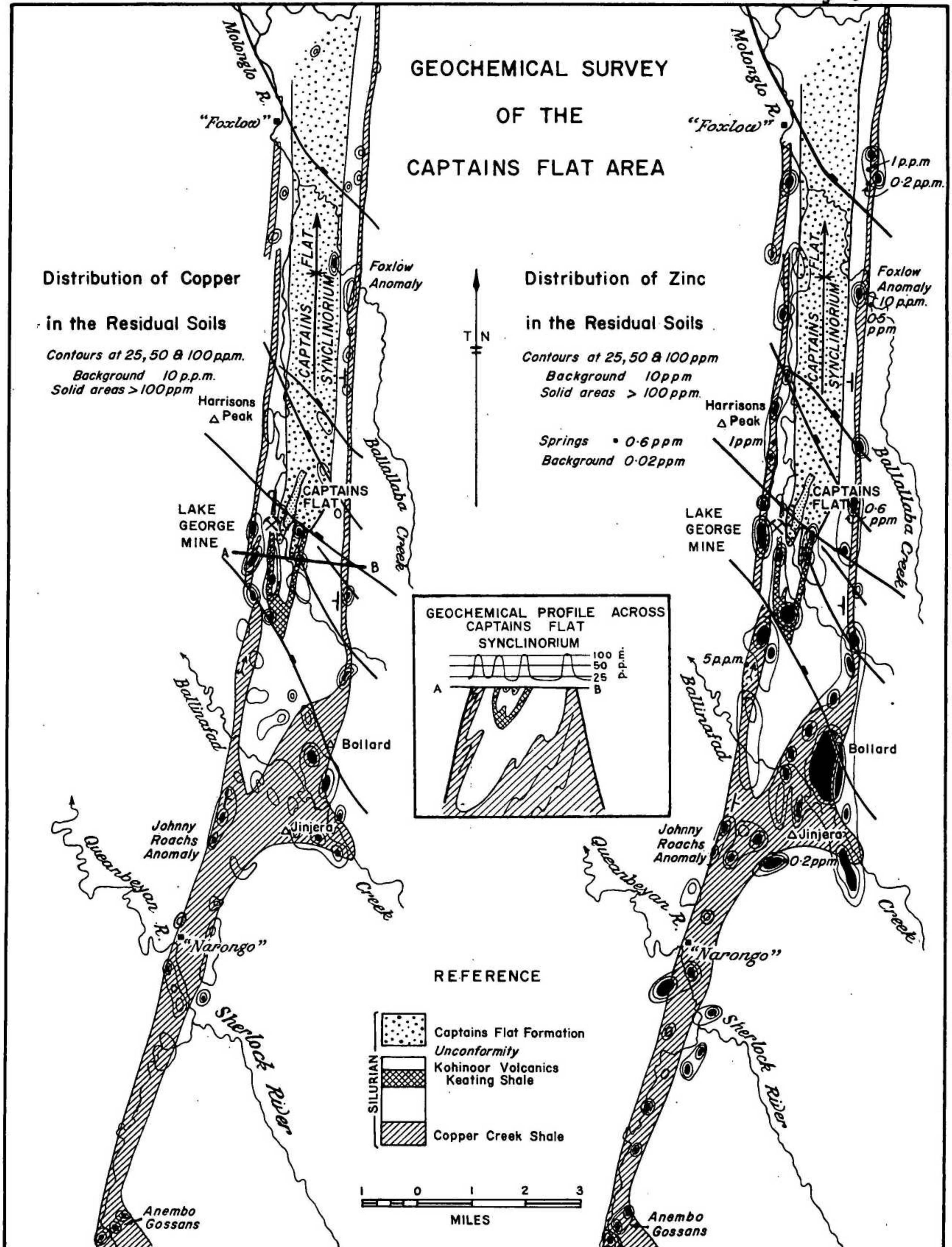
The staff of the Lake George Mine collected soil samples from around the gossan above Keatings Orebody. A geochemical anomaly was found extending only 300 feet across the strike of the orebody and the highest value was 200 ppm Cu.

The Mine staff found several anomalies over "Keatings Extended"; the anomaly at 5500 feet South extended over an area 400 feet by 500 feet and ranged up to 300 ppm Cu. This anomaly was drilled by the Mine and the borehole (T 55) intersected five feet of pyrite containing one percent of copper.

The Mine staff made a detailed geochemical survey over traces of mineralization on Bollard Mountain (Fig.12, and plates 4 & 5) and found anomalies extending over an area 4000 feet by 1500 feet and ranging up to 400 ppm Cu. The 1961 reconnaissance survey delineated the same general area of mineralization and found anomalies ranging up to 5500 ppm Zn and 300 ppm Cu.

Lake George Mines tested the northern anomaly on Bollard by sinking four diamond drill holes into a lead anomaly (550 ppm Pb, 100 ppm Cu) at 5,000 E, 22,000 S (Fig.18). Drilling conditions were very difficult, and core recovery was very poor. One hole was abandoned, and no core was recovered for the first 400 feet of the others. In spite of the poor core recovery, some mineralization was found - a minimum of six feet of 1.3 percent Pb in one hole and six inches of massive sulphide with 9 percent Pb and 5.4 percent Zn in another.

The figures quoted above show that the size of the



Bureau of Mineral Resources Geology and Geophysics. December 1963. To accompany Record Nº 1964/99

I55/A16/301

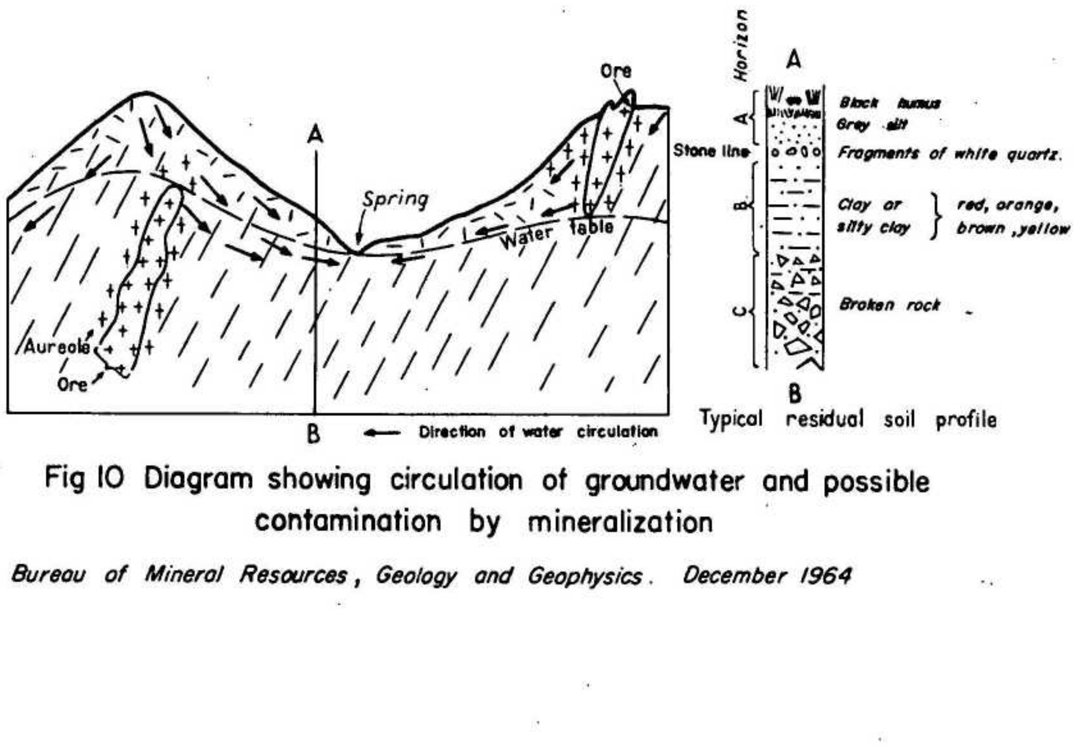


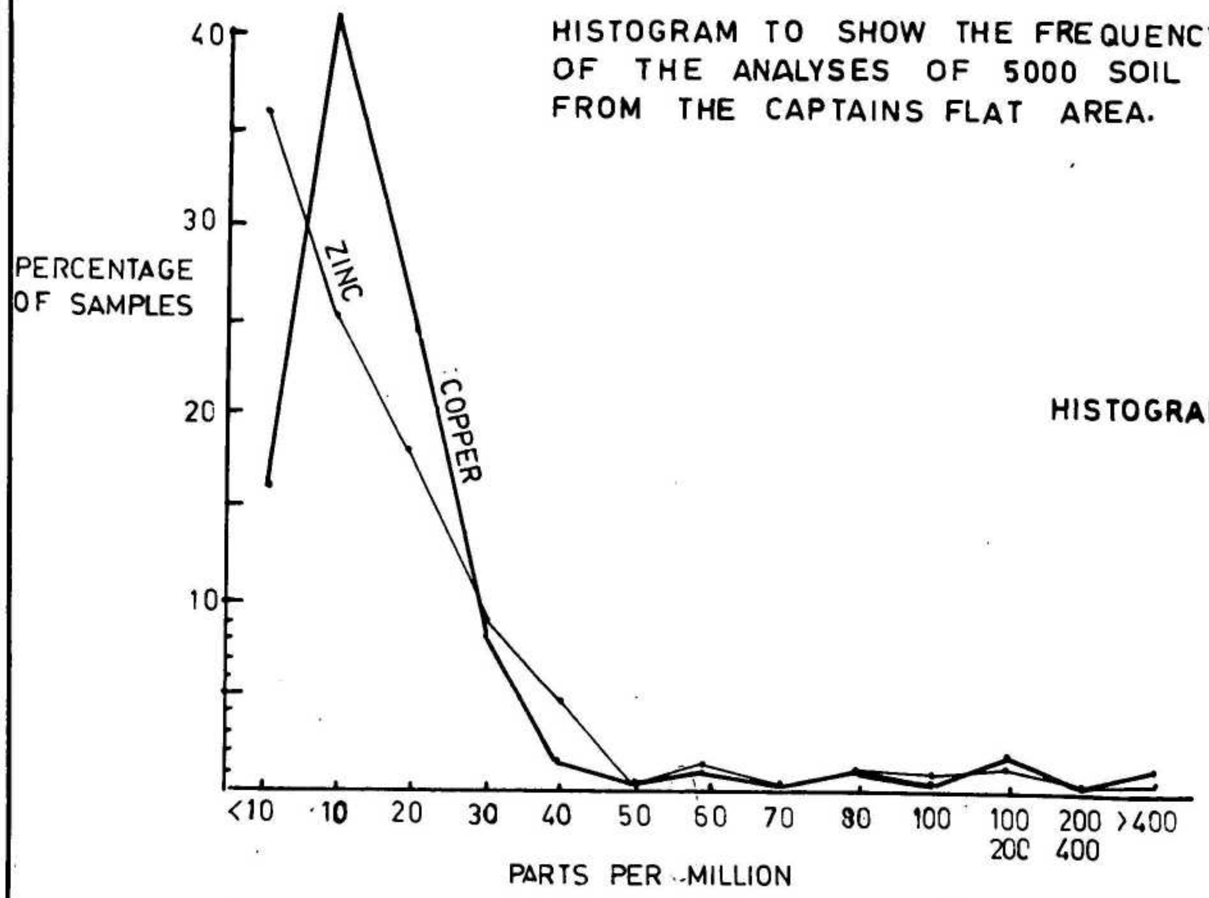
Fig 10 Diagram showing circulation of groundwater and possible contamination by mineralization

Bureau of Mineral Resources, Geology and Geophysics. December 1964

FIG. 11

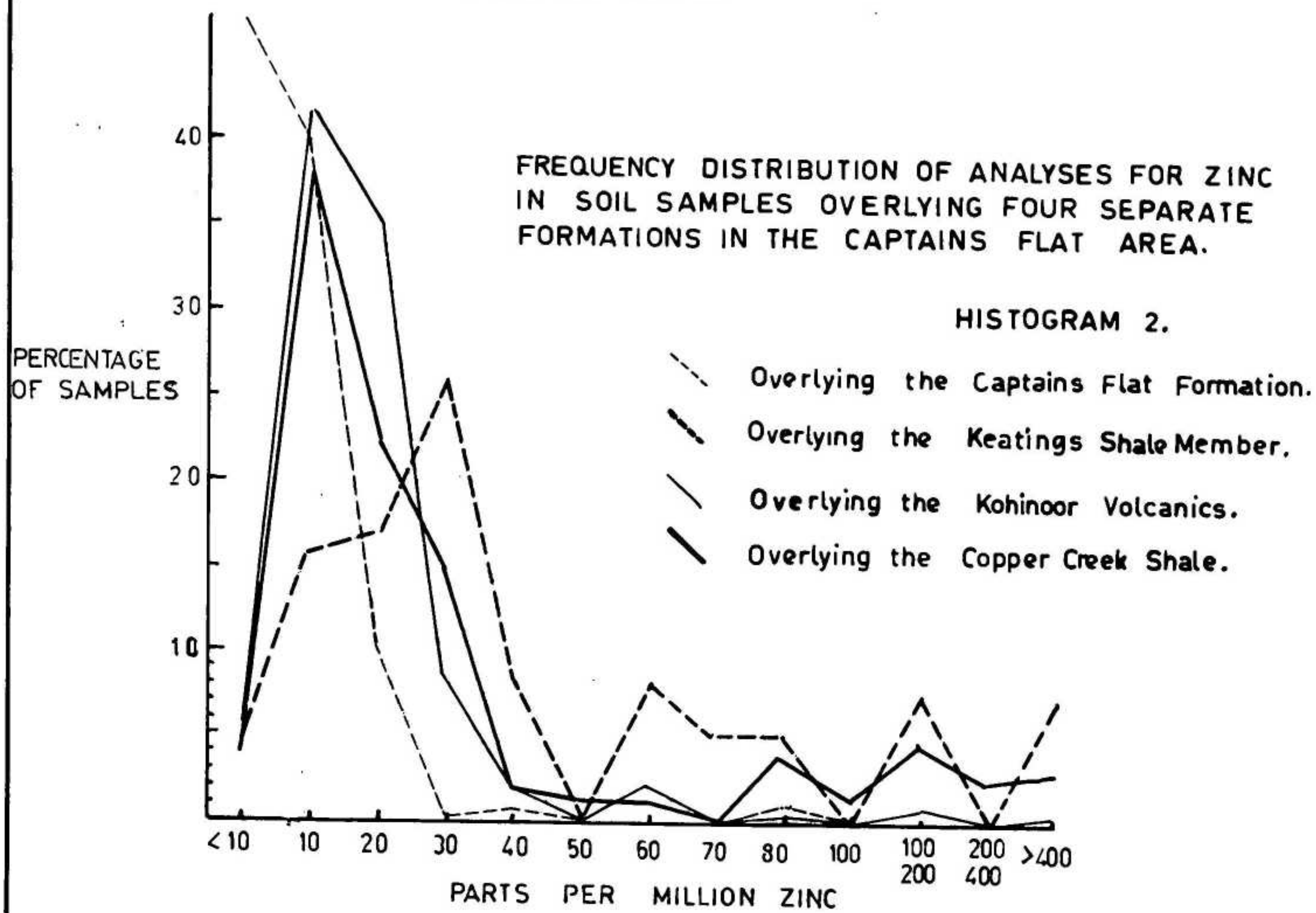
HISTOGRAM TO SHOW THE FREQUENCY DISTRIBUTION OF THE ANALYSES OF 5000 SOIL SAMPLES FROM THE CAPTAINS FLAT AREA.

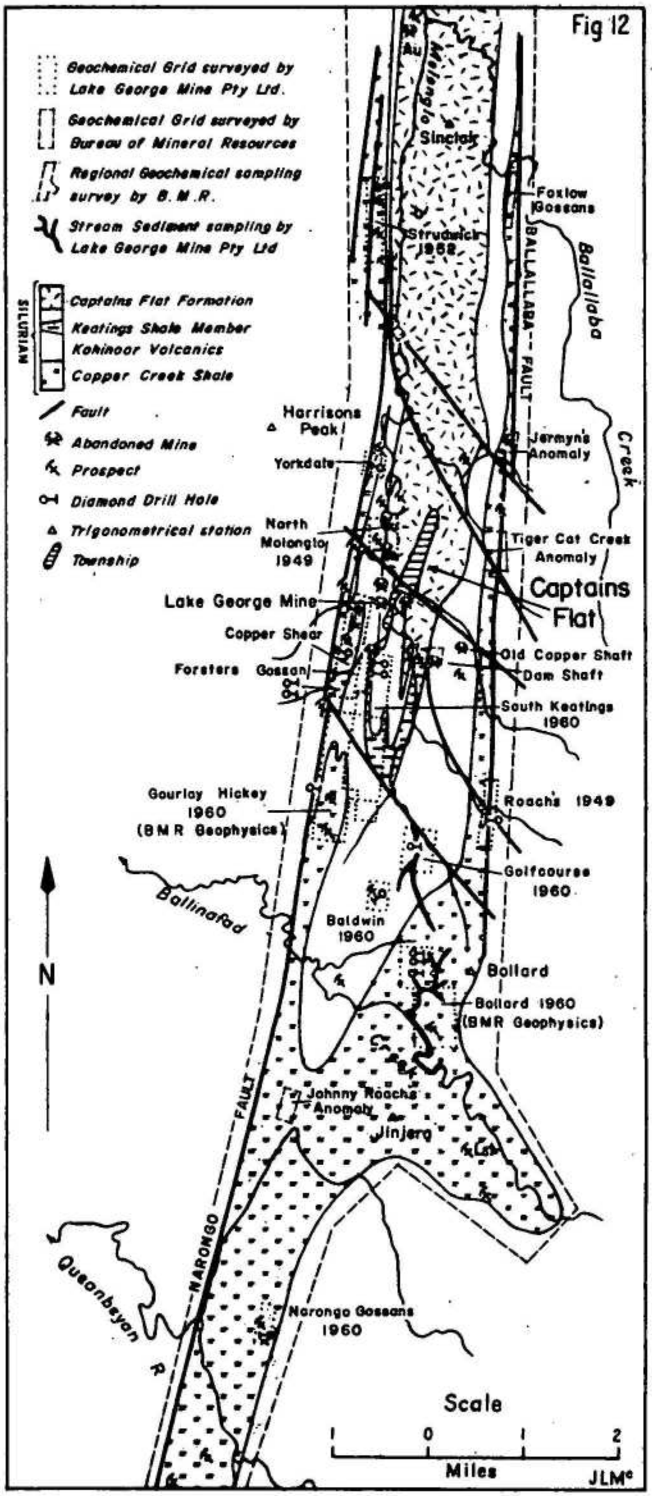
HISTOGRAM 1.



FREQUENCY DISTRIBUTION OF ANALYSES FOR ZINC IN SOIL SAMPLES OVERLYING FOUR SEPARATE FORMATIONS IN THE CAPTAINS FLAT AREA.

HISTOGRAM 2.





Bureau of Mineral Resources, Geology and Geophysics. March 1965

155/A16/329

The search for base-metal sulphide deposits in the Captains Flat area anomaly depends on both the size of the orebody and the ease of leaching. The latter depends on groundwater flow, acidity, oxidizing and reducing conditions, porosity, and permeability. The orebody at the Lake George Mine occurs in silicified sheared shale enclosed in silicified sheared volcanics. The host rocks are not permeable, and therefore the orebody is not greatly leached. The mineralization at Bollard occurs in alternating graphitic black shale and porous sandstone. The poor core recovery in the diamond drill holes suggest that the host rocks are intensely shattered. The host rocks are thus very permeable, and the weak mineralization in them is probably subjected to intense leaching, and therefore the anomalies around the mineralization are disproportionately large.

MINERALIZATION

INTRODUCTION

Sulphide mineralization occurs in the Captains Flat area as:-

1. Large masses of sulphides, up to 40 feet thick and several hundred feet long, in Keatings Shale Member of the Kohinoor Volcanics: i.e. Keatings, Central, and Elliots orebodies.
2. Mineralized shear zones in the Kohinoor Volcanics.
3. Small masses of sulphides, up to several feet thick, in the Copper Creek Shale and the Bullongong Shale Member.
4. Disseminated sulphides in the Copper Creek Shale and in the Bullongong Shale Member of the Foxlow Beds.

The Captains Flat orebodies are part of a north-trending zone of mineralization within a north-trending belt of Silurian shale, volcanics and limestone. Sulphide mineralization occurs along this line at Cowra Creek, Jerangle, Anembo, Narongo, the Briars Copper Mine, Woodlands Copper Mine, Bungendore, Currawong, and Breadalbane.

MINERALIZATION IN THE KOHINOOR VOLCANICS

The major orebodies in the Captains Flat area occur in the Keatings Shale Member of the Kohinoor Volcanics at Captains Flat. These orebodies - Keatings, Central, and Elliots - consist of thin, north-striking lenses of pyrite, sphalerite, galena and chalcopyrite.

Keatings, Central, and Elliots orebodies have been described in detail by Glasson (1953 and 1957). The mineralogy of the orebodies has been described in detail by Edwards (1943) and by Edwards &

Baker (1953). The accompanying diagrams and cross-sections (Fig.13) were compiled from their work and from recent mapping by the Bureau of Mineral Resources. The cross-section of the synclinorium was drawn by a geometrical projection McIntyre D 1951. of the geological map of the synclinorium. The upper part of the cross-section correlates closely with available drill-hole information and with cross-sections of the mine workings.

Keatings, Central and Elliots Orebodies

The ore consists of pyrite, sphalerite, galena, and chalcopyrite, with a little gold (1.1 dwt per ton), silver (1.63 oz per ton), antimony, and arsenic contained in tetrahedrite (Edwards 1943).

The pyrite appears to have been the first mineral to have been emplaced, for it consists of corroded and embayed euhedral crystals (Edwards & Baker 1953). On the other hand, the euhedral shape of the pyrite may be due to its high force of crystallization (Stanton, 1960). The sphalerite has enclosed and embayed the pyrite. The galena and chalcopyrite occur as intergrowths in fracture filling and veins ramifying through the orebodies.

In places, the ore is massive and homogeneous; in others, it has a well-marked banded structure with bands of pyrite alternating with bands of other minerals or with bands of shale.

The orebodies occur as flattened lenses which dip westwards at 80° and pitch northwards at 60 - 70° (see Fig.13). The major orebodies trend 010°, but in places they can be seen to consist of small, contiguous, en-echelon lenses of ore trending 020° (Glasson, 1957). The orebodies developed along the intersections of the Narongo Shears with the Main Lode Shear. The Narongo Shears are an extensive series of shears, trending 020° and dipping westwards at 70 - 80°, which diverge from the Narongo Fault in the Mine area. The Main Lode Shear lies within Keatings Shale Member and trends 010° and dips westwards at 80°. The footwalls of the orebodies are very sharp, whereas the hangingwalls are more diffuse and traces of pyrite persist for a few hundred feet into the contiguous Kohinoor Volcanics.

The orebodies occur on the overturned western limb of the Captains Flat Synclinorium. During the folding of the synclinorium the Kohinoor Volcanics above the Keatings Shale Member folded disharmonically to the volcanics below. Extensive differential slip occurred along the shale member and it was sheared out along the major limbs of the synclinorium. The Main Lode Shear may be part of this differential slip. The orebodies are restricted to the most highly stressed part of the shale bed near its northern limit. The bottoms of the successive orebodies increase in depth northward, showing that the ore-bearing zone plunges northwards at about 20° parallel to the plunge of the synclinorium.

During an early stage of folding the synclinorium was disrupted along the Waterfall Fault, and the whole of the western limb was thrust upwards and to the east over the eastern limb. Thus the eastern limb, which is less mineralized, escaped the later stresses which plicated and sheared the western limb.

The western limb contains several minor folds overturned to the east, and plunging northwards at about 20°. The Mess Anticline contains a small lens of mineralization in its crest below the overlying Kohinoor Volcanics. The Hickey Anticline is a major anticline with a core of mineralized Copper Creek Shale which plunges northward beneath Keatings, Central, and Elliots orebodies (Fig.13).

Later deformation caused thrusting and shearing along the axial planes of some of the minor folds on the western limb - e.g., Dam Shear, Vanderbilt Shear; and the formation of the Narongo Shears.

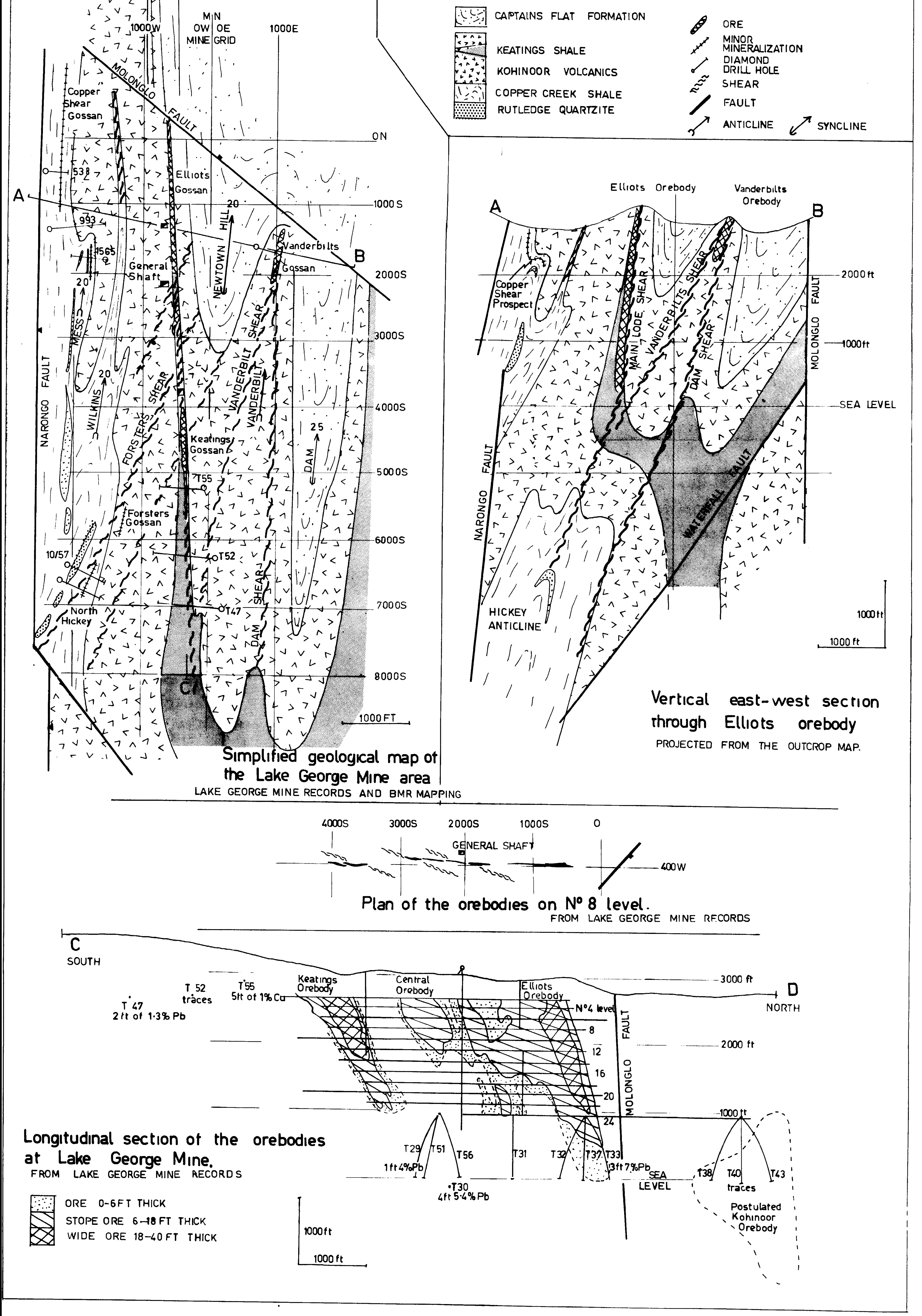
Vanderbilts Orebody

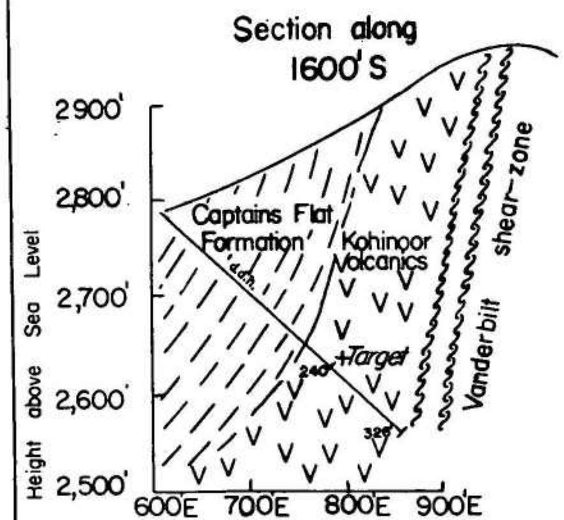
Vanderbilts orebody is a thin vertical lens of pyrite, galena, and chalcopyrite, with minor amounts of gold and silver. It occurs in highly-sheared, foliated, kaolinized Kohinoor Volcanics at the intersection of the Vanderbilt Shear, trending 020°, with the mineralized Dam Shear, trending 010° along the axial plane of the Vanderbilt Anticline. The orebody plunges gently northwards but does not persist below 300 to 400 feet and is cut off to the north by the Molonglo Fault. It has been worked out.

Vanderbilts orebody differs from the other main orebodies in that it does not occur in Keatings Shale. The orebody could have developed where the mineralized shears intersected the overlying shale in the Captains Flat Formation, and the existing orebody may merely be the bottom of a much larger orebody developed in the Captains Flat Formation. The major part of this postulated orebody may have been faulted down to the north of the Molonglo Fault. On the other hand, the orebody may be a small lens which developed where the Vanderbilt Shear intersected a large body of kaolin within the kaolinized Dam Shear, which thus acted as a sheared and stressed shale bed.

FIG 13

THE WESTERN LIMB OF THE CAPTAINS FLAT SYNCLINORIUM SHOWING THE DISTRIBUTION OF THE OREBODIES AT LAKE GEORGE MINE.





Depth of Sample	Formation	Lithology	Number of Sample	Cu ppm	Zn ppm
196'	Captains	Red slate			
206'	Flat Formation	Red slate			
216'	* Shearing	Ironstone			
226'	*	Sheared kaolinitic dacite	3955	10	30
236'	Fine-	4" qtz vein with 5% pyrite Sheared kaolinitic dacite	3954	10	500
246'	grained White	Disseminated pyrite	3953	20	750
256'	Kohinoor	Sheared dacite	3952	30	30
266'	Volcanics	Disseminated pyrite	3951	20	300
276'		Disseminated pyrite	3950	10	150
286'		Sheared dacite	3949	10	30
296'		Sheared dacite	3948	10	20
306'		Sheared dacite	3947	10	20
316'		Sheared dacite	3946	10	30
326		Dacite with 3% pyrite	3945	20	1200

Zinc profile

Bureau of Mineral Resources Geology and Geophysics To accompany Record No 1964/99 I 55/A16/

Fig 14 Vanderbilt diamond drill hole. November 1961

Vanderbilt diamond-drill hole

A gravity high on Vanderbilt Hill (Gibbons, 1962) was drilled in November 1961. (Fig.14). The bore core contained traces of zinc at the target depth, but no extensive mineralization was found. The hole was continued 80 feet beyond the target to 326 feet. The bottom three feet of core contained small pods and stringers of pyrite which made up about 3 percent of the rock. The hole was probably entering the Vanderbilt Shear.

The traces of zinc (750 ppm) at the target depth are interesting and it is possible that the drill passed through part of the 'mineralized halo' around a small lens of sulphides at the target depth.

Forsters Gossan

This is a zone of small gossans, each up to two feet long, in sheared, kaolinized Kohinoor Volcanics in Forsters Gully half a mile south of the General Shaft. The zone is about four feet wide, and has been traced 600 yards along Forsters Shear. The gossans contain up to 80 ppm Cu and 200 ppm Zn, and the surrounding soil samples contain up to 180 ppm Cu and 250 ppm Zn.

Sample	Copper (ppm)	Zinc (ppm)
5303	60	50
6264 gossan	80	200
5309	15	60
6126	120	250
6129	180	30
4321	80	80

Dam Shaft

The Dam Shaft prospect on the eastern limb of the synclinorium occurs where a north-west trending fault intersects the Waterfall Fault along the western contact of the Kohinoor Volcanics (see fig. 12).

The spoil heap around the abandoned 150-foot deep shaft consists of red shale stained by malachite and azurite. The reconnaissance survey found values up to 500 ppm Zn and 80 ppm Cu, but the results of a detailed geochemical survey by Lake George Mines Pty Ltd revealed only a few areas of 100 ppm Cu. The results were disappointing, and the prospect was abandoned for it appeared to be merely minor mineralization along a shear zone in the Kohinoor Volcanics.

Old Copper Shaft

The spoil heap around the Old Copper Shaft, 1500 feet east of the Dam Shaft (see Fig.12), contains samples similar to Elliots ore. The shaft was sunk in a north-trending shear-zone in Kohinoor Volcanics.

No gossans were visible along the shear, and no geochemical anomalies were found, except for a small one 1200 feet to the north, where the deeply incised Jinero Creek has cut down across the shear.

If the samples in the dump are from the shaft, it has been sunk into a pod of rich mineralization along a shear-zone in the Kohinoor Volcanics. The absence of geochemical anomalies, except in Jinero Creek, suggests that the mineralization is below the depth of leaching.

MINERALIZATION IN THE COPPER CREEK SHALE

Throughout its outcrop from Jerangle northwards to Bungendore and Breadalbane, the Copper Creek Shale contains pyrite, chalcopyrite, sphalerite, and galena, in the form of disseminated crystals, small pods and blebs (one or two inches long), veinlets, and thin layers (a quarter of an inch thick). Larger bodies of sulphides up to 20 feet thick occur at Jerangle, Anembo, Narongo, Bollard Mountain, Captains Flat, Foxlow, and Woodlands. Copper-zinc geochemical anomalies, associated with small gossans a few feet across, occur along the outcrop of the Copper Creek Shale where it is cut by cross-faults or distorted by strike shearing (see Fig.9), and metal-rich springs emerge along some of these cross-faults, e.g. at Tiger Cat Creek.

The Copper Shear Gossan

The Copper Shear Gossan (fig.13) is about 2 feet wide, but can be traced discontinuously over 1000 feet northward along the strike. It occurs in sheared Copper Creek Shale, striking 010°, intersected by Narongo Shears trending 020°. A shallow drill-hole (No.538) drilled beneath the gossan intersected twelve feet of 1.4 percent lead. The gossan crops out again near the Staff Mess on the eastern limb of the Mess Anticline, which plunges north at about 20°. Two drill-holes sunk into the crest of this anticline intersected fourteen to fifteen feet of mineralization:-

D.D.H. 993: 15 ft of 2.05% Pb, 3.4% Zn, 0.2% Cu.
D.D.H.1565: 14 ft of 1.5 % Pb, 2.0% Zn, 0.1% Cu.

Other drill-holes showed the lode to thin out rapidly to the north and south and also on the limbs of the anticline.

The significant feature of this small mass of mineralization is its development in the core of an anticline disrupted by the Narongo Shears, and its thinning out on the limbs of the fold.

The prospect was not sampled geochemically because of the widespread contamination by mine tailings and rubbish.

Jermyns Anomaly

This anomaly was detected by a few reconnaissance samples and the area appeared so promising that detailed sampling was carried out on a grid pattern (Figs 12 and 15, Plates 2 and 3). However, the results were disappointing, and no extensive anomalies were discovered. The area overlies strongly sheared Copper Creek Shale between the Kohinoor Volcanics and the Ballallaba Fault. The highest anomalies occur where the north-west trending Kanga Fault cuts the Ballallaba Fault.

The Tiger Cat Creek Anomaly

A few metal-rich soil samples and a mineralized spring were found during the reconnaissance survey, but detailed grid sampling failed to find any extensive anomalies (Fig.16). The area consists of sheared Copper Creek Shale trending northwards and containing small pods of gossan up to two feet long. A two-foot lens of sheared Rutledge Quartzite crops out near the western margin of the area and contorted black slate crops out along the Ballallaba Fault 200 feet to the east. A mineralized spring containing 0.6 ppm Zn (30 times background for water) emerges along the Tiger Cat Creek Fault, which trends north-westerly across the area (Plates 2 and 3).

The Foxlow Anomaly

The Fowlox Anomaly consists of three small areas of over 80 ppm copper around a mineralized spring on the eastern limb of the synclinorium (Figs. 12 and 17). The anomaly overlies sheared north-trending siltstone and shale, probably the Copper Creek Shale, margined to the west by faulted lenses of Rutledge Quartzite and to the east by the Ballallaba Fault, which is marked by a zone of contorted black slate. The Copper Creek Shale contains pods of gossan up to thirty inches long with 400 ppm Cu and 200 ppm Pb. The mineralized spring emerging from the centre of the anomaly contains 10 ppm Zn, i.e. 500 times background for water, and another spring emerging 1200 feet to the south-east contains 0.5 ppm Zn, i.e. 25 times background for water.

A later and more detailed analysis of a sample of water from the main spring after a period of two to three months of little rain showed the water to have not only a high zinc content, but also an abnormally high sulphate to chloride ration and a very low pH value.

Conductivity	(micro ohms/cm	1790
pH		2.9
Sulphate (SO_4) ppm		940
Chloride (Cl)	"	25
Calcium (Ca)	"	18
Magnesium (Mg)	"	136
Sodium (Na)	"	173
Zinc (Zn)	"	13
Ratio SO_4/Cl		37.6

Analyst S. Baker.

Although the geochemical anomalies are small, they surround a very rich mineralized spring, and should be investigated by detailed geophysics.

Johnny Roach's Anomalies

These geochemical anomalies occur over sheared and contorted Copper Creek Shale to the south-west of the southern keel of the Captains Flat Synclinorium (see Fig.12, Plates 4 & 5). The sheared shale and siltstone trend northwards, and contain lenses of sheared, foliated quartzite contorted about steeply north-plunging fold axes.

The major anomalies (Fig.19a & b) occur on a steep, wooded hillside covered with a scree of fragments of shale, mineralized shale, gossan, and foliated quartzite. This anomaly should be mapped in detail and geophysically surveyed.

The Bollard Anomalies

The Bollard Anomalies (Fig.12) were examined, geochemically sampled, and drilled by the Lake George Mines Pty Ltd between 1956 and 1960 (Glasson & Paine, 1959; Paine, 1961). Electromagnetic surveys were made over the area by the Geophysical Branch of the Bureau of Mineral Resources in 1960 (Sedmik, 1961). Large geochemical anomalies were detected in the area by the Bureau's reconnaissance survey in 1961 (Plates 4 & 5). The area was not re-sampled in detail, for the previous work was regarded as adequate, but further geological mapping and drilling appear warranted.

The geochemical anomalies (Fig.18) overlie contorted metal-rich Copper Creek Shale, Rutledge Quartzite, and the Bullongong Shale Member of the Foxlow Beds. The strata are tightly folded about north-plunging axes, and are sheared along zones trending 350°, possibly axial plane shearing. However, the structure and stratigraphy are not known in detail. The shales and quartzite contain pods and stringers of gossan up to three feet long, which in places contain gold.

Only the smaller and more easily accessible lead anomalies at the northern end of the prospect have been tested (Fig. 18). Four holes were drilled into a lead prospect at 5,000'E, 22,000 S. Drilling conditions were very difficult, core recovery was very poor, and the holes were abandoned before reaching the target of mineralized sandstone. One hole yielded no core and two holes yielded no core for the first 400 feet. However, the table in Fig. 18 shows that some mineralization was intersected, but it is not known how much friable ore or interlayered ore and sediment was lost in the drilling; no analyses of the drilling sludge were made.

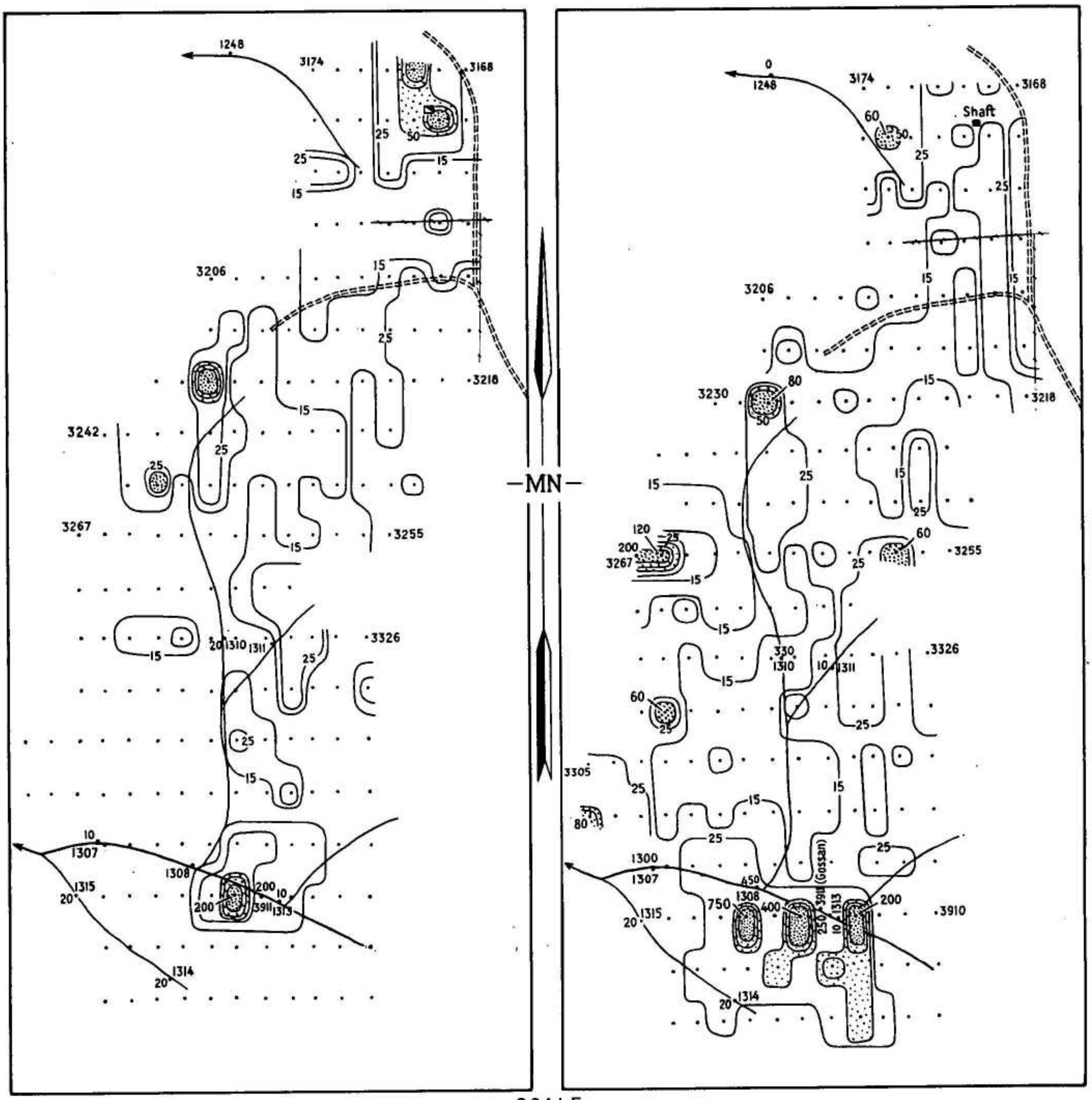
The electromagnetic surveys by the Bureau of Mineral Resources discovered no large anomalies. Three small electromagnetic anomalies were discovered, but they could not be correlated with any of the geochemical anomalies.

As a result of the difficulties and the disappointing results of drilling the lead anomalies and also the absence of any large electromagnetic anomalies, the copper anomalies to the south were not drilled.

The geochemical anomalies in the Bollard prospect are the largest in the Captains Flat Area, and some of the associated mineralization has been intersected in the drill holes. However, the large geochemical anomalies may be due to the extensive leaching of minor mineralization in easily permeable host rocks. But the prospect cannot be evaluated properly until the geological structure is known and the geochemical and geophysical anomalies have been studied in relation to the structure of the three sulphide-bearing units in the area.

Gourlay-Hickey Anomaly

Detailed geochemical and geophysical surveys were made over the Gourlay-Hickey area (Fig. 12), and a few promising anomalies were discovered (Sedmik, 1961). The area contains a tightly folded anticline, the Hickey Anticline, of Copper Creek Shale, which plunges gently northwards underneath the Lake George Mine. The core of the anticline consists of sheared Rutledge Quartzite. The strata are sheared along zones trending 010°, and are cross-faulted along faults striking 300° and 320°. The major electromagnetic anomaly occurs along the



Copper Anomalies

SCALE

0 100 200 300 400

FEET

Zinc Anomalies

REFERENCE

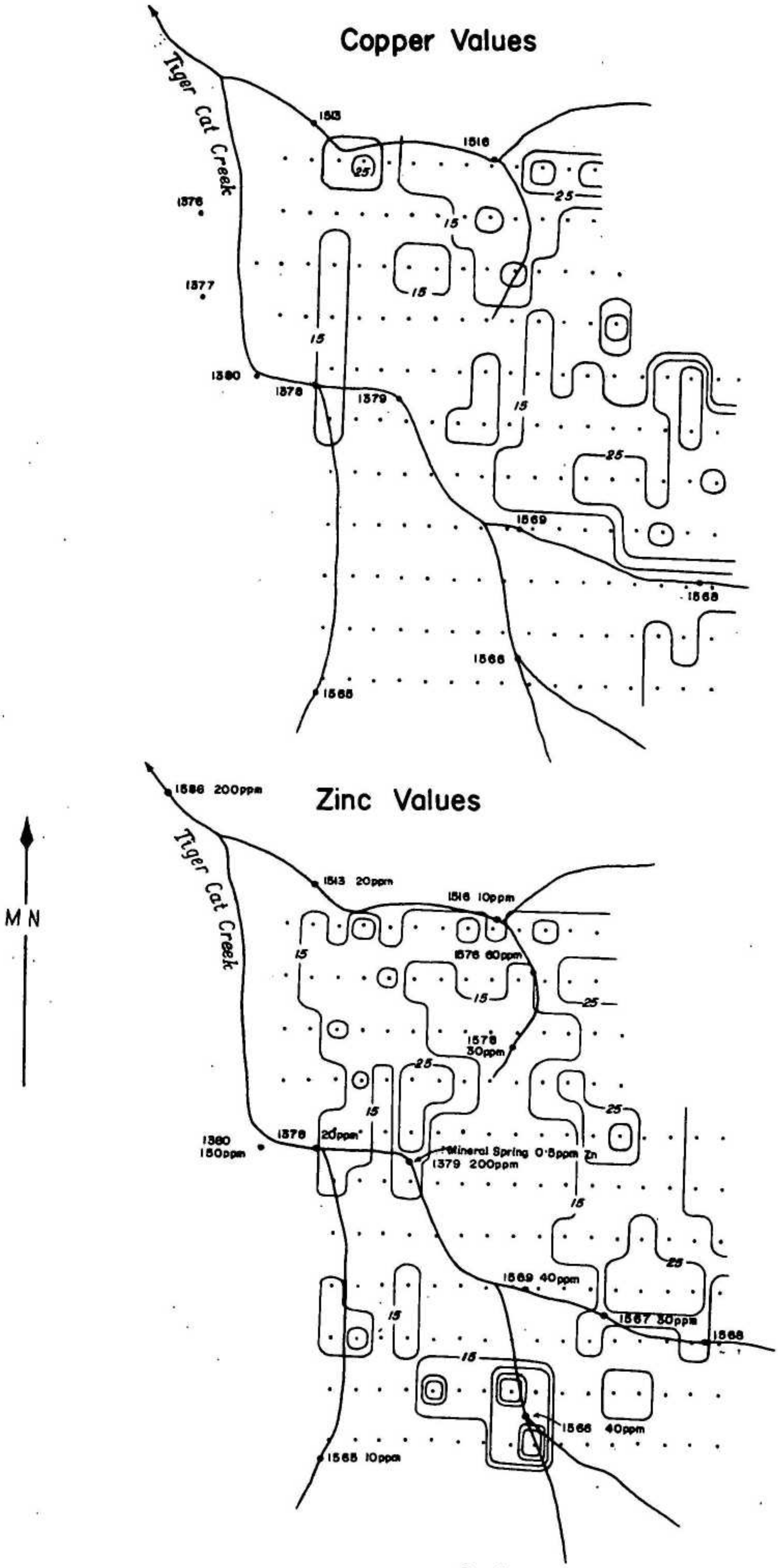
Values in p.p.m. —— *Fence.* ====== *Track.* *Contours at 15, 25, 50, 75 and 100 p.p.m.*

10/1307 *Reconnaissance Samples (with results of over 10 p.p.m.).* . . . *Grid samples*

Fig.15. Jermyn Geochemical Anomalies

G.M.

Bureau of Mineral Resources, Geology & Geophysics. January, 1965 *To accompany Record No 1964/99*



Scale

300 0 300 600 Feet

Reference

1567 30ppm • Reconnaissance Samples (with results if over 10ppm)

• • Grid samples

—15— Contours at 15,25,50, and 75ppm

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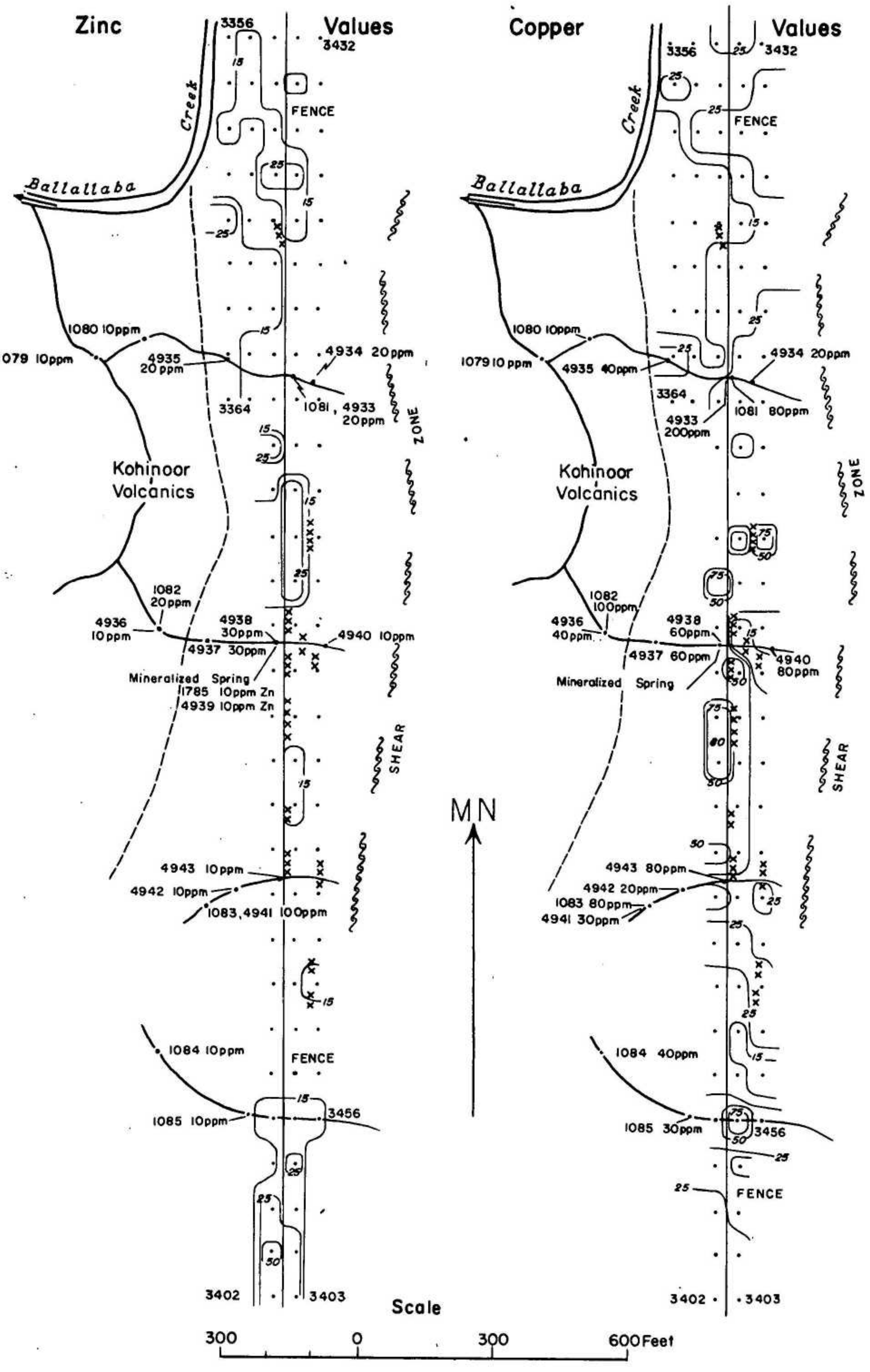
Fig 16 Tiger Cat Creek Geochemical Anomalies

JLM



Reference

1084 40ppm — *Reconnaissance Samples, values in p.p.m.*

• • *Grid samples*

x x x *Gossans*

— 15 — *Contours at 15,25,50 and 75ppm*

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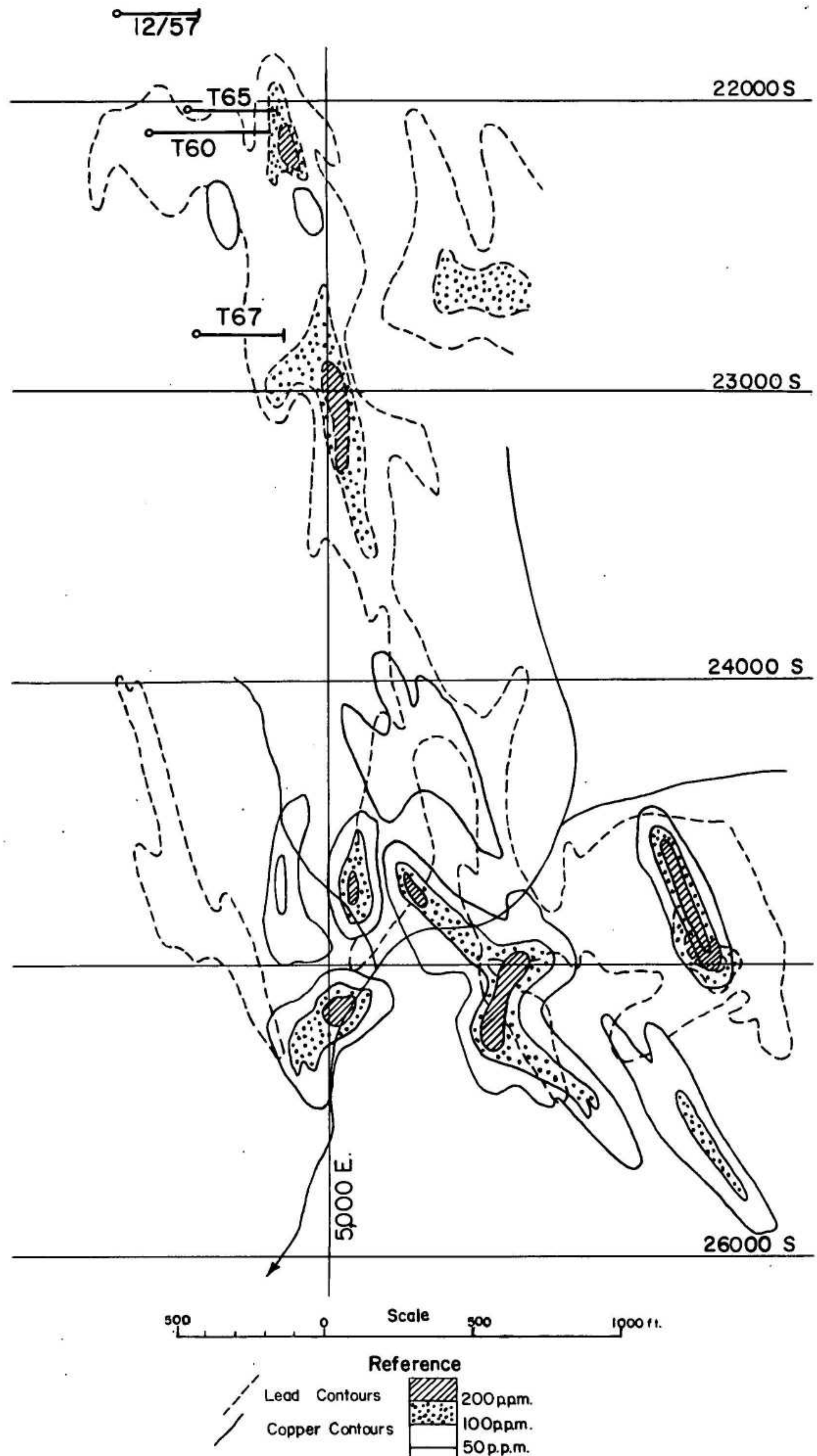
Fig 17 Zinc and Copper Anomalies at Foxlow Gossans.

Fig 18.



D. D. H. No	Target:- Mineralized Sandstone at	Core recovery	Depth Reached	Mineralization Intersected				
				Depth	Thickness	Lead %	Zinc %	Copper %
12/57	——	——	——	——	7	1·54	1·62	——
T60	900'	No Core for 400'	Abandoned at 581'	513'	6	1·3	2·35	0·07
T65	800'	No Core for 400'	Abandoned at 620'	415'	0·5	8·9	5·4	0·65
T67	800'	No Core	Abandoned at 440'	——	——	——	——	——

Bollard Prospect, Geochemical Anomalies and Mineralization.

Compiled from Lake George Mine Pty. Ltd. records by W. Oldershaw.

Bureau of Mineral Resources Geology and Geophysics. To Accompany Record No. 1964/99

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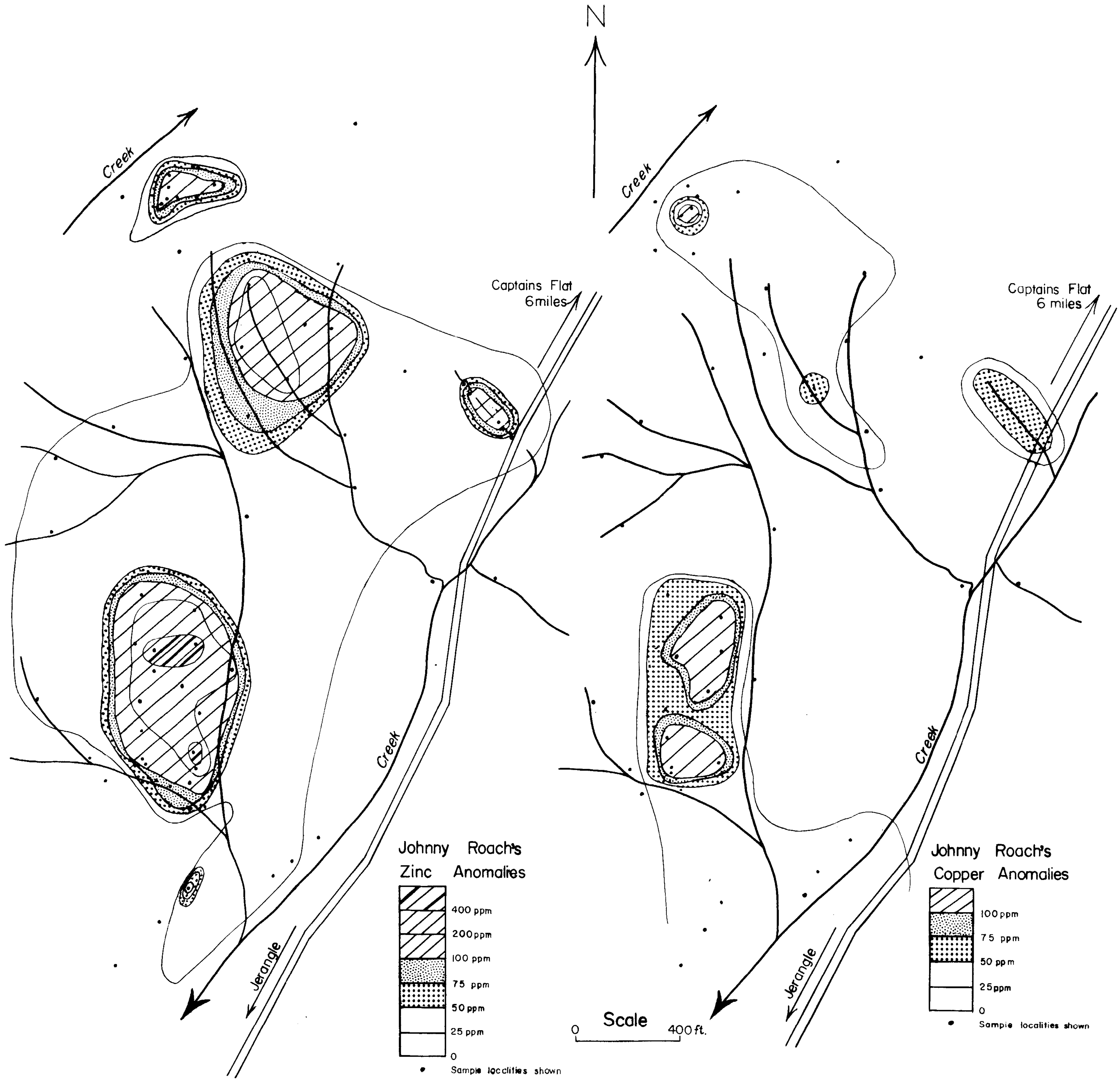

Fig. 19 Johnny Roach's Zinc and Copper Anomalies

base of the volcanics on the western limb of the anticline and is associated with a small geochemical anomaly (120 ppm Zn). The anomaly was drilled (Gourlay DDH No.1), and a few inches of chalcopyrite in graphitic black shale were intersected.

Narongo Gossans

The Narongo Gossans occur in an outlier of Copper Creek Shale containing siltstone and limestone lenses, eight miles south of Captains Flat (Fig.12). The gossans consist of open siliceous limonitic boxworks. They were explored by shafts, costeans, and one drill-hole, but only a few traces of pyrite were found.

The reconnaissance geochemical survey undertaken by the Bureau of Mineral Resources found anomalies of 80 ppm Cu; and the detailed geochemical survey carried out by Lake George Mines Pty Ltd detected anomalies of 50 ppm Cu.

The area has not been mapped geologically in detail and no geophysical surveys have been made. However, there appears to be little probability of extensive mineralization.

Anembo Gossans

Soil samples near the Anembo Gossans contained 1000 ppm Cu, and samples of the gossan contained 800 and 400 ppm Cu. (Fig 9 and Plates 4 & 5).

The gossans are extensive (one measures 300 feet by 150 feet), and attracted early prospectors. They were mapped and drilled by Electrolytic Zinc Co. of A/sia Ltd in 1950 (Company Report). Some pyrite and sphalerite were intersected in the three drill-holes, but not enough to warrant further exploration. The largest gossan is underlain by a limestone lens, and limestone crops out farther south near the other gossans. The gossans were not formed by the weathering of large orebodies but are merely ferruginous precipitates from acid metal-bearing waters passing over, or through, limestone.

Jerangle Gossan

In 1961 Lake George Mines Pty Ltd drilled a geochemical anomaly associated with a small limonitic gossan near a porous silicified limestone in sheared Copper Creek Shale. The area was boggy, drilling conditions were difficult, and core recovery was poor; the hole caved, and only a few traces of mineralization were recovered.

PROBABLE ORIGIN OF THE SULPHIDE MINERALIZATION IN THE CAPTAINS FLAT AREA

Sulphide mineralization in the Captains Flat area is restricted to three shale beds and occurs as:-

1. Large lenses of sulphides in the Keatings Shale Member i.e. Keatings, Central and Elliots orebodies.

2. Replacements in shear zones in the Kohinoor Volcanics

3. Small lenses of sulphides in the Copper Creek Shale and Bullongong Shale Member.

4. Disseminated sulphides in the Copper Creek Shale and the Bullongong Shale Member of the Foxlow Beds.

This mineralization could be:-

1. Syngenetic deposits in the form of
   a. Sulphides disseminated through the Copper Creek Shale and the Bullongong Shale Member.
   b. Minor masses of sulphides deposited with the Copper Creek Shale.
   c. Large lenses of sulphides deposited with the Keatings Shale Member.

2. Epigenetic deposits of various sizes formed by:-
   a. Replacement of favourable beds by hydrothermal solutions from granite.
   b. Lateral secretion, or accretion, of disseminated syngenetic sulphides from :-
      i The Copper Creek Shale,
      ii The Keatings Shale Member,
      iii The Kohinoor Volcanics.

Richards (1962) dated several samples of galena from Keatings, Central, and Elliots orebodies. The ages determined range from 150 m.y. to 310 m.y. and average 300 m.y. - i.e., Middle Carboniferous. However, he states (p.881) 'if the large uncertainties in the model age are taken into account, the value obtained for Captains Flat of 300 m.y. can be happily reconciled with either the Stanton (1960, 1961) model' [syngenetic precipitation of lenses of sulphide ore from sea water along with the surrounding sediments during the Silurian] 'or the earlier ideas (Brown, 1949) of correlation of mineralization with magmatic activity' [Carboniferous].

Syngenetic Mineralization

The strong stratigraphic control of the mineralization suggests that it is syngenetic. Stanton (1960 & 1961) argues that vast quantities of metal halides and sulphur are introduced into the sea during periods of volcanism and that there is a large increase in bacterial activity which could result in the adsorption and fixation of the metals in some form of biogenetic deposit. The Silurian strata at Captains Flat contain volcanics, limestone, and graphitic shales. The mineralization, however, has a strong tectonic control and is not closely associated with the most extensive volcanics.

Many modern marine muds contain traces of metal sulphides; but the formation of large rich lenses of sulphide ore twenty feet thick containing six percent lead and ten percent zinc is difficult to conceive, and no such lenses have yet been discovered in modern marine muds. However, the widespread disseminated sulphides in the Copper Creek Shale are probably syngenetic.

Epigenetic Mineralization

There is a strong structural, as well as stratigraphical, control of the sulphide mineralization in the Captains Flat area. The small lenses of sulphide in the Copper Creek Shale occur near folds, shears, and faults; and Keatings, Central, and Elliots orebodies occur where the Narongo Shears intersect the attenuated Keatings Shale Member.

The main orebodies in the Keatings Shale Member and the small lenses of sulphide in the Copper Creek Shale could be epigenetic deposits formed by the replacement of a favourable bed by hydrothermal emanations moving along shears or faults.

It was thought that the mineralization was due to replacement along shear zones of favourable beds by hydrothermal emanations from Carboniferous granites (Browne, 1949), but recent work by Evernden & Richards (1962), who determined the ages of the local granites by their K/Ar ratios, shows that they are all Silurian-Devonian with an average age of 390 million years. Keatings, Central, and Elliots orebodies are only a mile from Harrisons Peak Granite and from the Rocky Peak Granite; but these granites appear to have been low temperature intrusions, poor in volatiles, and contain no pegmatite veins or vugs, nor any mineralization.

The lenses of sulphides at Captains Flat are part of a belt of sulphide lenses which occur at intervals along the belt of Silurian sediments extending seventy miles from Cowra Creek, south of Jerangle, to Breadalbane, near Goulburn. This widespread mineralization shows no apparent systematic spatial relationship to the granitic masses which crop out in the area, and large volumes of hydrothermal solutions would be required to permeate a belt of rocks seventy miles long.

The sulphide orebodies at Captains Flat and the small lenses of sulphide mineralization scattered through the Copper Creek Shale could have been formed by the lateral accretion of syngenetic sulphides disseminated through the Silurian volcanics and shales. Disseminated mineralization may become unstable under the changes of pressure, stress and temperature induced in the strata by structural disturbance, and may migrate to areas of lower pressure, stress, or temperature - usually areas of stress relief, such as shears, faults, and crests of anticlines. The mode of transport of the sulphides is difficult to conceive; they may move by ionic migration through pore fluids, or by movement of connate water, or by some form of gas fluxing, or by hydrothermal solutions generated by the tectonic disturbance. One attraction of this theory is that the size of the orebody so formed should be proportional to the amount of disseminated mineralization and to the amount of tectonic disturbance.

The most probable source of the sulphides would appear to be the volcanic strata, for it is known that large quantities of metal halides are evolved during volcanic eruptions (Fenner, 1933; Williams, 1962). However, little mineralization and few geochemical anomalies were found in the Kohinoor Volcanics. No mineralization nor geochemical anomalies were found in the overlying Carwoola Beds and very little in the volcanics and shale of the Captains Flat Formation. The mineralization and the geochemical anomalies are restricted to the Copper Creek Shale and to the Keatings Shale Member (see histogram of geochemical anomalies Fig.11); therefore these two shale beds are the most probable source of the sulphides.

Although the Keatings Shale Member is the host rock for Keatings, Central, and Elliots orebodies, it crops out only over a small area around Captains Flat and could not be the source of the lenses of sulphide outside that small area. Lenses of sulphide occur in the Copper Creek Shale at intervals from Jerangle to Bungendore, and thus it would appear that it is the major source of sulphides in the area.

Some attention should be directed towards a study of the tonnages of sulphides disseminated through the Copper Creek Shale Formation and the Keatings Shale Member. From a consideration of their extent, it is estimated that they contain more than 50,000 million and 2000 million tons of shale respectively. Disseminated sulphides occur in the outcrops of shale and if it is assumed that the shales contain one percent by weight of sulphides (Love (1957 p.37) records that some oil shales contain 8 percent of minute pyrite spheres), considerable tonnages of disseminated sulphides are available for aggregation into mineral deposits.

Such a study could lend support to the author's hypothesis that the orebodies are derived by lateral accretion from syngenetic sulphides disseminated through the Copper Creek Shale. These sulphides may have become unstable under changes of pressure and temperature caused by folding and may have migrated to, and aggregated in, areas of relief along faults, shears and the crests of folds. Most of the lenses of sulphide and the geochemical anomalies in the Copper Creek Shale occur at such localities, e.g. the small lens of sulphide intersected along the crest of the Mess Anticline (see Fig.13).

Keatings, Central, and Elliots orebodies lie about 2000 feet above the Hickey Anticline (see Fig.13). This anticline contains a core of over 6000 million tons of contorted Copper Creek Shale. If most of this shale contained one percent of disseminated syngenetic sulphides when it was deposited, then the core of the Hickey Anticline contained 60 million tons of sulphides, some of which could have migrated upwards along the Narongo Shears and the Main Lode Shear into the highly stressed Keatings Shale Member.

Thus in the search for new sulphide orebodies in the Captains Flat area, contorted and sheared Copper Creek Shale and lenses of sheared shale in the Kohinoor Volcanics would appear to be the most promising environments.

POSSIBLE NEW OREBODIES IN THE CAPTAINS FLAT AREA

Repetitions of Keatings, Central, and Elliots orebodies

Keatings, Central and Elliots orebodies developed along the intersections of the Narongo Shears and the Main Lode Shear within the Keatings Shale Member. The orebodies plunge northward at 60° to 70°, and increase in depth northward with the plunge of the Captains Flat Synclinorium (see Fig.13).

It was thought that there would be repetitions of Elliots orebody to the north of the Molonglo Fault, which appears to have downfaulted the ore-bearing zone at least two thousand feet to the north. However, exploratory boreholes drilled from the northern end of the 24 level intersected only a few traces of sulphides in a few feet of sheared shale. Geological mapping indicates that the Keatings Shale Member is sheared out to the north; thus the favourable shale horizon is missing. Furthermore the Narongo Shears appear to flatten at depth and the length of intersection decreases.

There appears to be no possibility of any downward repetition of Elliots, Central, or Keatings Orebodies because the ore-forming structures diverge with depth:-

i. The Keatings Shale Member bends away to the east round the keel of the Captains Flat Synclinorium (Fig.13).

ii. The Main Lode Shear continues downwards into Koh-i-noor Volcanics;

iii. The Narongo Shears bend away to the west as their dip decreases with depth in the mine workings.

The Main Lode Shear persists southwards from the orebodies, but Keatings orebody thins southwards to a few feet thick. The absence of major orebodies to the south of Keatings is due to several factors:-

i. The Keatings Shale Member thickens southwards, and is less stressed.

ii. The steep westerly dip of the member reverses to a steep easterly dip as the shale trends round the keel of the Captains Flat Synclinorium. Thus the intersections of the Narongo Shears with the shale become shorter and less acute.

iii. The Narongo Shears are less numerous southwards.

Thus, as the exploratory holes drilled by Lake George Mines Pty Ltd show (Fig.13), Keatings, Central and Elliots orebodies do not persist downwards, nor are there any repetitions to the north or south.

Vanderbilts Orebody

Vanderbilts orebody is cut off to the north by the Molonglo Fault, which may thus have cut off and downfaulted a possible extension of the orebody to the north. No northern or upper limit of Vanderbilts orebody is known other than the Molonglo Fault. Thus the orebody on Vanderbilt Hill could merely be the bottom of a much larger orebody, the major part of which has been faulted to the north of the Molonglo Fault.

No attempt has been made to find this postulated northern extension under the township owing to the small size of the known orebody and the large throw of over 2000 feet of the Molonglo Fault.

Gravity surveys made across the Newtown Hill Syncline (Sedmik, 1961) closely reflect the structure of the syncline. More traverses farther north would delineate the position and indicate the depth of the Vanderbilt Anticline to the north of the Molonglo Fault and may even be able to detect any mineralization along its crest.

There is a possibility of a repetition of Vanderbilts orebody at a depth of 2000 to 3000 feet below the orebody. Keatings Shear intersects the mineralized Dam Shear within the contorted Keatings Shale Member core of the Vanderbilts Anticline. The thin contorted shale core of the anticline would be a favourable locus for mineralization where intersected by mineralizing shears, for it contains minor mineralization where it crops out on the golf course.

This favourable environment for mineralization may persist to the north of the Molonglo Fault, but it would be thrown down, at least, an additional 2000 feet. Thus lenses of sulphide minerals could have developed where this shale core, containing the Dam Shear, is intersected by Narongo-type shears. However, the Narongo Shears appear to be mainly developed on the overturned western limb of the Captains Flat Synclinorium and may not persist at depth within the core of the synclinorium, or they may flatten out at depth, and not give such long intersections with favourable shale beds as at Elliots orebody.

<u>Forsters Gossans</u>

These gossans (Fig.13) appear to have developed from small lenses (a few feet long) of sulphide along Forsters Shear. Geophysical methods might assist in prospecting the area.

<u>Old Copper Shaft</u>

A spoil heap containing abundant pyrite surrounds the Old Copper Shaft (Fig.12). No geochemical anomalies, gossans, or copper stains in the shear zone were discovered. Geophysical surveys might be useful to prospect the area.

<u>Bollard Anomalies</u>

The Bollard Anomalies (Fig.12) are the largest and most extensive geochemical anomalies in the Captains Flat Area. Some sulphide mineralization was intersected by the four exploratory boreholes drilled into the northern anomalies. These large geochemical anomalies may be due to intensive leaching of small lenses of sulphide scattered through easily permeable host-rocks, or they may be due to the leaching of a major orebody.

The prospect cannot be evaluated until the geology of the area has been mapped in detail, and the complicated structure deciphered. Then the geochemical and geophysical anomalies can be co-ordinated with the geological structure and the exploratory drilling.

Foxlow Gossans

The geochemical anomalies are neither big nor extensive, but the two mineralized springs show that the area contains sulphide mineralization, either as many small lenses a few feet long or as one medium-sized orebody a few hundred feet long. Geophysical surveys over the area may detect some anomalies.

Johnny Roach's Anomaly

The geochemical anomalies, the gossans, and the intense deformation make the prospect appear promising, but detailed geological mapping and geophysical surveying are required before the prospect can be evaluated.

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APPENDIX

TABLE OF GEOCHEMICAL ANOMALIES

The anomalously high reconnaissance sample is tabulated first e.g. 297s, 10 ppm Cu, 400 ppm Zn. Three or four check samples were taken around the reconnaissance sample and are tabulated thus: 4150, 30 ppm Cu, 60 ppm Zn. If the check samples contained low values of copper and zinc, the anomaly was abandoned. If the check samples contained high values, additional check samples were taken around the original check samples until the anomaly was delineated. Sample numbers are shown on the geochemical maps (Plates 2, 3, 4 and 5).

g = sample of gossan
s = sample of salt encrustation
w = sample of water.

The rest are samples of soil from the "B" horizon of the residual soils.

Sample	Result Copper	Result Zinc	Geological Environment	Comment
297s	10	400	Sheared Copper Creek siltstones with some quartz veins & hematite stringers	Minor mineralization in Copper Creek Shales
4150	30	60		
4151	20	20		
4152	10	20		
4153	10	100		
311s		200	Alluvial flat	Contamination from Molonglo River
1390	0	10		
1082	100	20	Sheared Gossans Copper Creek Shale	Foxlow Gossans (see text)
1081	80	10		
1083	80	10		
1785w		10	Mineral Spring	
1126	160	20	Anomaly occurs over small mass of amphibolite	Minor Copper mineralization associated with a minor basic intrusion
1394	100	20		
1398	50	20		
1400	70	30		
1723	200	30	Specimen of amphibolite	
1307	-	1300	Sheared Copper Creek siltstones with small gossans	Jermyn Anomaly (see text)
1308	-	450		
1310	20	330		

Sample	Result Copper	Zinc	Geological Environment	Comment
1346	10	4000	Black Shales in	Contamination by
1559	-	10	Captains Flat	scraps of galvan-
1560	-	10	Formation	ised iron wire
1561	-	10		
1562	-	10		
1563	-	10		
1383	-	100	Over faulted	Possibly contami-
1385	-	20	Kohinoor Volcanics	nated by scraps of
1583	-	10		galvanised iron
1584	-	10		wire
1379	-	200	Overlies sheared	Tiger Cat Creek
1380	10	150	faulted Copper	Gossans
1570w		0.6	Creek Shales con-	(see Text)
			taining gossans	
1414	-	30	Overlies sheared	Minor mineraliza-
w	0.05	0.2	gossanous grey	tion over sheared
s	-	400	shales & siltstones.	shale along
1415	-	100	May be Copper Creek	Ballallaba Fault
1416	-	100	shales or Ordovician.	
1836	-	-	Sediments strike 010°,	
1837	30	20	and are cut by quartz	
1838	20	20	veins striking 010°	
1839	20	10	and 350°	
1842	40	80		
1451	60	1000	Occurs over sheared	Minor mineraliza-
w	0.05	2 ppm	shales & siltstones	tion in shales
1453	20	20	striking 010° and	near Ballallaba
w	0.05	1.0	containing pods of	Fault
1843	30	80	gossan near Ballallaba	
1844	60	20	Fault. May be Copper	
1845	10	10	Creek Shales or Ord-	
1846	40	20	ovician. Quartz veins	
1847	40	30	strike 010° and 350°	
1848	40	20		
1525	250	40	Overlies black slate	Contamination due
3883	10	100	in the Captains	to scrap metal
3882	10	20	Flat Formation	
3884	10	80		
1629	70	30	Overlies weathered	Minor mineraliza-
1626	50	10	Kohinoor Volcanics	tion in Kohinoor
3886	10	50	Quartz vein nearby	Volcanics
3885	10	20		
3887	10	20		
1674	60	20	Overlies Copper	Minor mineraliza-
1677	60	20	Creek shales & thin	tion in sheared
1664	60	10	shale lens in	volcanics and
1665	30	10	Kohinoor Volcanics	shales

Sample	Result Copper	Zinc	Geological Environment	Comment
1909	-	200	Occurs in a shear-zone in Kohinoor Volcanics near an old shaft	Minor mineralization along shear-zone
6058	20	30		
6059	20	20		
6060	10	20		
1957	30	500	Occurs over a fault in the Kohinoor Volcanics a few hundred yards north of the Dam shaft	Minor mineralization along a fault
1956	20	120		
1952	40	20		
1953	30	400		
1981	80	30		
5003	10	20		
5004	20	30		
5005	20	30		
1991	80	30	Iron-stained shear-zone in Kohinoor Volcanics	Minor mineralization along a major shear-zone
4042	30	10		
4041	30	10		
2014	50	30	Overlies Narongo Fault (specimen of fault Breccia 400 ppm Cu)	Minor mineralization along Narongo Fault
2013	30	30		
1076	40	10		
1078	30			
2094	30	1500	Limonitic rubble over limestone in sheared Copper Creek Shale	"Northern Gossans" tested and abandoned by Lake George Mines. Minor mineralization along Narongo Fault
2093	-	200		
3881	10	500		
3888	10	400		
2135	-	100	Faulted Kohinoor Volcanics	Strudwick's Anomaly a small grid survey failed to find any more metal
2133	-	70		
2261	-	200	Sheared Copper Creek Shale with small gossans. Surface limonite rubble resembles that developed over limestone.	Minor mineralization in sheared Copper Creek Shale
4142	-	100		
4143	-	20		
4144	-	30		
4145s	40	1000		
4146	-	20		
4147	20	20		
4148	10	30		
2357	-	1	Occurs over Narongo Shears carrying strong Gossans.	Yorkdale Prospect, trial pits & shafts intersected some lead mineralization. Drilled by Lake George Mine but no significant mineralization was intersected
2355	-	80		
4135		100		
4136	20	150		
4137	10	20		
4138	-	20		
4139	20	100		
4140	20	300		
4141	40	30		

Sample	Result Copper	Result Zinc	Geological Environment	Comment
2395	-	2000	Overlies sheared black and green Copper Creek Shales. White salt encrustations.	Minor mineralization close to Narongo Fault
4130	-	20		
4131	20	30		
4132	10	20		
4133s	20	10		
4134s		100		
2441	-	1000	Overlies contorted Bullongong Shale containing patches and vugs of gossan	Minor mineralization associated with the Narongo Fault
4124	60	20		
4125	40	20		
4126	200	20		
4127	60	60		
4128	80	20		
4129	30	20		
2700w		5	Overlies the Narongo Fault	Mineral spring emerging along the Narongo Fault
2700	10	10		
2694	-	10		
2676	10	10		
2713	20	20		
2654w		1	Overlies Narongo Fault	Mineral spring emerging along Narongo Fault
4156s	20	200		
4156w		0.08		
2653	-	10		
2670	10	10		
2652	-	10		
2655	-	-		
3462	200	20	Close to contact between Copper Creek Shale and Kohinoor Volcanics	Minor mineralization in sheared shale
3963	10	100		
5185	20	150		
3964	20	20		
3965	40	30		
3471g	600	40	Overlies contorted Copper Creek Shale in keel of Captains Flat Synclinorium.	Part of Johnny Roaches Anomaly (see text)
3966	40	30		
3967	40	30		
3968	30	100		
3969	50	150		
3970	20	150		
3971	30	20		
3563	10	120	Contorted Copper Creek Shale in keel of Synclinorium	Minor mineraliztion
5155	10	120		
5156	20	120		
5154	30	30		
3570	60	300	Sheared Copper Creek Shale in keel of synclinorium	Minor mineralization
5141	40	30		
5142	30	30		
5140	20	20		

Sample	Result Copper	Result Zinc	Geological Environment	Comment
3576	20	600	Sheared Copper Creek Shale	Minor mineralization
5143	40	30		
5144	40	30		
5145	40	30		
3582g	1000	50	Gossanous Copper Creek Shale in keel of synclinorium	Gossan
5184g	600	100		
3583	10	-		
3587	20	10		
3586	20	120	Sheared gossanous Copper Creek Shale in keel of synclinorium	Minor mineralization
3582g	1000	50		
5148	80	120		
5149	30	80		
5150	40	20		
3601g	4000	1000	Gossanous Copper Creek Shale near lens of recrystallised limestone	Minor mineralization
5119g	400	30		
3631	-	10		
3639	40	10		
5269	30	-		
5270	60	-		
5271	-	-		
3636	120	-	Stained shear zone in Copper Creek Shale	Minor mineralization
5098	80	10		
5099	40	20		
5100	40	10		
3647	120	10	Contorted sheared Copper Creek Shales on Jinjera in keel of synclinorium	Minor mineralization
5089	100	20		
5090	100	10		
5091	100	20		
5092	40	20		
5093	50	20		
5094	50	10		
3658	250	30	Contorted Copper Creek Shales in the keel of the synclinorium	Minor mineralization
3661	20	120		
3650w	-	0.2		
5081	30	20		
5082	20	20		
5083	30	20		
3683	30	120	Contorted Copper Creek Shale	Minor mineralization
5072	20	20		
5073	20	20		
5074	20	150		
3699	20	300	Contorted Copper Creek Shale	Small shear zone
5169	30	30		
5170	30	20		
5168	20	20		

Sample	Result Copper	Zinc	Geological Environment	Comment
3708	20	200	Contorted Copper Creek Shale	Minor staining
5171	10	20		
5172	20	20		
5173	10	10		
3719	20	120	Contorted Copper Creek Shale	Small gossanous area
5174	20	30		
5175	30	150		
5176	20	30		
3727	20	120	Contorted Copper Creek Shale	
5181	20	20		
5182	10	10		
5183	10	20		
3743	30	120	Small lens of Kohinoor Volcanics in Copper Creek Shale.	Trace of mineralization
3988	-	10		
3989	20	20		
3990	10	10		
3746	60	300	Overlies western contact of a small lens of Kohinoor Volcanics in Copper Creek Shale.	Trace of mineralization
3744	40	120		
3972	30	20		
3973	30	20		
3974	30	30		
3975	20	100		
3976	50	300		
3764	20	750	Contorted Copper Creek Shale and Rutledge Quartzite	Southern part of Johnny Roach's Anomaly (see text)
3760	30	500		
3754	20	200		
3789	10	120	Contorted Copper Creek Shale	Trace of mineralization
5023	10	30		
5024	30	10		
3819g	200	150	Contorted shale	Small gossan. Part of Anembo Gossans (see text)
5330	-	40		
5331	-	-		
3821g	400	2000	Large gossan over Copper Creek Shale with lens of limestone	Main Anembo Gossan. Drilled by Electrolytic Zinc.Corp in 1950. Traces of sulphides, but size of gossan is due to precipitation of limonite by limestone
5359	1000	120		
5360	200	120		
5362	30	120		
3822g	800	200	Sheared volcanics	Small gossan
5353	-	15		
5354	-	25		

Sample	Result		Geological Environment	Comment
	Copper	Zinc		
3846	120	20	Contorted Copper Creek Shale	Trace of mineralization
5116	100	10		
5117	30	30		
5118	80	10		
3855	40	120	Contorted Copper Creek Shale	
5113	20	20		
5114	10	20		
5115	30	10		
3858	80	40	Contorted Copper Creek Shale	Trace of mineralization
5102	500	100		
5103	40	20		
5104	60	10		
3869g	2000	5000	Contorted Copper Creek Shale in south east keel of synclinorium	Small gossan
5066g	1600	750		
5067	40	10		
5068	40	10		
3922	20	100	Overlies thin vein of granite intruding shale	Trace of mineralization. A continuation of 3926
5042	30	20		
5041	20	20		
5043	30	10		
3926	80	20	Overlies thin vein of granite intruding Shale	Minor mineralization
5059	200	10		
5060	60	20		
5061	120	10		
3939	20	80	Overlies Narongo Fault	Trace of mineralization
5028	10	20		
3943	10	100	Overlies the Narongo Fault	Trace of mineralization
5065	20	20		
3958	20	100	Contorted Copper Creek Shale	Trace of mineralization
5085	40	100		
5084	40	20		
5086	30	10		
3980	300	500	Contorted Copper Creek Shale	Johnny Roach's Anomaly(see text)
3984	600	30		
4016	80	120	Occurs over Ballallaba Fault and Copper Creek Shale	Minor mineralization along Ballallaba Fault.
6061	20	20		
6062	30	30		
6063	10	30		
6064	150	300		
6065	10	20		
6066	150	300		

Sample	Result Copper	Result Zinc	Geological Environment	Comment
4063	30	120	Occurs over contact between Kohinoor Volcanics and Copper Creek Shale	Minor mineralization
4117	-	50		
6067	30	30		
6068	30	30		
6069	10	30		
4083	10	120	Overlies sheared Kohinoor Volcanics	Mineralized shear
4088	10	60		
6082	10	30		
6085	10	30		
4120	10	80	Overlies sheared Copper Creek Shale and Rutledge Quartzite	Part of Roach's Prospect. Drilled 1949. Only traces of sulphides were found
4119	10	60		
6077	30	150		
6078	20	30		
6079	40	30		
6080	30	150		
6081	60	120		
4168	40	120	Copper Creek Shale near Narongo Fault	Part of Copper Shear Prospect. Drill holes intersected mineralization (see text)
6131	30	150		
6132	60	150		
6133	60	150		
4171	100	30	Copper Creek Shale	Part of Copper Shear Prospect
4170	20	120		
4172	60	30		
6139	160	30		
6134	100	30		
4180	10	400	Close to small infold of Copper Creek Shale in Kohinoor Volcanics	Part of Copper Shear Prospect
4181	20	30		
4179	10	10		
4187	80	120	Contact of Copper Creek Shale and Kohinoor Volcanics	Part of North Hickey Prospect
4188	160	400		
6144	250	500		
6145	60	300		
4189	60	100	Close to small infold of Copper Creek Shale in Kohinoor Volcanics	Close to Forsters Gossan
6147	60	200		
6146	30	10		
6148	40	150		
4199	30	750	Overlies keel of Keatings Shale Member	Part of Keatings Extended Prospect (see text)
4198	40	300		
6019	20	20		
6023	10	10		
6020	30	100		
6021	150	1500		
6022	10	20		

Sample	Result Copper	Result Zinc	Geological Environment	Comment
4224	100	20	Overlies sheared Kohinoor Volcanics	Part of Gourlay Hickey Prospect. Traces of mineralization found (see text)
6041	100	20		
6042	10	10		
4251	30	150	Occurs over sheared Kohinoor Volcanics close to Waterfall Fault	Minor mineralization along Fault zone
4250	20	80		
6047	10	20		
6048	10	10		
6049	10	10		
4260	30	100	Occurs over contorted Copper Creek Shale in Hickeys Anticline	Form part of Gourlay Hickey prospect. Some Electromagnetic anomalies. One drill hole and trenching gave disappointing results (see text
4261	30	500		
4262	10	250		
6031	30	40		
6032	40	120		
6033	20	40		
6034	20	40		
6035	10	20		
4293	-	70	Overlies mineralized shear zone in Kohinoor Volcanics	Trace of mineralization along the Dam Shear
4292	-	60		
4947	40	150		
4948	40	200		
4949	30	20		
6000	10	20		
4301	80	30	Overlies Keatings Shale Member	Forms northern part of Keatings Extended (see text)
4944	300	80		
4945	30	100		
4946	40	20		
4305	100	40	Overlies Keatings Shale	Forms part of Keatings Extended. Drill holes intersected sulphides (see text)
4304	60	40		
6001	60	20		
6002	100	10		
6003	100	30		
6004	120	100		
4311	80	20	Overlies Keatings Shale	Forms part of Keatings Extended
6017	150	10		
6018	50	20		
4320	20	100	Overlies gossanous sheared Kohinoor Volcanics	Forsters Gossan Prospect (see text)
4321	80	80		
4319	40	100		
6127	20	100		
6126	120	250		
6128	20	10		
6129	180	30		
6130	60	80		

Sample	Result		Geological Environment	Comment
	Copper	Zinc		
4322	100	20	Overlies contorted Copper Creek Shale between Rutledge Quartzite and Kohinoor Volcanics	Part of North Hickey Prospect. Drilled in 1955. 11 feet of 1 percent lead and 3 percent Zn.
4325	50	20		
6123	100	100		
6124	40	10		
6125	40	10		
4519	-	100	Overlies contorted Copper Creek Shale and Rutledge Quartzite	Forms northern part of Bollard Prospect. Drill holes intersected some mineralization (see text)
6052	10	10		
6053	10	20		
6054	10	40		
4524	60	750	Overlies contorted Copper Creek Shale	Part of Bollard Prospect
6055	30	10		
6056	40	10		
6057	40	10		
4541	30	120	Over Kohinoor Volcanics and Narongo Fault. Mineral spring	Part of Gourlay Prospect. Drilled 1961, traces of sulphides (see text)
4541w		5		
6120	30	20		
6121	10	10		
6122	20	20		
4579	120	30	Over Narongo Fault	Trace of mineralization
4924	20	10		
4923	20	10		
4582	30	120	Near outlier of Kohinoor Volcanics	Trace of mineralization
4926	20	10		
4927	20	10		
4928	20	10		
4668	20	300	Near outlier of Kohinoor Volcanics in Copper Creek Shale	Trace of mineralization (gossan)
4930	100	20		
4931	70	20		
4932	20	20		
4779	10	400	Contorted Copper Creek Shale	Trace of mineralization
6229	50	20		
6230	10	30		
6231	10	10		
4802	10	600	Contorted shales	Minor mineralization ½ mile south of prospect pits
4803	10	100		
4804	10	500		
6216	20	50		
6217	10	50		
6221	10	30		
6219	10	30		

Sample	Result Copper	Result Zinc	Geological Environment	Comment
4857	200	20	Contorted shale close to Granite	Trace of mineralization along strike from Narongo Gossans, ¾ mile to the north
4861	30	100		
4859	30	120		
6239	30	150		
6237	10	100		
6236	30	120		
6235	10	20		
4887	80	10	Contorted shales near outlier of Kohinoor Volcanics	Trace of mineralization ¼ mile south of prospect pits
6224	40	10		
6222	30	30		
6225	10	30		
5051	10	200	Contorted shale	Trace of mineralization
5050	-	-		
5049	10	10		
5219	-	5500	Contorted Copper Creek Shale	Part of Bollard Anomaly (see text)
6170	40	1000		
6175	100	1200		
6174	80	500		
5220	270	60	Contorted Copper Creek Shale	Part of Bollard Anomaly
6170	40	1000		
5226	300	300	Contorted Copper Creek Shale	Part of Bollard Anomaly
5225	150	600		
5224	60	60		
5227	170	500		
5231	300	25	Contorted Copper Creek Shale	Part of Bollard Anomalies
5230	150	500		
5279	120	75	Contorted Copper Creek Shale	Part of Bollard Anomalies
6207	40	300		
6259	200	50		
5299g	350	10	Contorted Copper Creek Shale	Gossan from Bollard Anomalies
5301	400	-		
6277	10	100		
6278	60	30		
6093	10	150	Occurs over the Golf course fault in Kohinoor Volcanics	Forms northern Golf course Prospect. This was drilled in 1960 but only traces of sulphides were found.
6094	10	150		
6096	10	100		

Sample	Result Copper	Result Zinc	Geological Environment	Comment
6153	60	1200	Contorted Copper	Bollard Anomalies
6150	40	150	Creek Shale	
6152	40	750		
6154	40	1200		
6194	600	500	Contact of Kohinoor	Trace of minerali-
6195	150	10	Volcanics	zation near
6193	100	120		abandoned pros-
6284	600	50		pect shaft
6251	40	300	Contorted Copper	Part of Bollard
6211	10	150	Creek Shale	Anomalies
6252	80	30		
6250	30	300		
6259	200	50	Contorted Copper	Part of Bollard
5280	60	-	Creek Shale	Anomalies
5281	50	-		
5279	120	75		
6281	300	25	Contact between	Trace of minerali-
6190	-	30	Copper Creek Shale	zation.
6197	15	60	and Kohinoor	
			Volcanics.	


GEOLOGICAL MAP
CAPTAINS FLAT AREA
Scale
1 Miles
Geology 1961-2 by W. Oldershaw G.R. Pearson E.G. Wilson C.M. Gregory
Compiled 1962 by W. Oldershaw
Drawn by R.J. Pennington and A. Tatarow
Reference
CAINOZOIC QUATERNARY Undifferentiated Alluvium
PALAEOZOIC
PERMIAN ? Pg Gravel
SILURIAN TO DEVONIAN
Harrison Peak Granite gbx Biotite granite
Rocky Peak Granite gho Hornblende-biotite granite
a Amphibolite
SILURIAN
Captains Flat Formation Suf Shale
Sinclair Conglomerate Member Sufc Conglomeritic reworked lithic tuff
Suft Reworked lithic tuff
Sufb Basalt
Sufd Dacite
Yandyguinula Member Sufy Alternating thin beds of siltstone and shale
Carwoola Beds Suwa Shale
Suwb Alternating thin beds of shale and argillaceous sandstone
Kohinoor Volcanics Smk Porphyritic dacite flows tuff agglomerate welded tuff
Keating Shale Member Smks Shale
Copper Creek Shale Smc Siltstone, graphitic shale, shale limestone, minor tuff
Rutledge Quartzite Smr Quartzite conglomerate
ORDOVICIAN
Undifferentiated Os Siltstone shale greywacke
Bullongong Shale Oub Siliceous black shale
Od Dacite
Geological boundary
Anticline
Syncline, showing plunge
Plunge of minor anticline
Plunge of minor syncline
Plunge of drag fold
Plunge of fold axis
Measured plunge of fold axis
Fault, showing relative horizontal movement
Fault breccia
Where location of boundaries, folds and faults is approximate line is broken; where inferred, queried; where concealed, boundaries and folds are dotted, faults are shown by short dashes
Strike and dip of strata
Prevailing strike and dip of strata
Strike, dip not determinable
Vertical strata
Horizontal strata
Generalized strike and dip of undulating strata
Trend of bedding
Strike and dip of foliation
Prevailing strike and dip of foliation
Graded bedding
Strike, dip not determinable
Vertical foliation
Strike and dip of cleavage
Prevailing strike and dip of cleavage
Vertical cleavage
Apparent dip of bedding on cleavage plane
Apparent dip of cleavage on bedding plane
Strike and dip of joints
Prevailing strike and dip of joints
Dyke or Vein; d-dolerite, Fe-Iron, j-jasper, q-quartz
Abandoned Mine
Prospect
Quarry
Scarp
Road
Vehicle track
Railway
Fence
Building
Trigonometrical Station
Dump
SECTION
Natural Scale V/H = 1
A
B
Copper Creek
Molonglo R
Jinero Creek
3000ft.
2000ft.
1000ft.
Sea level
Narongo Fault
Ballallaba Fault
Hoskinstown
Carwoola
Spire
Molonglo River
Primrose Valley Cr.
Grose Meadow
Rutledge
Foxlow
Lake
Yandyguinula Cr.
Forbes Creek
Thurlilly Creek
Thurlilly
Sinclair
Silver Hills
Ballallaba Cr.
Harrisons Peak
Molonglo Fault
Tiger Cat Creek Fault
Lake George Mine
Captains Flat
Copper Creek
Narongo Fault
Ballallaba Fault
Golfcourse Fault
To Braidwood
To Jerangle and Cooma
To Queanbeyan and Bungendore
149°22'
149°25'
149°30'
35°25'
35°30'
35°31'
35°35'
35°38'


PLATE 2
GEOCHEMICAL SURVEY of the CAPTAINS FLAT AREA.
COPPER CONTOURS.
Contours at 15, 25, 50, 75, and 100 ppm
2014 = Sample Number
(50) = value in ppm
The anomalies are referred to by the sample with the highest value.
GEOLOGICAL SUCCESSION
SILURIAN
CAPTAINS FLAT FORMATION
Dacite tuff
KOHINOOR VOLCANICS
KEATINGS SHALE MEMBER
COPPER CREEK SHALE
TN
1/2 Mile
Yandyguinula Creek
1674 (60)
1629 (70)
GROSE MEADOW
Molonglo River
1525 (250)
THURLILLY
"Foxlow"
SINCLAIR
2014 (50)
1126 (160)
1082 (100)
FOXLOW GOSSANS
"Silverhills"
Ballallaba Creek
HARRISONS PEAK
JERMYN ANOMALY
Tiger Cat Creek
CAPTAINS FLAT
TIGER CAT CREEK ANOMALY
LAKE GEORGE MINE
Not Sampled
1850 (100)
4171 (100)
4283 (200)
4322 (100)
1991 (80)
4305 (100)
4311 (80)
4224 (100)

PLATE 3
GEOCHEMICAL SURVEY of the CAPTAINS FLAT AREA.
ZINC CONTOURS.
Contours at 15, 25, 50, 75 and 100ppm
2094 = Sample Number
(1500) = value in ppm.
The anomalies are referred to by the sample with the highest value.
GEOLOGICAL SUCCESSION
CAPTAINS FLAT FORMATION
DACITE TUFF
SILURIAN
KOHINOOR VOLCANICS
KEATINGS SHALE MEMBER
COPPER CREEK SHALE
T.N.
½ mile
Yandyguinula Creek
GROSE MEADOW
Molonglo River
THURLILLY
"Foxlow"
SINCLAIR
"Silverhills"
Foxlow Gossans
Ballallaba Creek
HARRISONS PEAK
Tiger Cat Creek
JERMYN ANOMALY
TIGERCAT CREEK ANOMALY
CAPTAINS FLAT
LAKE GEORGE MINE
Not Sampled
2700 (5)
2654 (1)
1451 (1000)
311 (200)
297 (400)
1414 (2ppm)
1785 (10)
2094 (1500)
2135 (100)
2261 (200)
4140 (300)
2357 (1)
2395 (2000)
1307 (1300)
1346 (4000)
1383 (100)
1379 (200)
2441 (1000)
4168 (120)
4180 (400)
4189 (100)
4187 (120)
4293 (70)
1957 (500)
1909 (200)
4320 (100)
4016 (120)
4199 (750)
4063 (120)
4120 (80)
4541 (120)
4262 (250)
4260 (100)
4251 (150)
6093 (65)
4083 (120)

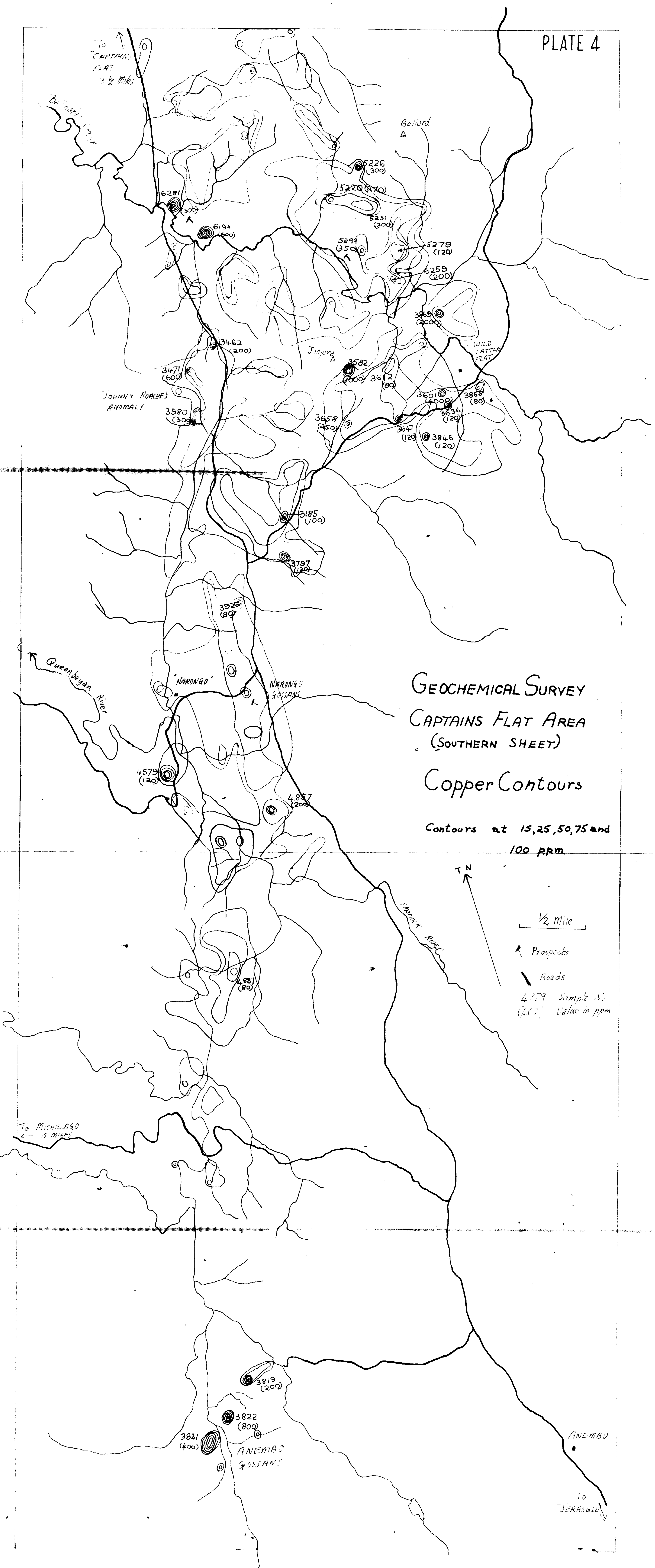
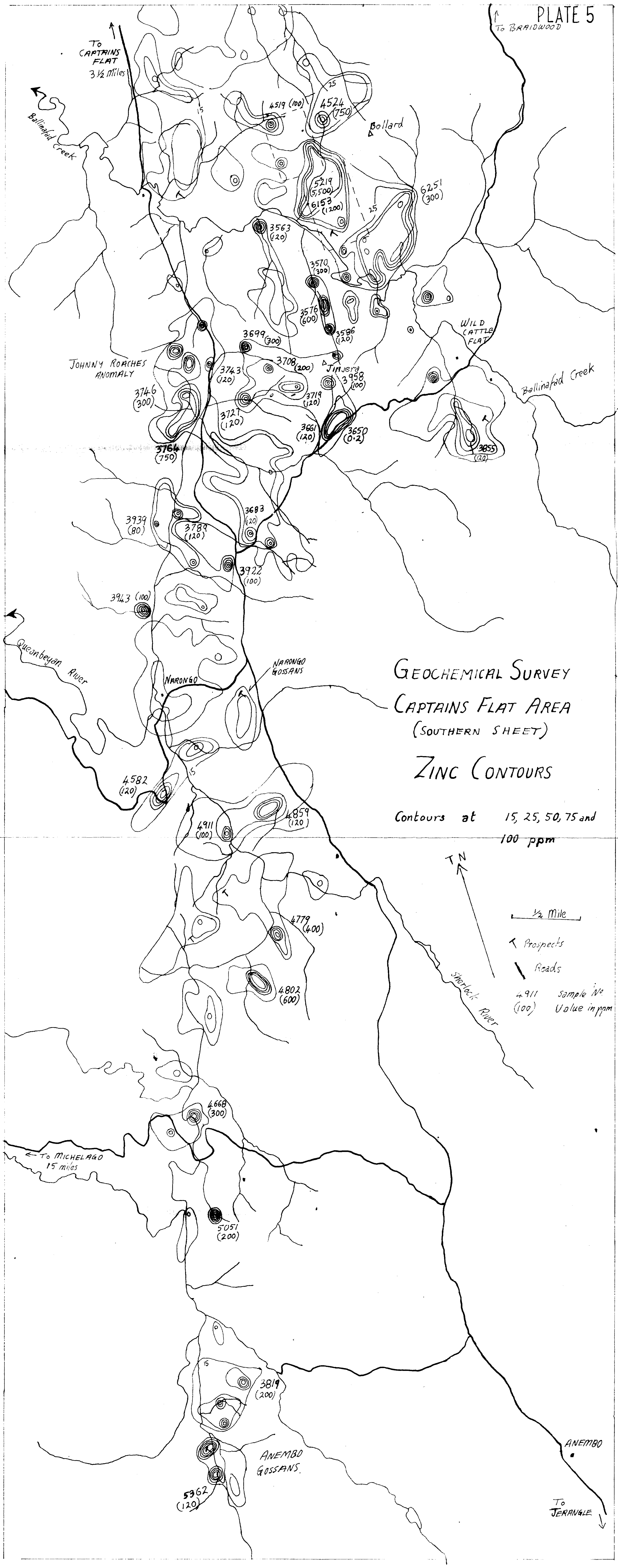


PLATE 4
To "CAPTAINS FLAT" 3½ Miles
Bollard
5226 (300)
5220
6281
6194 (600)
5231 (300)
5299 (350)
5279 (120)
6259 (200)
Jinjera
3462 (200)
3471 (600)
3582
3612 (80)
3601 (4000)
3858 (80)
3636 (120)
3647 (120)
3846 (120)
WILD CATTLE FLAT
JOHNNY ROACHE'S ANOMALY
3980 (300)
3658 (250)
3185 (100)
3797 (120)
(80)
Queanbeyan River
"NARONGO"
NARONGO GOSSANS
4579 (120)
4857 (200)
Shoebrook River
4887 (80)
To MICHELAGO 15 MILES
3819 (200)
3822 (800)
3821 (400)
ANEMBO GOSSANS
ANEMBO
To JERANGLE
GEOCHEMICAL SURVEY
CAPTAINS FLAT AREA
(SOUTHERN SHEET)
Copper Contours
Contours at 15, 25, 50, 75 and 100 ppm.
TN
½ Mile
Prospects
Roads
4779 Sample No.
(400) Value in ppm

PLATE 5



GEOCHEMICAL SURVEY
CAPTAINS FLAT AREA
(SOUTHERN SHEET)
ZINC CONTOURS

Contours at 15, 25, 50, 75 and 100 ppm