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DEPARTMENT OF
MINERALS AND ENERGY

# BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD NO. 1971/56



## GEOLOGY OF THE MARRABA 1:100 000 SHEET AREA QLD.



by



G.M. DERRICK
I.H. WILSON, R.M. HILL,
J.E. MITCHELL

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*Initials indicate chief authors of various sections; however most sections have been written from contributions by all authors.

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## APPENDICES

Appendix 2 - Geochemistry

## SUMMARY

The Marraba 1:100 000 Sheet area, No. 6956, lies between latitudes 20°30' and 21°S, and longitudes 140° and 140°30'E, in northwest Queensland. The townships of Cloncurry and Mary Kathleen lie near the eastern and western margins of the Sheet area, respectively.

Most of the area contains Proterozoic rocks of probable Carpentarian age, 1 800 to 1 400 m.y. old. The oldest unit is the Argylla Formation, a sequence of acid lava, crystal tuff, and metasedimentary rocks which forms the core of two broad anticlines along the southern Sheet boundary, and also a narrow belt along the western Sheet boundary. In the centre of the Sheet area it is overlain by basalt (Marraba Volcanics) and quartzite (Mitakoodi Quartzite), but in the west these units are absent and the Corella Formation, a widespread diverse unit of mainly carbonate-rich and calc-silicate granofels overlies the Argylla Formation unconformably. In the centre of the area, the Corella Formation appears to be conformable on the Mitakoodi Quartzite, the transitional beds from quartzite to limestone being a jaspilite-limestone sequence known as the Overhang Jaspilite. The Marimo Slate flanks the eastern limb of the Mitakoodi Quartzite anticline and is considered to be a facies equivalent of the Corella Formation.

The Roxmere Quartzite overlies the Corella Formation and the Marimo Slate disconformably, and is the youngest Carpentarian unit in the Sheet area. In the central north the Quamby Conglomerate of probable Adelaidean age forms a narrow graben filling. The Mitakoodi Quartzite and older rocks are thought to be shallow shelf or near-shore deposits; the Corella Formation was probably laid down on a shallow shelf characterized by little detrital sedimentation and local depressions of restricted circulation.

All these units, except the Roxmere Quartzite, are intruded by granite and basic rock, although the Wonga Granite in the west is possibly older than the sedimentary succession. The first major period of deformation and metamorphism affecting the area produced broad, open folds with north-trending axes; low pressure regional metamorphism, which reached the middle amphibolite facies, took place at the same time. Minerals such as diopside, andalusite, garnet, vesuvianite, cordierite, actinolite, epidote, and scapolite formed in the impure carbonate or pelitic sequences of the Corella Formation.

Continued deformation produced major northeast-trending dextral strike-slip faults in the west, and was accompanied by widespread intrusion of dolerite sills and dykes. Intrusion of the syn or post-kinematic Naraku and Burstall Granites caused extensive cross-folding in the whole succession, and particularly in the Corella Formation, and produced contact aureoles containing cordierite-anthophyllite hornfels and calc-silicate skarns. Widespread brecciation of the Corella Formation accompanied the cross-folding.

Copper mineralization throughout the Sheet area is related mainly to dolerite dykes and sills, particularly where they intrude the Marraba Volcanics and Corella Formation. Numerous small fissure deposits of copper

in the Marimo Slate are probably a result of leaching of trace amounts of copper from the slate during metamorphism; subsequently deposition of copper minerals took place in shear, fold, and fault-zones, especially those in carbon-rich parts of the formation. Some copper deposits are related to the Burstall Granite; other in the west are commonly located near the Corella Formation-Argylla Formation contact. Hydrothermal fluids associated with the copper mineralization may have been especially saline as a result of metamorphism of possible evaporitic metasediments and their incorporation in igneous rocks.

Economic limestone deposits have been formed in the Corella Formation through recrystallization, movement, and precipitation of carbonate during metamorphism. Uranium, the most valuable metal in the Sheet area, is found at Mary Kathleen, where it is related to the Burstall Granite. The slate deposits of the Marimo Slate and Corella Formation contain minor traces of lead and zinc, but no syngenetic ore-bodies have been found in these rocks.

Supergene enrichment in mineralized zones has been a major factor in the upgrading of most deposits in the area.

Uplift associated with the intrusion of the younger granites was followed by a continued period of erosion and some faulting. The Quamby Conglomerate represents a graben deposit in a relatively stable continental environment. Much of the Cambrian sequence in the area has been eroded through uplift and reactiviation of old faults. Mesozoic strata overlie some of the Proterozoic rocks, most of which have been exposed to erosion from the late Mesozoic or Tertiary to the present.

# GEOLOGY OF THE MARRABA 1:100 000 SHEET AREA, NORTHWEST QUEENSLAND

## INTRODUCTION

### Location

The Marraba 1:100 000 Sheet area, No. 6956, lies between latitudes 20°30' and 21°S, and longitudes 140° and 140°30'E, in northwest Queensland. It forms part of the Cloncurry 1:250 000 Sheet area SF/54-2.

The township of Cloncurry, situated 1.6 km east of the eastern Sheet boundary, is 1 760 km by road from Brisbane, and 125 km from Mount Isa (Fig. 1).

### Object

Detailed geological mapping carried out by members of the Bureau of Mineral Resources (BMR) and the Geological Survey of Queensland (GSQ) from May to October 1969 had the following objectives:

(1) present a detailed geological map at 1:100 000 scale of the Precambrian outcrops

(2) reassess the stratigraphy, structure, petrology, and economic geology of the region, with particular reference to the work of Carter et al (1961)

(3) study in detail the types of controls of mineralization, and

(4) undertake a geochemical examination of various rock units, and detailed stream and/or soil geochemical examination in selected areas.

### Access

The main access routes are the Barkly Highway, a sealed road joining Cloncurry with Mount Isa; the Cloncurry-Duchess road, a gravel road with some sealed sections; and the Cloncurry-Quamby road in the northeast. The most important of the numerous gravel tracks are the old Mount Isa road across the northern part of the sheet area; and the Slaty Creek-Duck Creek track which traverses east-west the entire southern part. The long history of mining in the area has resulted in a network of miner tracks, most of which are suitable only for 4-wheel-drive vehicles.

The Townsville/Cloncurry/Mount Isa railway passes through the southeast part of the area, and the Cloncurry-Kajabbi railway through the northeast.

Population and Industry

The townships of Cloncurry (population 2 600) and Mary Kathleen (population about 50) lie just outside the eastern and western boundaries of the Sheet area, respectively. Most of the population lives in the homesteads of Timberu, Chumvale, Jersey Plains, Carsland, Lanark, and Corella Park, and the railway sidings of Ginburra, Dolomite, Marimo, etc. About fifty semi-permanent miners work the numerous small mines in the area.

Mining and cattle-raising are the major industries, but road construction and railway maintenance also provide employment.

Climate

The area is characterized by a semi-arid tropical climate, with warm to hot summers and warm to cool, dry winters. The area lies between the 370 mm and 485 mm rainfall isohyets; rainfall is highest in the north and northwest. The rain is monseonal, and falls mainly between November and March, but there may be minor falls, up to 45 mm, in the winter.

Average maximum temperatures for Cloncurry during summer and winter are 31.8°C and 26°C, respectively, and the average minimum temperatures, 19°C and 10°C for summer and winter, respectively; local frosts have been recorded in winter. More detailed accounts of climate of the area are given by Slatyer (1964) and Carter et al (1961).

Vegetation and Pastures

The whole area, except the southeast and northeast, supports low stunted eucalypts 3 to 8 m high, some acacia scrub, scattered kurrajong trees, and abundant spinifex. The southeast and northeast parts also contain clumps of gidyea and bauhinia and greater amounts of pasture grasses. Along the larger watercourses, large red gums and ti-trees (paperbark) are common.

Timber resources throughout the area are small, mainly because of earlier extensive exploitation for mine timber. During 1969 in the Cloncurry area, gidyea scrub was used as stock feed because of severe drought.

Detailed accounts of vegetation and pasture throughout the area are given by Perry & Lazarides (1964) and Carter et al (1961).

Surface water

Surface water is found in waterholes in the major watercourses (Cloncurry, Corella, and Cameron Rivers, Slaty and Duck Creeks), Lake Corella in the southwest, and in scattered small dams. In 1969 surface water was virtually non-existent in the streams and only rare deep rockholes contained

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# LOCALITY MAP

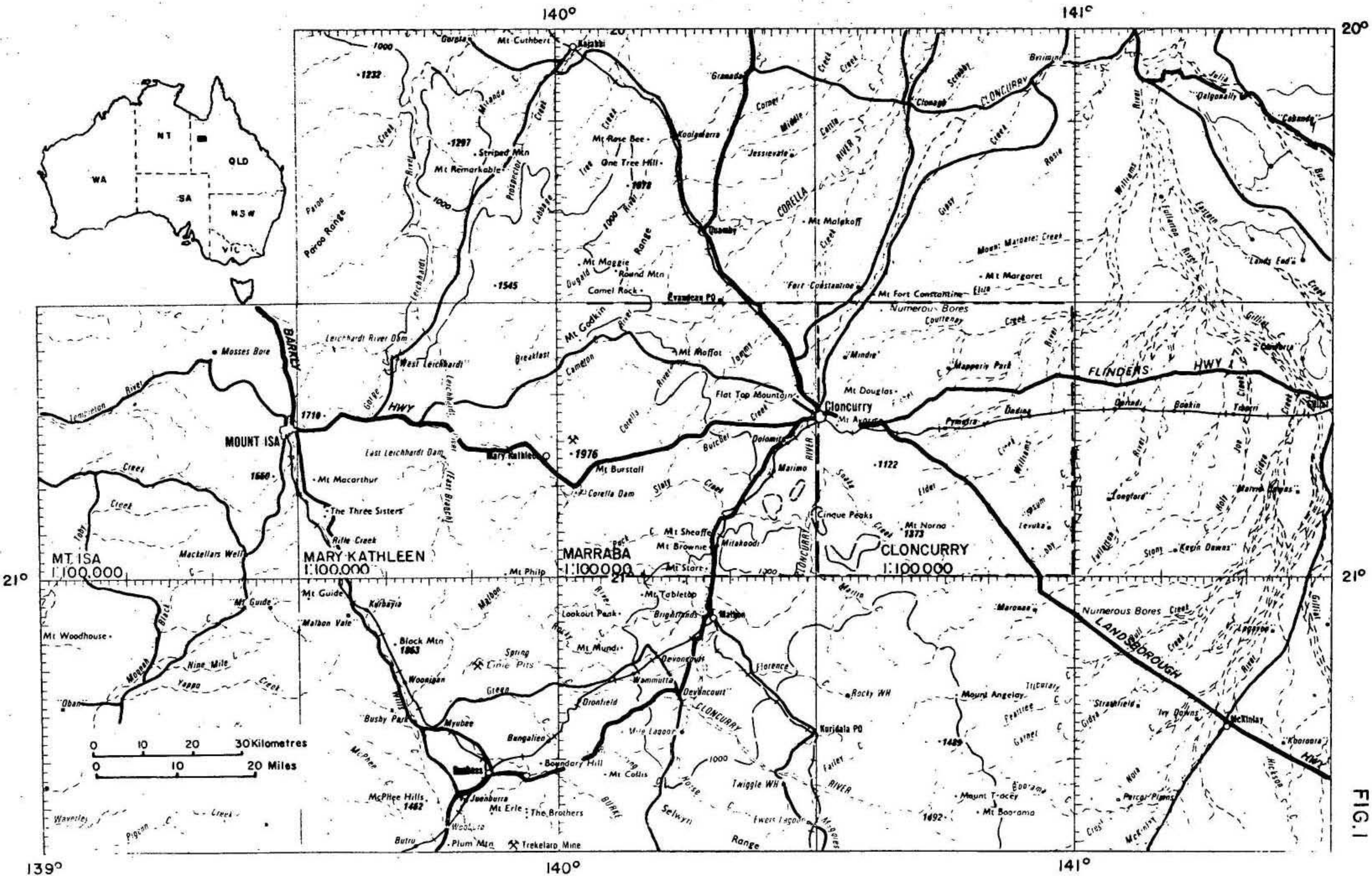


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FIG. 1

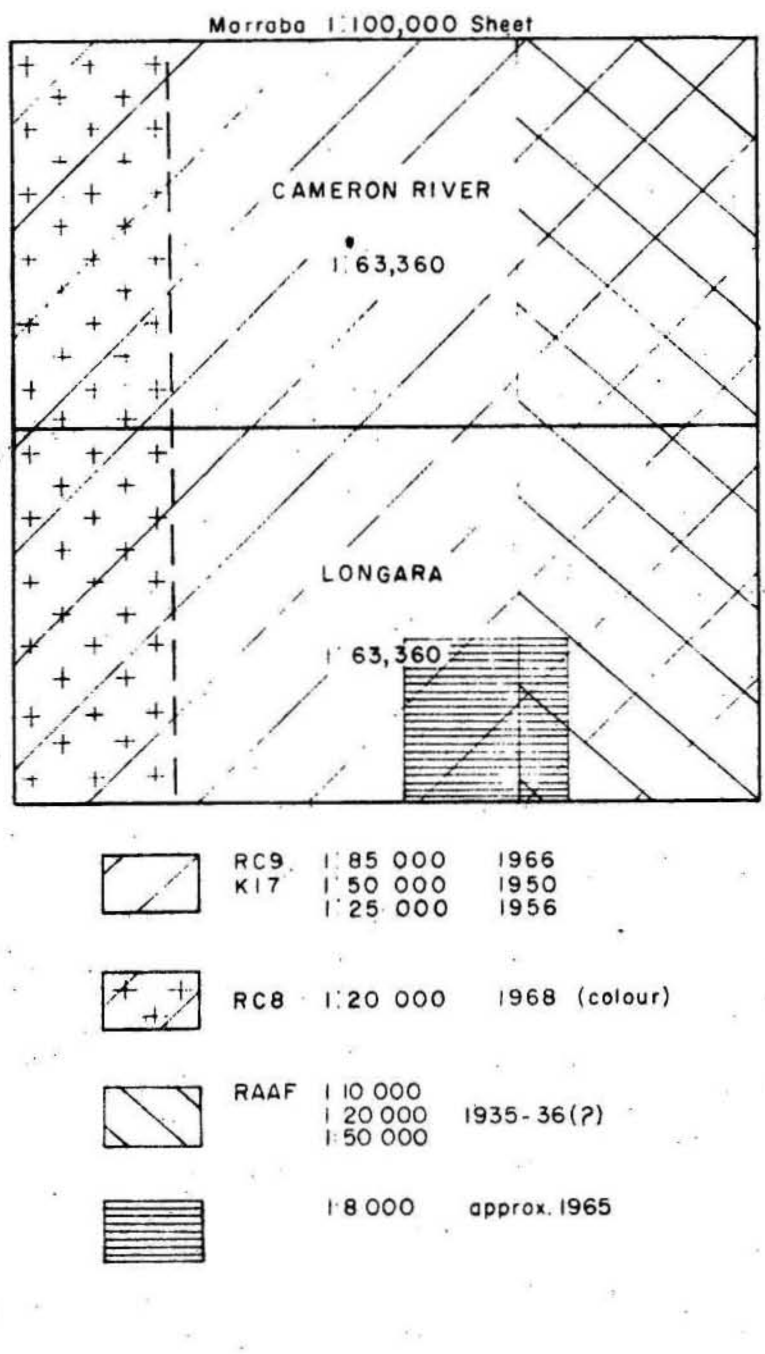


Fig.2. Aerial photo coverage, Marraba 1:100 000 Sheet

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water, usually in areas of little pastoral use. Underground water, raised by windmills and powered pumps from bores 5 to 60 m deep, sustains the pastoral industry most of the time. In 1969, drilling by pastoralists with cable-tool equipment in the Cameron River area 10 km north of Mary Kathleen produced a number of dry holes.

Lake Corella, a dam of permanent water on the Corella River, supplies the Mary Kathleen township 10 km to the northwest. Bores in the Cloncurry River provide an inadequate supply of water for Cloncurry; plans for a new twon water supply dam on Slaty Creek were discussed by State Government agencies during 1969, and investigation has continued at a site about 8 km upstream from the Slaty Creek-Cloncurry River junction.

## Previous Literature

A comprehensive list of geological work in the whole Precambrian belt of northwest Queensland before 1960 is in Carter et al (1961, pp 25-30). Most of this material is relevant to the Marraba Sheet area but is not duplicated here. More recent geological works are listed in the bibliography of this Record.

In sections where it is relevant to discuss the previous literature, an introductory statement is included. Such sections can be found at the beginning of most formation descriptions in the Stratigraphy section and at the beginning of the Economic Geology Section.

## Present Investigation

This Record presents the results of mapping by five geologists, four from BMR (G.M.D., A.Y.G., R.M.H., J.E.M.), and one from GSQ (I.H.W.). Closely spaced Landrover and extensive foot traverses covered the area. The base camp for the survey was located on the Cloncurry River, 5 km south of Cloncurry. Glikson mapped some areas of the Marimo Slate near Slaty Creek, but was occupied mainly with mapping the adjoining Cloncurry 1:100 000 Sheet area to the east.

The following air-photographs and maps covering all or part of the Sheet area were available in May 1969:

### Air-photographs

(1) RC9, 1:85 000, 1966, 6 800' = 1", flown by Adastra

(2) RC8, 1:20 000, 1968, 1 600 = 1", flown in colour by QASCO

(3) 1:25 000, 1956, 2 000' = 1" flown by Adastra

(4) K17, 1:50 000, 1950, 4 000' = 1", flown by the RAAF.

### Maps

(1) 1:250 000 scale topographic map, compiled in 1961 from 1950 air-photographs by Royal Australian Survey Corps

(2) 1:50 000 scale topographic base maps of the 1:63 360 scale Cameron River and Longara Sheet areas, compiled in 1960 by the Royal Australian Survey Corps

(3) Planimetric lease plan maps compiled from 1:25 000 scale 1956 air-photographys covering Cameron River A and C and Longara A areas at 1:31 680 scale and Beaconsfield and Slaty Creek Sheet areas at 1:50 000 scale. These are available from the Department of Mines, Brisbane (Fig. 2b & c).

(4) Lease map at 6 miles = 1 inch scale (2nd edition) of the Cloncurry/Mount Isa district, published by the Department of Mines, Brisbane

(5) Airphoto-mosaics, compiled from 1:25 000 scale photography at 1:32 000 and 1:63 360 scales, available from the Surveyor-General, Brisbane.

Since the field work was completed, base maps at 1:100 000 scale have been produced by the Division of National Mapping from 1966 air-photos at 1:85 000 scale.

The distribution of photographic coverage and the relationship between the various map areas in the Marraba 1:100 000 Sheet are shown in Figures 2 and 3. The distribution for the Cloncurry 1:250 000 Sheet area is presented in Derrick (1969).

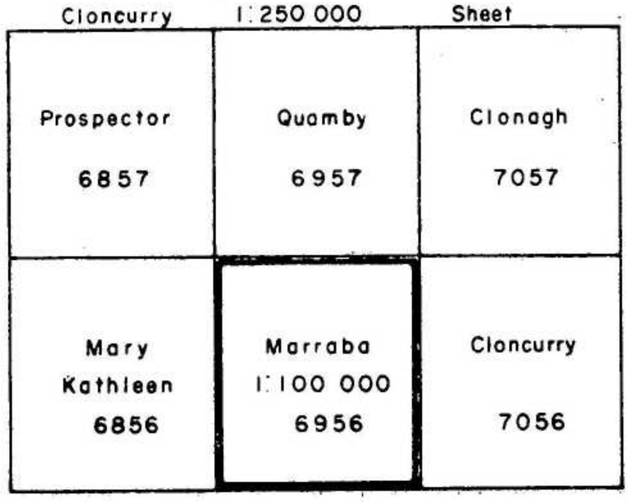
Detailed mapping of the Marraba area was carried out using the 1956 air-photographs at 1:25 000 scale. Colour aerial photography at 1:20 000 scale was used in mapping the western part of the area. Transparent overlays of the geology were plotted on topographic bases enlarged from 1:50 000 to 1:25 000 scale.

## GEOMORPHOLOGY

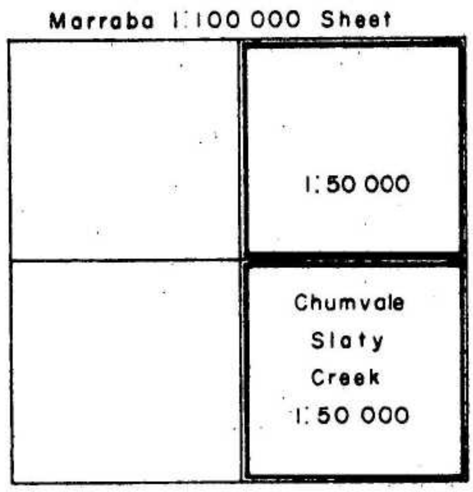
The Sheet area falls within the southwest part of the Leichhardt-Gilbert area, whose geomorphology is described by Twidale (1964). He recognizes three physiographic divisions, two of which are represented in the Sheet area (Fig. 4): a. Isa Highlands, and b. Carpentaria and Inland Plains.

### a. Isa Highlands

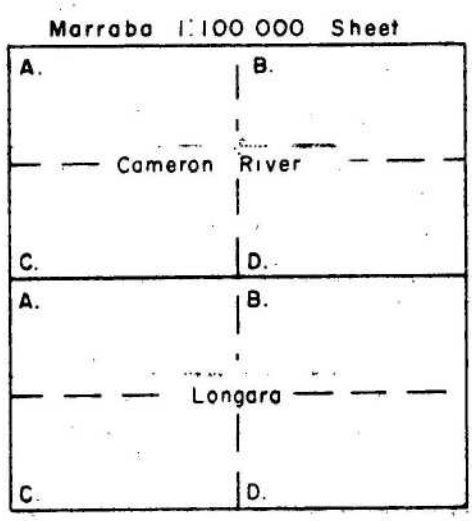
The Isa Highlands consist of Precambrian igneous and metasedimentary rocks, and form an elevated block 200 m to over 500 m above sea level. Mount Burstall, north of Lake Corella, is 540 m above sea level. Relief throughout the highlands is extremely variable e.g. from 250 to 10 m and is influenced by the interbedding of resistant quartzites, granites etc. with more easily eroded rocks; within quartzite units (e.g. Mitakoodi Quartzite) the weathering




(a) Relationship between 1:100,000 and 1:250,000 Sheets.

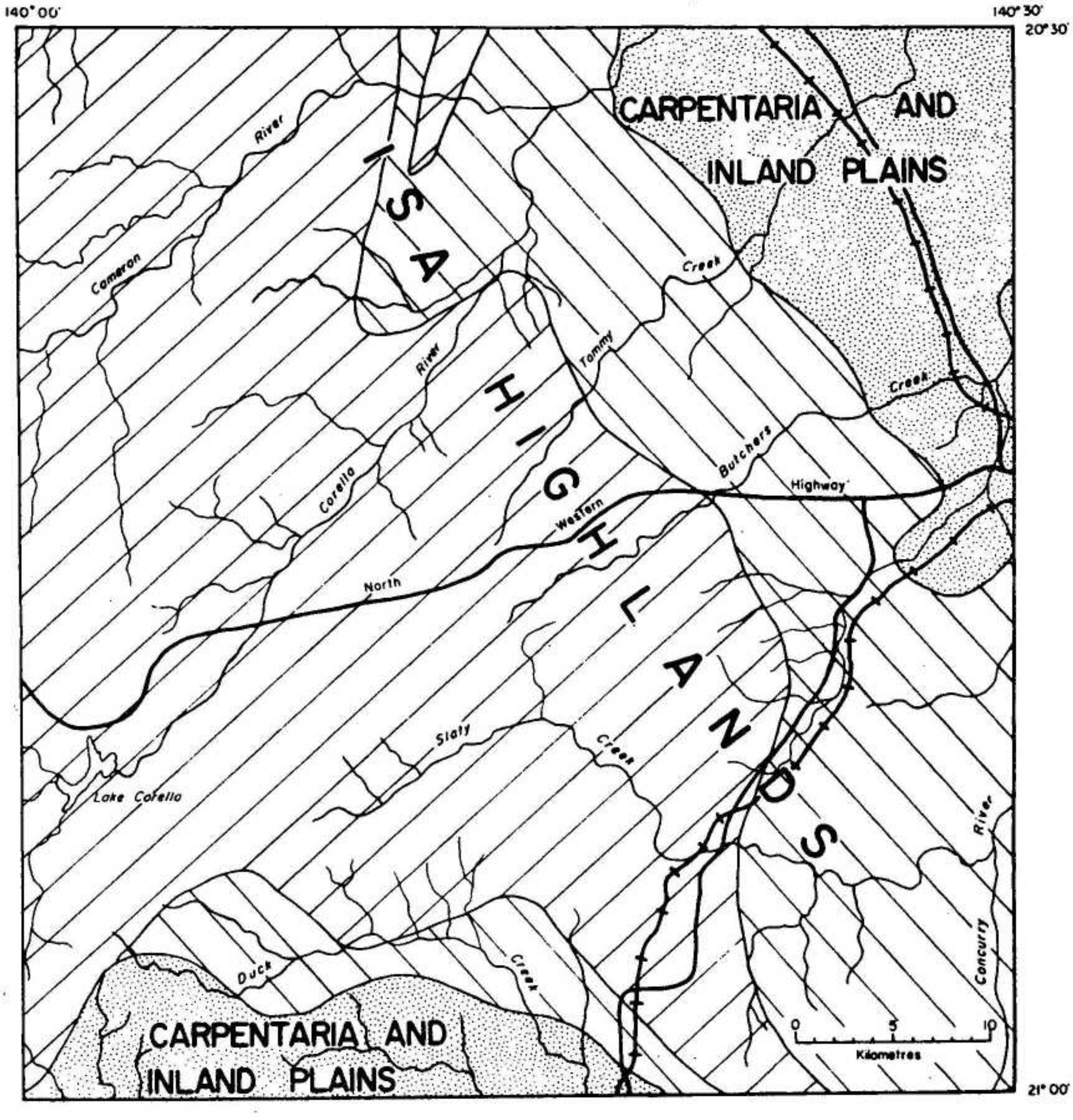



(b) Relationship between 1:100 000 and 1:50 000 Sheets




(c) Relationship between 1:100 000 and 1:63 360 Sheets

Fig 3. Relationships between various map sheets, Cloncurry area




PHYSIOGRAPHIC DIVISIONS

ISA HIGHLANDS

CARPENTARIA AND INLAND PLAINS

GEOMORPHOLOGICAL UNITS

Maturely dissected plateaux and high plains — Lesser maturity / Greater maturity

Plains of erosion

Fig 4. Physiographic and Geomorphological Sketch Map, Marraba 1:100 000 Sheet area

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of dykes has produced an irregular system of narrow steep-sided valleys and gorges. Carter et al (1961) noted that juxtaposition by faulting of blocks of different erosional characteristics also influence relief and drainage. Twidale (1964) noted that upthrust structures generally form high ground, and down-faulted structures low ground, but this is so only locally; for example the graben of Quamby Conglomerate is topographically high, but has relief of up to 100 m.

The Isa Highlands are further divided by Twidale into immaturely dissected plateaux and high plains, and maturely dissected hill country. Hill country occupies most of the Sheet area (Fig. 4), and dissection increases from the west to the northeast, east and southeast.

b. Carpentaria and Inland Plains

These broad plains lie in the northeast where the average elevation is 170 to 190 m above sea level, and in the central south where the plains are higher (280 to 320 m) and less mature.

Erosion Surfaces

Three erosional surfaces were recognized by Twidale: a. pre-mid-Mesozoic, b. early to mid-Tertiary, and c. late Tertiary-Quaternary.

The Sheet area contins remnants of all three surfaces, of which the pre-mid-Mesozoic surface is the most extensive. Cretaceous cappings preserved 3 km northwest of Cloncurry (Table Top) and 3 km west of Marraba are products of cycles b and c; the dissection of the Cretaceous sediments and the mid-Tertiary laterite surface followed uplift in the Miocene and consequent stream rejuvenation.

Apart from the lateritized cappings in the Sheet area there is little indication of lateritization in the Precambrian belt. Possibly the only remnants of the laterite profile are zones of silicification in slate and quartzite in the Marraba-Slaty Creek area, where ridge tops and narrow plateaux of the Mitakoodi Quartzite and Marimo Slate are highly silicified, as are low-lying quartzites in the Marraba Volcanics. In a broad belt stretching from the Cloncurry River in the southeast to the Corella River, this zone of silicification appears to be an undulating surface which rises over quartzite and is depressed over other rock types. One km east of the Cloncurry River in the southeast, slate immediately underlying Mesozoic capping is highly altered, ferruginized, and leached.

Land Systems

These were described by Perry and Lazarides (1964). Those within the Marraba Sheet area are the Kuridala, Argylla, and Quamby Land Systems, examples of which are shown in Figures 5, 6, and 7.

## Drainage

All streams drain northeastwards and eastwards into the Cloncurry River. Those in the northern half of the Sheet (e.g., Corella and Cameron Rivers, Tommy Creek) are partly or wholly fault-controlled, but the minor streams are incised in complexly cross-folded strata, and drainage patterns are irregular as a result. Some are dendritic and others, e.g. along the Corella River and Tommy Creek, are trellised.

The southern part of the area is characterized by superimposed streams such as Slaty and Duck Creeks, which flow in a general easterly direction cutting across the Mitakoodi Quartzite at the Gorge. The Cloncurry River is a major stream whose course is controlled partly by north-south faulting and partly by easily eroded slate and siltstone. In contrast with the northern half, minor streams are notably subsequent, following favourable rock types (southeast area) or joint systems (Duck Creek area).

## STRATIGRAPHY (Table 2)

The oldest unit, the Argylla Formation, occupies the core of two broad anticlines in the centre and southern part of the Sheet area, and a narrow belt along the western boundary. In the centre it is overlain by basalt (Marraba Volcanics) and quartzite (Mitakoodi Quartzite), but in the west these units are absent, and the Corella Formation, a widespread diverse unit of predominantly carbonate and calc-silicate rocks, overlies the Argylla Formation unconformably; in the centre of the Sheet area the Corella Formation appears to be conformable on the Mitakoodi Quartzite, the transitional beds from quartzite to limestone being a jaspilite-carbonate sequence known as the 'Overhang Jaspilite.'* The Marimo Slate flanks the east limb of the Mitakoodi Quartzite anticline and is considered to be a facies equivalent of the Corella Formation.

The Roxmere Quartzite disconformably overlies the Corella Formation and Marimo Slate and is the youngest Carpentarian unit in the Sheet area. In the central northern part the Quamby Conglomerate (probably Adelaidean) forms a narrow graben filling.

Most of the sequence, except for the Quamby Conglomerate and Roxmere Quartzite, is intruded by granite (Burstall, Naraku) and dolerite, but the Wonga Granite along the western margin is possibly older than the sedimentary sequence.

### Stratigraphic Nomenclature

All the Precambrian rocks in the Marraba Sheet area are part of the 'Cloncurry Complex' (see Table 1), a complicated mass of igneous and metamorphic rocks of diverse types. All the formation names used by Carter et al (1961) have been retained, but most require redefinition since our detailed mapping. Most formations have been informally subdivided into members which retain the symbol of the parent formation together with numerical or letter subscripts or both. The more important members have been informally named e.g. Mt Start Member, Wakeful Basalt Member and some new formational names have been proposed

*Note: Stratigraphic names in inverted commas refer to names not yet approved.

TABLE I: STRATIGRAPHIC NOMENCLATURE MARRABA 1:100000

| REFERENCE | Argylla Fmn. Ᵽln | Wonga Granite Ᵽgw | Marraba Volcanics Ᵽla | Mitakoodi Quartzite Ᵽlt | Overhang Jaspilite Ᵽlj | Chumvale Breccia Ᵽlv | Corella Formation Ᵽlc | Marimo Slate Ᵽlm | Roxmere Qtzite Ᵽlt | Burstall Granite Ᵽgb | Naraku Granite Ᵽgu | Quamby Conglomerate Ᵽuq | Mesozoic Outliers M | Cainozoic Cz |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Present work | | | | | | CLONCURRY COMPLEX | | | | | | | | |
| Daintree, 1872 | | | | | | Lower Silurian or older metamorphics | | | | | | | | |
| Jack, 1885 | | | | | | Silurian to Archaean metamorphics | | | | | | | Desert sandstone | |
| Cameron, 1900 | | | | | | Older metamorphic series (Silurian) | | | | | | | Lower Cretaceous | |
| Cameron, 1901 | | | | | Silurian metamorphic and granitic series | | | | | | | A Devonian Series new Lawn Hill | | Lower Cretaceous Rolling Downs Sandstone |
| Rutherford and Kitchener 1904 | | | | | | Schists and slate unconformably overlain by sandstone and limestone | | | | | ? | | | |
| Ball, 1908 | | | | | | Schist, quartzite and limestone of undetermined age | | | | | Granite | Not Differentiated from Schist | Upper Cretaceous Desert Sandstone | Lower Cretaceous Rolling Downs Sandstone |
| Gregory, 1910-1911 | | | | | | Archaean and plutonic rocks | | | | | | | | |
| Dunstan, 1913 | | | | | | Silurian Cloncurry Series | | | | | Granite | | | |
| Dunstan, 1920 | | | | | | Silurian Cloncurry Series (mineral belt) | | | | | Granite | | Tertiary billy | Jurassic |
| Ball, 1921 | | | | | | Silurian Cloncurry Series (a fundamental complex) | | | | | Granite | Post-Cloncurry Series Quamby Conglomerate | Upper Cretaceous Desert Sandstone | |
| Dunstan, 1925 | | | | | | (Reports discovery of Cambrian trilobites in undeformed sediments to the west of Mount Isa) | | | | | | | | |
| Shepherd, 1928 | Archaean<br>Argylla Series | Wonga Granites | | not exposed in section traversed | | | | Older Proterozoic<br>Mt. Isa Series and Corella Series | | | Granites of Cloncurry | Upper Proterozoic at Spring Creek near Mt Isa | | |
| David, 1932 | Archaean<br>Argylla Series | Wonga Granites | | (shown on map as Older Proterozoic) | | | | Older Proterozoic<br>Mt. Isa Series (Shales) and Corella Series (Limestone) | | | Granites of Cloncurry | | Not Differentiated on map | |
| AGGSNA, 1936 a | Archaeozoic<br>Kalkadoon Argylla Series | | | Archaeozoic in part<br>Soldiers Cap Series | | Older Proterozoic<br>Mt.Isa Series | | | | | Granite | Mt.Quamby Series | | Cretaceous |
| AGGSNA, 1937 a | Archaeozoic<br>Kalkadoon Argylla Series | | Soldiers Cap Series | Lower Proterozoic<br>Middle Mt Isa Series | | Lower Proterozoic<br>Upper Mt. Isa Series | | | | Granite | | Upper Proterozoic<br>Mt.Quamby Series | Cretaceous | |
| Nye and Rayner, 1940 | Archaean<br>Kalkadoon Argylla Series | Older granites | Soldiers Cap Series | | | | Proterozoic<br>Mt.Isa Series | | | Newer granites | | Upper Proterozoic<br>Mt. Quamby Series | Cretaceous | |
| Shepherd, 1946, 1953 | Archaean<br>Argylla Series | Wonga Series | Soldiers Cap Series<br>Argylla Series | | | | Proterozoic<br>Corella Series | | | Granite | Cloncurry Granite | Upper Proterozoic<br>Mt. Quamby Series | Lower Mesozoic Freshwater Series | Cretaceous Marine Series |
| David, 1950 | Archaean<br>Argylla Series | Kalkadoon gneiss Series | Lower Mt. Isa Series | Middle Mt.Isa Series | | | Lower Proterozoic<br>Upper Mt.Isa Series (Corella Beds) | | | | Cloncurry Granite | Upper Proterozoic<br>Mt Quamby Beds/Series | | |
| Geological map of Queensland, 1953 | | | | | Precambrian Cloncurry Complex | | | | | | | | | |
| Noakes and Traves, 1954 | | | Lower | Proterozoic | Carpentaria | Complex | | | | | | Upper Proterozoic Recognised to west | Tertiary Laterite | Lower Cretaceous |
| Joplin, 1955 | Acid and basic lavas | Porphyritic granite | Country rocks divided petrologically into, 1. Acid volcanics. 2. Basic lavas and intrusives. 3. Aluminous and siliceous rocks. 4. Calcareous and calc-silicate rocks. | | | | | | | | Microgranite | | | |
| Carter et al, 1961 | Ᵽln<br>in NW called Ᵽlc<br>in SW called Ᵽlt | Ᵽgw<br>(see Ᵽgb) | Ᵽla | Ᵽlt<br>in NE called Ᵽlc | Ᵽlc | Ᵽlv | Ᵽlc<br>(see Ᵽln, Ᵽlt, Ᵽlj, Ᵽlr, in synclines called Ᵽln) | Ᵽlm<br>(See Ᵽlc Ᵽlr) | Ᵽlv<br>in SE called Ᵽlc, Ᵽlm | called Ᵽgw | Ᵽgu<br>Some hypabyssal rocks called Ᵽlv | Ᵽuq | Mz | Cz |

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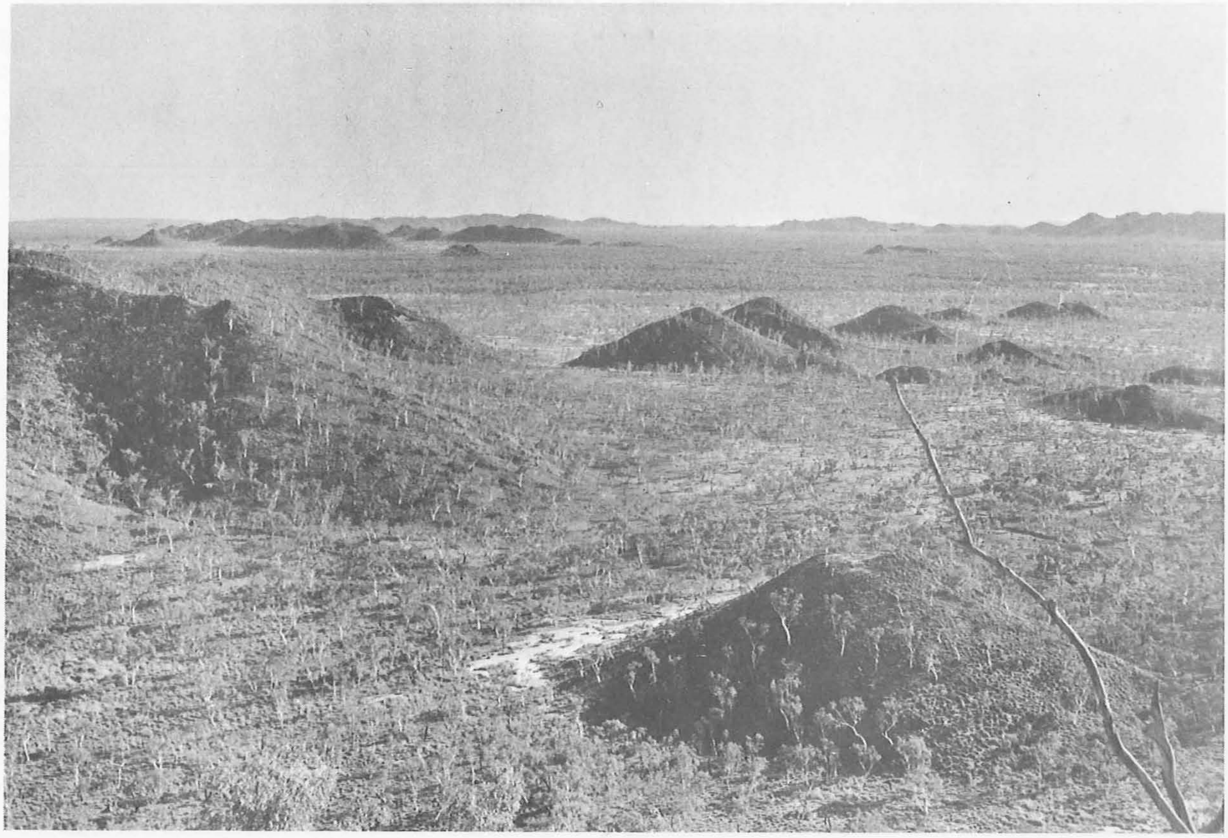

Fig. 5 Maturely dissected hill country in Marimo Slate, along the Cloncurry River; part of the Kuridala Land System M895/21 GMD

Fig. 6 Quartzite ridges of the Argylla Land System, northeast of Timberoo mine GA2800 RMH

TABLE 2. STRATIGRAPHY

| AGE | | ROCK UNIT | SYMBOL* | THICKNESS (m) | DESCRIPTION | RELATIONSHIPS |
|---|---|---|---|---|---|---|
| CAINOZOIC | | | Cz | | Soil, alluvium | |
| | | | Czg | | Gravel, cobbles | |
| MESOZOIC | | | M | | Conglomerate, sandstone, siltstone, porcellanite | Extensively lateritized |
| UPPER PROTEROZOIC | | Quamby Conglomerate | Ᵽuq | 300 | Conglomerate, sandstone, greywacke | Unconformably overlies Corella Formation (Ᵽlc) |
| LOWER PROTEROZOIC OR CARPENTARIAN | | Burstall Granite | Ᵽgb | | Leucocratic m-c gr. granite | Intrudes Ᵽlc |
| | | | $Ᵽgb_p$ | | C-gr. graphic pegmatite with tourmaline | " " |
| | | | $Ᵽgb_h$ | | Vf-gr. microgranite | " " |
| | | Tommy Creek Microgranite | $Ᵽgu_h$ | | F-gr. leucocratic porphyritic microadamellite. | Sills in Ᵽlc |
| | | Naraku Granite | Ᵽgu | | M-gr. leucocratic massive granite | Intrudes Ᵽlc |
| | | Lunch Creek Gabbro | Ᵽbk | approx. 1000 | Gabbro, diorite, tonalite | Intruded by Burstall Granite |
| | | Roxmere Quartzite | Ᵽlr | approx. 1000 | Feldspathic quartzite, minor siltstone conglomerate, and calcareous sandstone | Probably conformably ir disconformably overlies Corella Fmn; ?faulted against Marimo Slate |
| | Marimo Slate | Undivided | Ᵽlm | | Siltstone, slate, marl, limestone, calcareous sandstone | Marimo Slate probably correlates with $Ᵽlc_2$ |
| | | Mick Creek Sandstone Member | $Ᵽlm_{2q}$ | 50-380 | Quartzite | Conformably overlies $Ᵽlm_1$ |

| AGE | ROCK UNIT | SYMBOL* | THICKNESS (m) | DESCRIPTION | RELATIONSHIPS |
|---|---|---|---|---|---|
| LOWER PROTEROZOIC | Marimo Slate | $Elm_{1s}$ | 400 | Black and grey slate | (?)Conformably overlies $Elm_{1a}$, $Elm_{1t}$, and $Elm_{1q}$ |
| | | $Elm_{1a}$ | 280 | 'Attenuated siltstone, marl, limestone | Overlies or grades into $Elm_{1t}$ |
| | | $Elm_{1l}$ | 0-60 | Limestone, marl, marly siltstone | Lenses in $Elm_1$ |
| | | $Elm_{1t}$ | 380 | Phyllite, siltstone | Conformably overlies $Elm_{1q}$ |
| | Toby Barty Sandstone Member | $Elm_{1q}$ | 830 | Feldspathic quartzite | Base of sequence exposed east of Overhang mine. May include $Elm_{1t}$ and $Elm_{1a}$. |
| | Corella Formation: Undivided | $Elc$ | | Calcareous granofels, limestone, sandstone | |
| | | $Elc$ | | Breccia | Commonly restricted to $Elc_1$ and $Elc_3$ |
| | | $Elc_t$ | | Schist, phyllite, phyllonite | |
| | | $Elc_3$ | 300-500 | Calcsilicate granofels, limestone, marl | Conformably overlies $Elc_2$ |
| | | $Elc_{3q}$ | 0-50 | Quartzite | Lenses in $Elc_3$ |
| | | $Elc_2$ | 800 | Calcareous sandstone, shale, schist | Conformably overlies $Elc_1$ |
| | | $Elc_{2s}$ | | Slate with andalusite, kyanite, garnet | Cross-folded belt in $Elc_2$ |
| | | $Elc_{2l}$ | | Limestone with garnet, vesuvianite, microcline | Small lenses in $Elc_2$ |
| | | $Elc_{2t}$ | | Phyllite, basic tuff, schist, agglomerate | Restricted belt in $Elc_2$ south of Lalor mine |
| | | $Elc_{2b}$ | 800 | Metabasalt | One belt of lava in $Elc_2$ in NW |

| AGE | | ROCK UNIT | SYMBOL* | THICKNESS (m) | DESCRIPTION | DESCRIPTION |
|---|---|---|---|---|---|---|
| LOWER PROTEROZOIC OR CARPENTARIAN | Corella Formation | | Blc$_{2g}$ | | Conglomerate | Boulder beds near Mary Kathleen mine |
| | | | Blc$_{2r}$ | | Garnetite, garnet-diopside skarn | Veins in Blc$_{2}$ |
| | | | Blc$_{1}$ | 1200 | Calsilicate granofels, limestone, marl | (?)Conformably overlies Blj; associated with breccia |
| | | | Blc$_{1q}$ | | Quartzite | Minor lenses in Blc$_{1}$ |
| | | Chumvale Breccia | Blv | | Quartzite breccia (silicified) | Modification of Blj |
| | | Overhang Jaspilite | Blj$_{q}$ | 20-300 | Feldspathic quartzite and pebble quartzite | (?)Conformably overlies Blj |
| | | | Blj | 450 | Interbedded limestone, shale, and jaspilite | Conformably overlies Blt$_{3}$ |
| | Mitakoodi Quartzite | Undivided | Blt<br>Blt$_{3}$ | | Quartzite, siltstone basalt, schist, minor limestone, silt, and shale | Overlying Bln and Bla but contact faulted. Conformably overlies Blt$_{1}$ |
| | | Wakeful Basalt Member | Blt$_{2}$ | 0-340 | Massive and amygdaloidal metabasalt with minor sediments | Several conformable lenses in Blt$_{1}$ |
| | | | Blt$_{1}$ | 1300 | Feldspathic quartzite, minor siltstone | Conformably overlies Bla$_{2}$ |
| | Marraba Volcanics | Timberoo Member | Bla$_{3}$ | 50-750 | Slate, siltstone, sandstone, limestone metabasalt, dolerite | Conformably overlies Bla$_{2}$ |
| | | Mt Start Member | Bla$_{2}$ | 0-120 | Laminated silicified f-gr. calcareous sand-stone, limestone, chert | Conformably overlies Bla$_{1}$ |
| | | Cone Creek Volcanic Member | Bla$_{1}$ | 900-2800 | Massive and amygdaloidal metabasalt, pillow lava, dolerite and minor sediments, agglomerate | Overlies Argylla Formation - no unconformity observed in Marraba Sheet area |

| AGE | ROCK UNIT | SYMBOL* | THICKNESS (m) | DESCRIPTION | RELATIONSHIPS |
|---|---|---|---|---|---|
| | Wonga Granite | Egw | | F-gr granite and aplite intruding c-gr porphyritic gneissic granite | Intrudes Eln - affected by regional metamorphism |
| (?) LOWER PROTEROZOIC | Argylla Formation Undivided | Eln | | Acid volcanics and feldspathic quartzite | Poorly exposed sequence |
| | $Eln_q$ | | | Undivided quartzite | Lenses in Eln |
| | | $Eln_b$ | | Metabasalt | |
| | | $Eln_5$ | 100-800 | Cross-bedded m-cgr feldspathic quartzite/sandstone | Topmost part of formation, overlain by $Ela_1$. Thicker in east |
| | | $Eln_4$ | 0-440 | Quartz-rich porphyry porphyritic rhyolite and rhyodacite | Younger volcanic sequence; restricted to east. At least partly intrusive. |
| | | $Eln_3$ | 600 | Quartz-poor porphyry porphyritic dacite, and andesite | Dominant volcanic unit. Overlies $Eln_1$ (?) conformably |
| | | $Eln_2$ | 0-300+ | Laminated feldspathic quartzite, laminated siltstone, chert, tuffaceous and epidote sandstone | Large lenses in $Eln_3$ |
| | | $Eln_1$ | 550+ | Sericite quartzite | Oldest rocks exposed in Marraba Sheet area. |

*The symbols used here refer to the 1:50 000 scale geological maps; many symbols have been deleted, simplified, or replaced by patterns in the 1:100 000 scale preliminary geological map.

as a result of further subdivision of Carter's formations (Carter et al, op. cit.). Some are metasedimentary units, but most are meta-igneous units of importance, previously undifferentiated from the Corella Formation.

The metasediments were designed lower Proterozoic by Carter et al (op. cit.), but are possibly part of the Carpentarian system defined by Dunn, Plumb, and Roberts (1966), which is 1 800 m.y. to 1 400 m.y. old. Until further age determination results are available, symbols such as Blc, Bln, etc. (Bl = lower Proterozoic) will be retained in this Record.

In the following account, sedimentary rocks are named according to the classification of Crook (1960), and igneous rocks according to that of Strekeisen (1967).

## LOWER PROTEROZOIC(?) TO CARPENTARIAN(?)

### Argylla Formation

#### Introduction

The Argylla Formation is named after Argylla Creek, a few kilometres west of the northwest corner of the Sheet area. Our usage of the name follows that of Carter et al. (1961), who also list previous references to the formation.

In the Marraba Sheet area the Argylla Formation is exposed in two anticlinal belts here named the Duck Creek Anticline (eastern) and the Bulonga Anticline (western), which trend northeastwards from the southern boundary. Some small areas of Argylla Formation also occur along the western margin, north and south of Mary Kathleen, and in the core of a dome trending northwest from Chumvale.

The Argylla Formation generally forms low bouldery ridges and rounded hills; the quartzite in the formation forms low ridges or cuestas. In the south the formation is very poorly exposed and is characterized by high-level soil plains.

#### Stratigraphic Relations

The Argylla Formation is the oldest unit exposed. In the Duck Creek Anticline it is overlain conformably by basalt of the Marraba Volcanics; in the Bulonga Anticline, east of Lake Corella, it is overlain disconformably by, or faulted against, the Corella Formation. Farther south, in the Jimmy Creek area, the contact between Argylla Formation and Mitakoodi Quartzite is probably unconformable, but is also faulted.

#### Lithology and Field Occurrence

The Argylla Formation consists of feldspathic and micaceous quartzite, acid volcanic rocks, and minor schist, phyllite and siltstone. Metabasalt, calcsilicate rocks, and conglomerate, referred to by Carter et al., have not been recorded in the Marraba Sheet area. Five informal, unnamed members and an undivided unit have been mapped:

| | |
|---|---|
| Bln (top) | Undivided acid volcanics and feldspathic quartzite |
| $Bln_5$ | Cross-bedded medium to coarse feldspathic sandstone/quartzite |
| $Bln_4$ | Porphyritic rhyolite and rhyodacite, quartz-penocryst-rich |
| $Bln_3$ | Porphyritic dacite and andesite, quartz-phenocryst-poor |
| $Bln_2$ | Laminated feldspathic quartzite, laminated siltstone, chert, tuffaceous sandstone, epidote sandstone |
| $Bln_1$ | Sericite quartzite |

Minor quartzite lenses ($Bln_q$) and metabasalt ($Bln_b$) have also been recorded.

Composite measured sections of the formation in the Duck Creek and Bulonga Anticlines presented as Figures 8 and 9, respectively show that the sericite quartzite member $Bln_1$ occurs only in the Bulonga Anticline, and that quartz-rich acid volcanics, $Bln_4$, occur only in the Duck Creek Anticline.

Description of Members

$Bln_1$ is generally white to cream or pale fawn sericite quartzite characterized by fine grainsize, poorly developed bedding, and up to 5 percent of coarse muscovite flakes. It is the oldest exposed unit of the Argylla Formation, and occurs in a folded and probably highly faulted belt near the Bulonga copper workings.

$Bln_2$ consists of thin-bedded to laminated feldspathic sandstone, laminated siltstone, chert, tuffaceous sandstone, and epidote-rich sandstone (Fig. 10). It is best exposed in the core of the Duck Creek Anticline, and could be equivalent to, and is probably younger than member $Bln_1$. Mica schist and magnetite phyllite in the Gum Creek area were also assigned to $Bln_2$.

$Bln_3$ is porphyritic rhyodacite, dacite, and andesite with sparse quartz phenocrysts. It is widespread in both the Bulonga and Duck Creek Anticlines, where it is generally interbedded with sandstone and quartzite of members $Bln_1$ and $Bln_2$. The rocks are grey to pink aphanitic flows and sills, and minor acid crystal tuff with prominent plagioclase and alkali feldspar phenocrysts, on weathered surfaces. Rhyolite? or chert fragments occur at the margins of some flows, and xenoliths of quartzite country rock occur along some intrusive sill contacts.

Amygdaloidal andesite in the axial zone of the Duck Creek Anticline, along Gum Creek, is intimately interlayered with lenses of finely cross-bedded sandstone and, to a lesser extent, porphyritic rhyodacite. Quartz, calcite, and chlorite fill the amygdales.

Fig.8. Composite section of the Argylla Formation, Duck Creek Anticline.

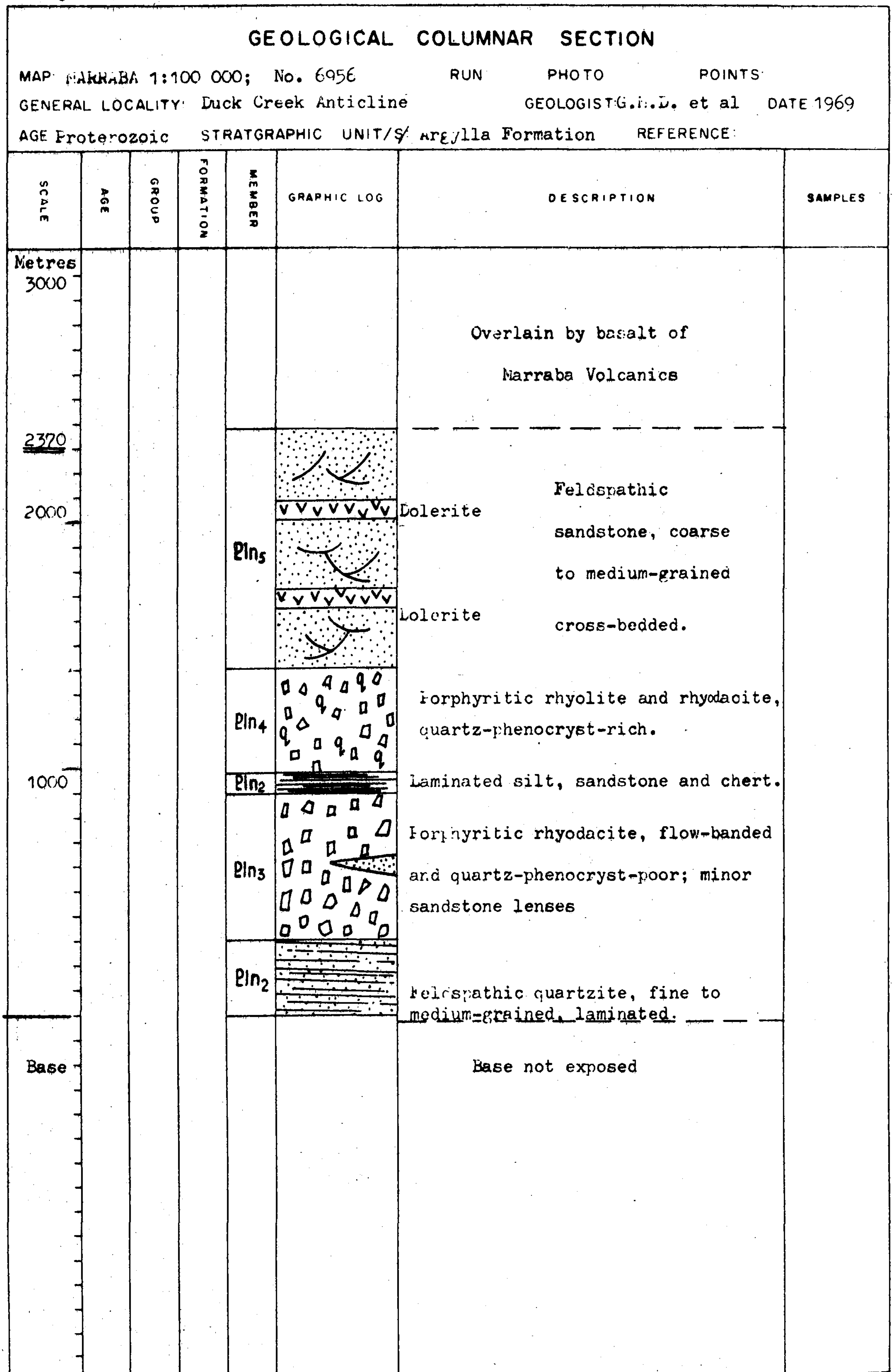


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Fig.9. Composite section of the Argylla Formation, Bulonga Anticline.

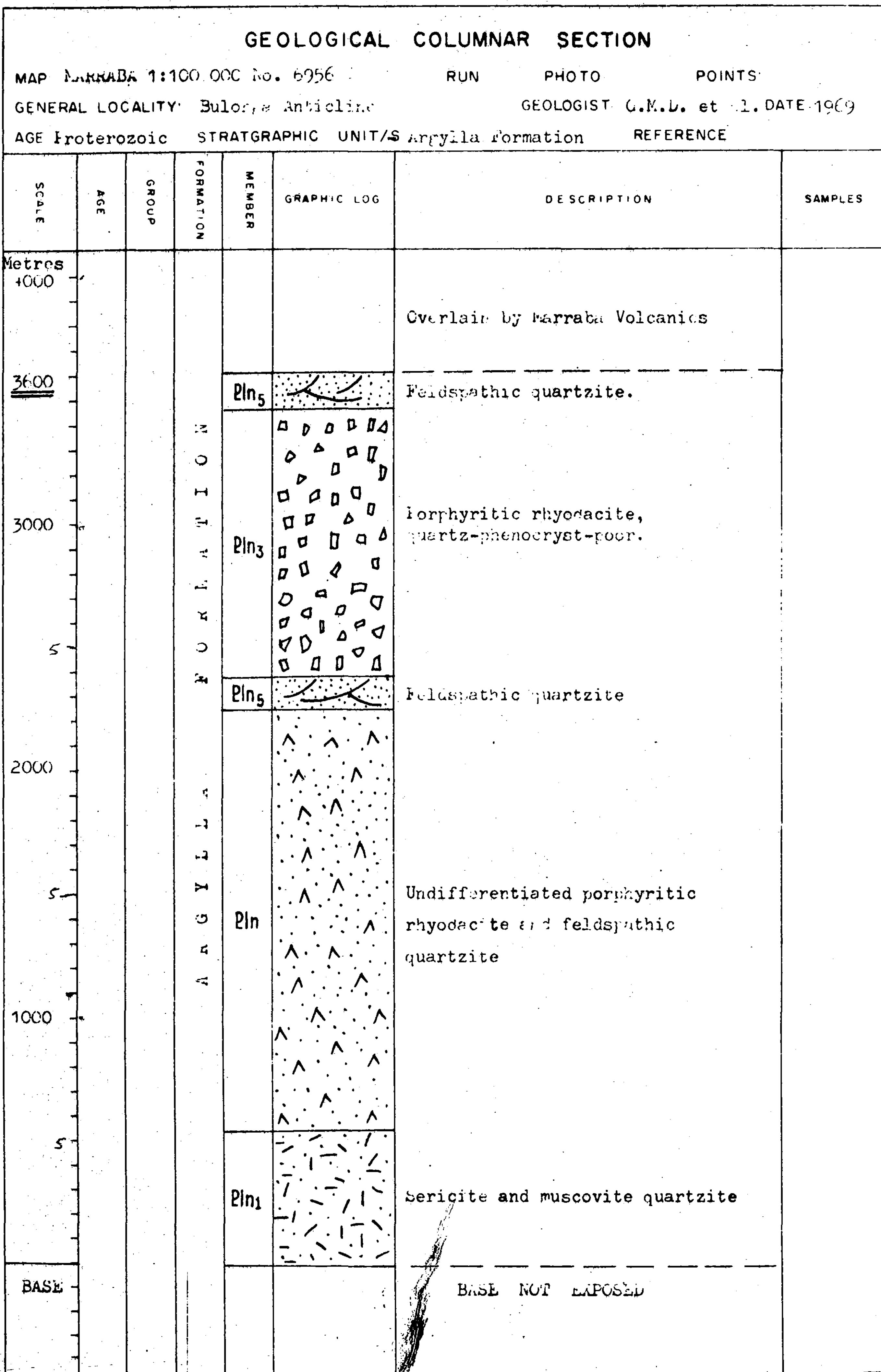


Fig. 7 Dissected hill country (Quamby Land System) of the Isa Highlands; Landscape north of Mount Burstall, showing hills of basic rock GA2742 GMD

Fig. 10 Epidote concretions in laminated sandstone ($Pln_2$) of Argylla Formation, 11 km west of Mitakoodi M929/5A GMD

Fig. 11 Banding in acid volcanics ($Pln_3$) of Argylla Formation, 9 km northwest of Mitakoodi M929/13A GMD

Fig. 12 Contorted banding in acid volcanics ($Pln_3$) of Argylla Formation, 9 km northwest of Mitakoodi M929/15A GMD

Fig. 13 Fine-grained laminated sandstone ($Pln_2$) with acid volcanics, 6 km west of Mount Sheaffe M929/18a GMD

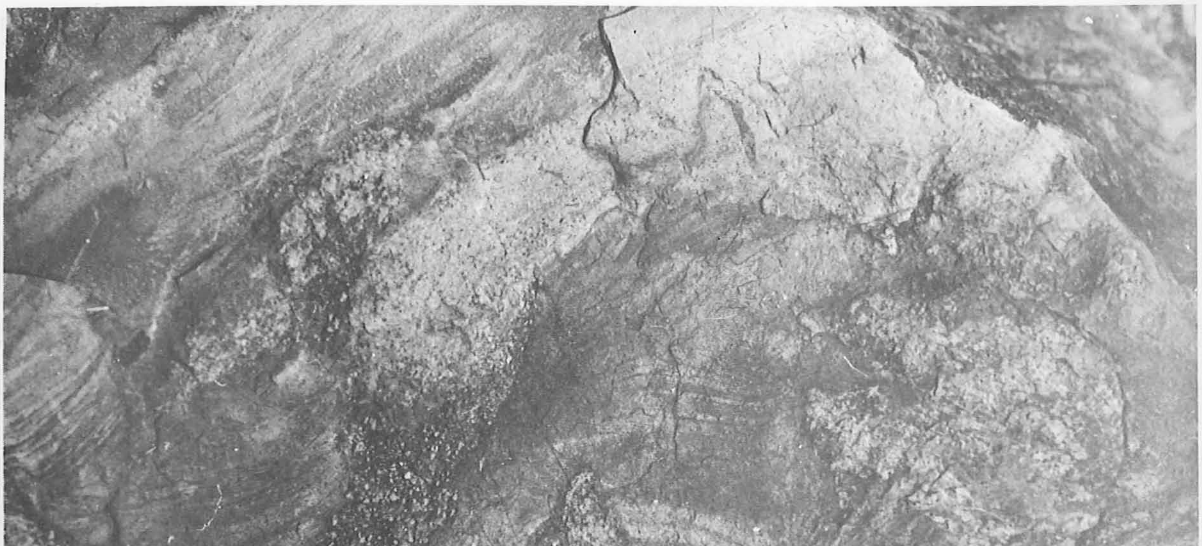


Fig. 14 Tongues of acid volcanic rock intermixed with and intruding fine-grained sandstone, in Argylla Formation 6 km west of Mount Sheaffe M929/17 GMD

TABLE 3. MODAL COMPOSITIONS, ARGYLLA FORMATION

| | MEMBER | ROCK NO. | PHENOCRYSTS | | | GROUNDMASS | | | | ACCESS. | NAME |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Q | Pl | Kf | q+f | bi | ch | m | | |
| VOLCANICS | $Eln_3$ | 416* | 3 | 15 | | 72 | 10 | tr. | tr. | Ca, op zr, ap, Sp | Porphyritic metadacite |
| | | 417 | 1 | 10 | | 84 | 3 | 2 | tr. | zr, op, ap, sp | " " |
| | | 418 | 1 | 10 | 3 | 78 | 8 | | | zr, ap, ep | " metarhyodacite |
| | | 421 | 2 | 8 | | 80 | | tr. | | sp, zr, op | " metadacite |
| | | 457 | 5 | 5 | | 84 | 5 | | 1 | ca, ep, Sp, op, zr | " " |
| | | 458 | 10 | 5 | 30 | 45 | 10 | tr. | tr. | ca, ep | metarhyolite |
| | $Eln_4$ | 414 | 8 | 10 | | 74 | 8 | tr. | tr. | zr, ap | Porphyritic metadacite |
| | | 419 | 10 | 15 | | 71 | 2 | 2 | | zr, op | " " |
| | | 440 | 10 | 6 | 4 | 80 | | | | | " rhyodacite |
| | | 5742** | 10 | 10 | 20 | 54 | op 2 | 2 | 2 | | Metarhyolite |
| | | 5723 | 6x | 16 | 1 | 75 | | 1 | | | Metadacite |
| | | 5727 | 1 | 18 | 3 | 68 | op 4 | 6 | | ap, op | Metadacite |
| | | | Q | Pl | Kf | Pl+Kf | bi | ch | mu | ACCESS. | NAME |
| SANDSTONES | $Eln_1$ | 5736** | 92 | | | | | 1 | 7 | sp | Micaceous quartzite |
| | $Eln_2$ | 423 | 74 | | | 15 | 5 | 2 | 4 | $CO_3$ 10% | Sideritic micaceous quartzite |
| | | 424 | 90 | | | 7 | 2 | 1 | | zr, ap, op | Feldspathic quartzite |
| | | 445 | 75 | | | 20 | ep 5 | tr. | tr. | ap, op, zr | Feldspathic sublabile quartzite |
| | | 461 | 85 | | | 14 | tr. | tr. | 1 | Zr, ap, op | Feldspathic sublabile quartzite |

TABLE 3. MODAL COMPOSITIONS, ARGYLLA FORMATION (Cont'd)

| | MEMBER | ROCK NO. | PHENOCRYSTS Q | Pl | Kf | GROUNDMASS q+f | bi | ch | m | ACCESS. | NAME |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Q | Pl | Kf | Pl+Kf | bi | ch | mu | ACCESS. | NAME |
| SANDSTONES | | 420 | 90 | 2 | 8 | | tr. | | | Zr, ap | |
| | Bln 5 | 441 | 70 | | | 29 | | | 1 | ap, Zr, op | Feldspathic labile quartzite |
| | | 455 | 80 | | | 20 | tr. | | tr. | Zr, op | " sublabile quartzite |
| | | 5728** | 86 | 3 | 10 | | | 1 | | Zr | " " " |
| | | 415Y | 74 | | | | | | 26 | Zr, sp, ru | |
| | | 442Y | 60 | | | | | | 40 | to | muscovite quartzite |

Q = quartz
Pl = plagioclase
Kf = alkali feldspar
q+f = quartzofeldspathic aggregate
bi = biotite
mu = muscovite
ch = chlorite

op = opaques
sp = sphene
zr = zircon
ep = epidote
to = tourmaline
ap = apatite
ru = rutile
ca = calcite

* BMR Registered Number e.g. 70200416
** GSQ Registered No.

Y Metasomatised equivalents

X Includes 1% quartz veining

Flow banding (Fig. 11) is particularly evident in the core of the Duck Creek Anticline, where it is intricately contorted (Fig. 12); the banded flows (or sills) are intimately mixed with and intrude fine-grained laminated sandstone (Figs. 13 and 14).

$\underline{Bln_4}$ is similar to $Bln_3$ except that blue to blue-grey quartz phenocrysts are abundant in the porphyritic rhyodacite. It is generally massive and concordant with overlying sandstone, and occurs as a mappable unit only in the Duck Creek Anticline. Quartz-rich flows occur in the Bulonga area, but are of minor importance.

$\underline{Bln_5}$ is a medium to coarse feldspathic quartzite which differs from $Bln_1$ and $Bln_2$ in being pale cream, pink, and fawn, massive to blocky, thick-to thin-bedded, and characteristically cross-bedded, in sets 25 cm to 1 m thick. Pyrite pseudomorphs and voids are abundant locally (Fig. 15). The unit appears to be thin from east to west.

All members of the formation are cut by dolerite dykes and sills of at least two ages, and minor pods of granite and pyritic monzodiorite intrude the volcanics 1.6 km southeast of Bulonga mine. In the Duck and Gum Creek areas, sandstone and volcanic rocks are highly altered to a quartz-muscovite-tourmaline assemblage associated with quartz-veining, and along the western margin of the area the acid volcanics (Bln) contain abundant augen and porphyroblasts of quartz and feldspar (Fig. 16). Amygdaloidal basalt ($Bln_b$) is associated with mica schist and acid gneiss in the Lakeview mine area.

Petrography

Twenty-seven samples from the Argylla Formation have been examined in thin section. Modal analyses of some of these rocks are listed in Table 3, and sample localities are plotted on the geological maps. None of the samples described by Carter et al. (1961) were from the Marraba Sheet area.

Volcanic rocks

The volcanic rocks are massive and banded porphyritic rhyolite, dacite, rhyodacite and andesite. The rhyolite and rhyodacite consist of quartz, plagioclase, and less commonly, alkali feldspar phenocrysts in a groundmass of granoblastic quartz, feldspar, and some oriented laths of biotite, chlorite, and muscovite. The major accessories are zircon and apatite, both of which form large (0.1 to 0.8 mm) euhedral crystals, and epidote, iron ore, and calcite. The quartz phenocrysts are clear, slightly rounded and euhedral, and are locally embayed (Fig. 17); the plagioclase is albite to oligoclase, and variably saussuritized and clouded, as is potash feldspar which commonly shows perthitic and checkerboard intergrowths with plagioclase. Some microbrecciation of the phenocrysts suggests a tuffaceous origin for some rocks, but eutacitic textures are absent. Banding mostly appears to be flow banding, but some is possibly preferential concordant silicification.

The andesite and dacite are locally amygdaloidal and are interbedded with the more acid volcanics. They consist of plagioclase phenocrysts in a fine-grained biotite-rich quartz-feldspathic groundmass, similar to that in most of the rhyodacites, in which curved zones of fine-grained quartzite (sample 460), resemble recrystallized spherulitic obsidian structures similar to those noted by Joplin (1955).

Sandstones/Quartzites

The sandstones/quartzites are incompletely recrystallized and metamorphosed to the greenschist facies. Quartz and feldspar form a moderately granular mosaic, with up to 30 percent feldspar in some samples. Apatite and zircon are abundant, and almost certainly have been derived from associated acid flows or tuffs. Some laminated sandstones contain thin heavy-material bands 1 to 5 mm thick which are rich in apatite, zircon, iron ore, and sphene. Euhedra of iron ore, possibly pyrite, and carbonate concretions in some samples appear to be post-metamorphic.

Metasomatized rocks

Muscovite-tourmaline quartzite, derived by alteration of dolerite, acid volcanics, and sandstone, consists of quartz-muscovite aggregates with scattered coarse-grained euhedra of zoned green-brown tourmaline. It is found along joints in diverse rock types, and is a result of intense local hydrothermal activity with associated boron metasomatism.

Discussion and Petrogenesis

Composite measured sections of the Argylla Formation show marked lithological changes from the Bulonga to the Duck Creek Anticline. These changes and their development, shown diagrammatically in Figure 18, are:

1. an increase in the proportion of quartzite from west to east
2. the appearance of quartz-bearing volcanics only in the eastern anticline
3. the occurrence of micaceous quartzite only in the western anticline
4. a gradation from laminated to cross-bedded quartzite upwards in the sequence
5. a general thickening of units towards the east.

These features, together with the possible disconformable relationships and rapid variations in rock type in the Bulonga Anticline area, suggest greater instability there during deposition of the Argylla Formation.

Apatite and zircon in Argylla Formation sediments directly reflect the heavy-mineral suite of the associated volcanics, and, together with ripple-marking and cross-bedding in the sandstones, suggest penecontemporaneous erosion and deposition of acid volcanic flows, tuff, and sandstone in a coastal or shallow-water environment.

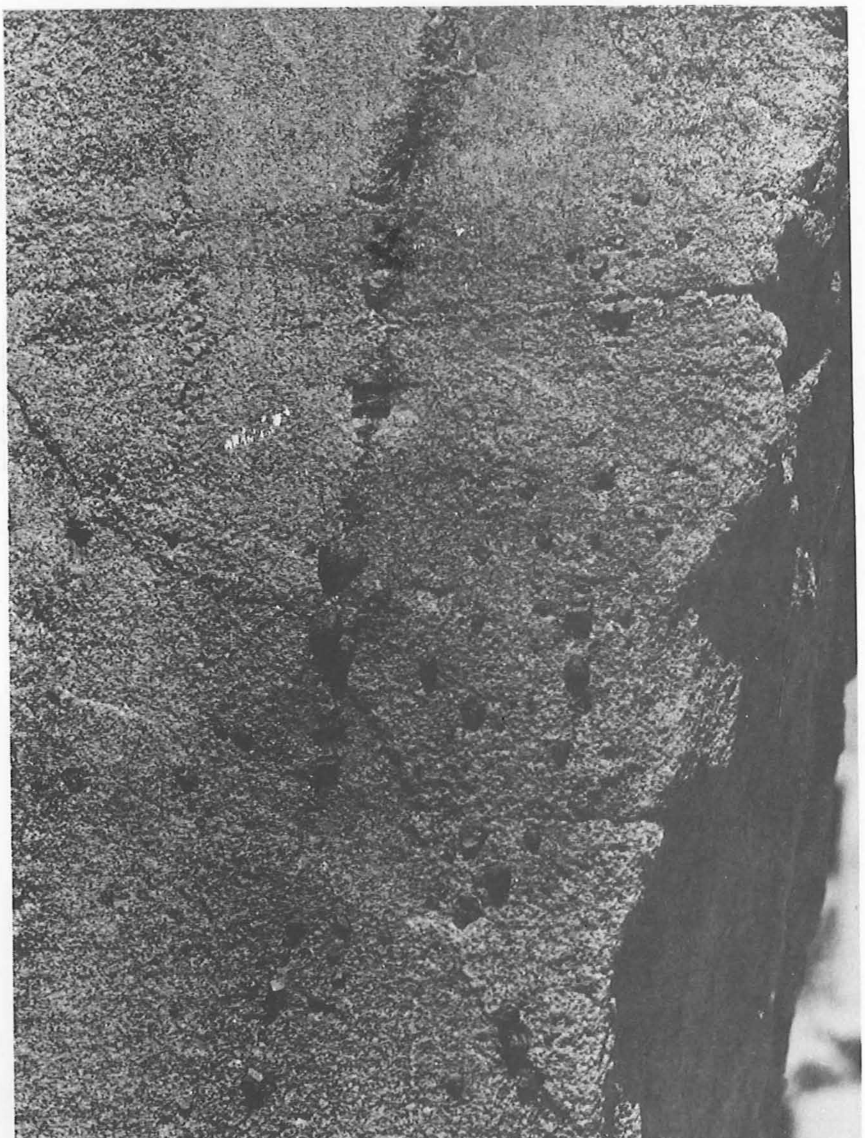


Fig. 15 Pyrite pseudomorphs in fractures across bedding in sandstone ($Pln_5$) of Argylla Formation, 17 km west of Mitakoodi M929/2A GMD

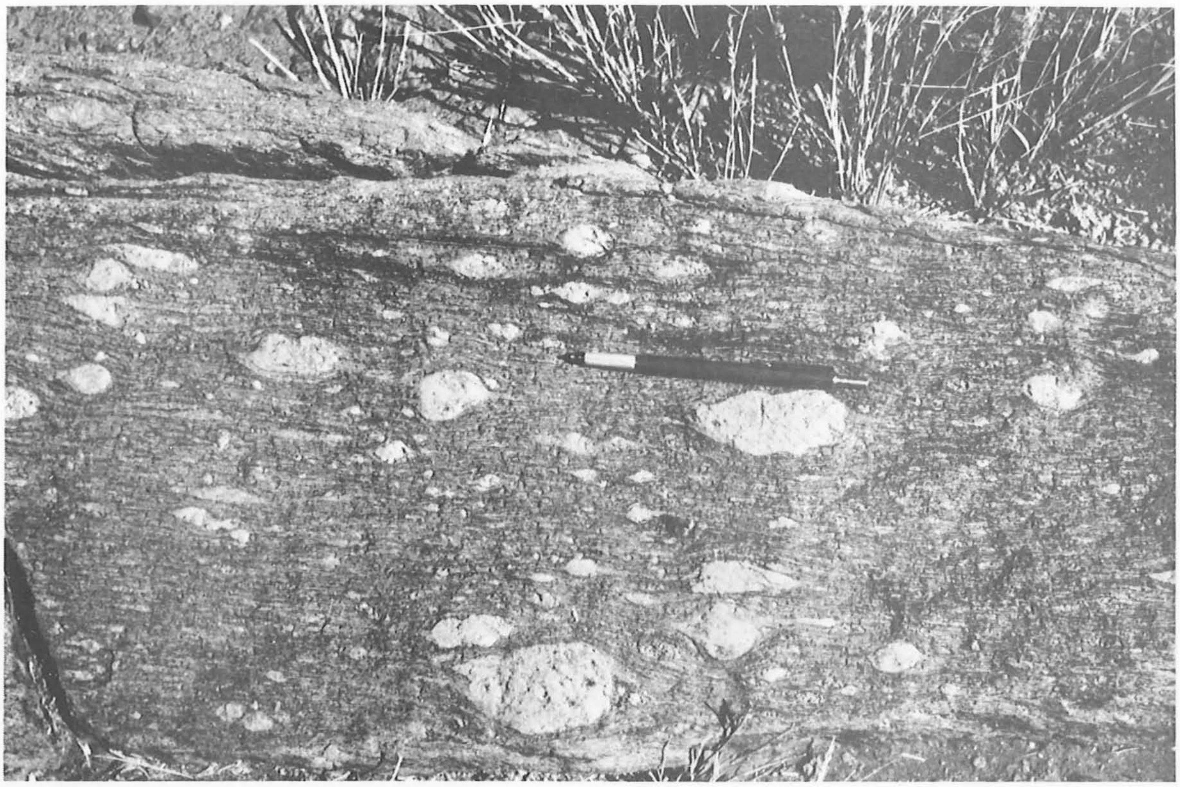


Fig. 16 Augen gneiss (acid volcanic) in Argylla Formation, near Lime Creek mine. GA2722 GMD

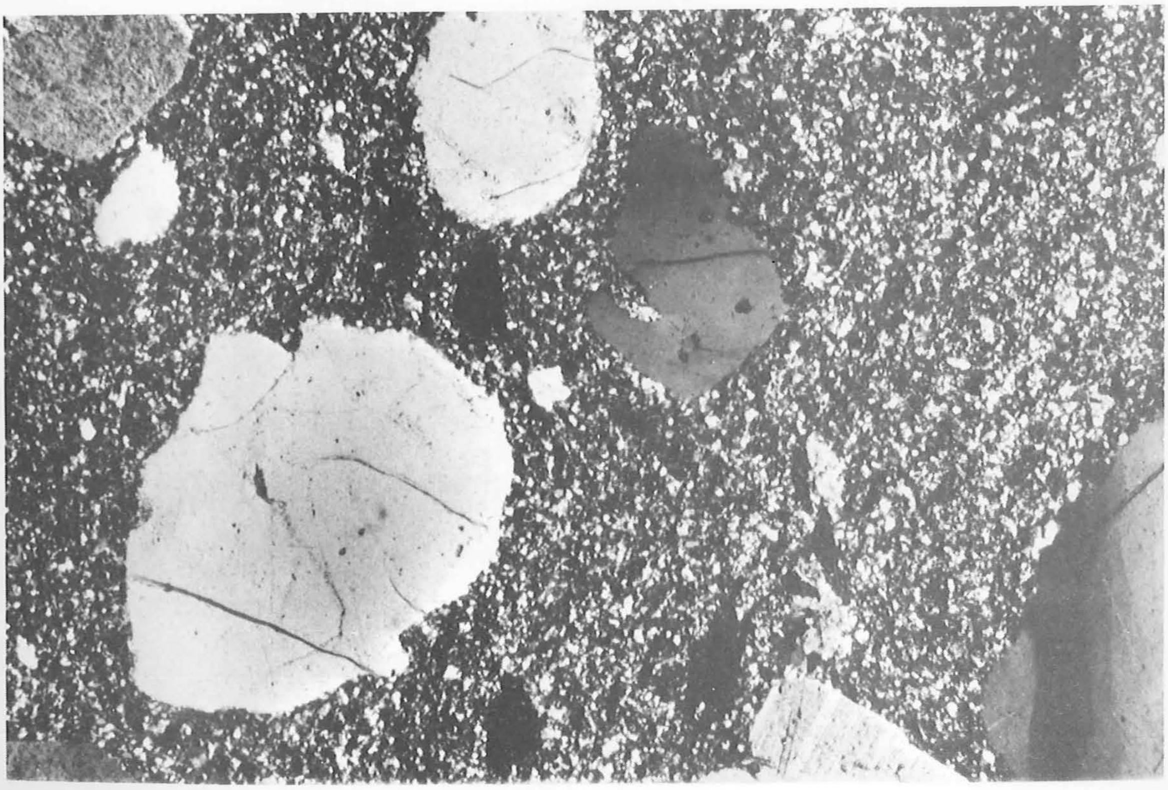
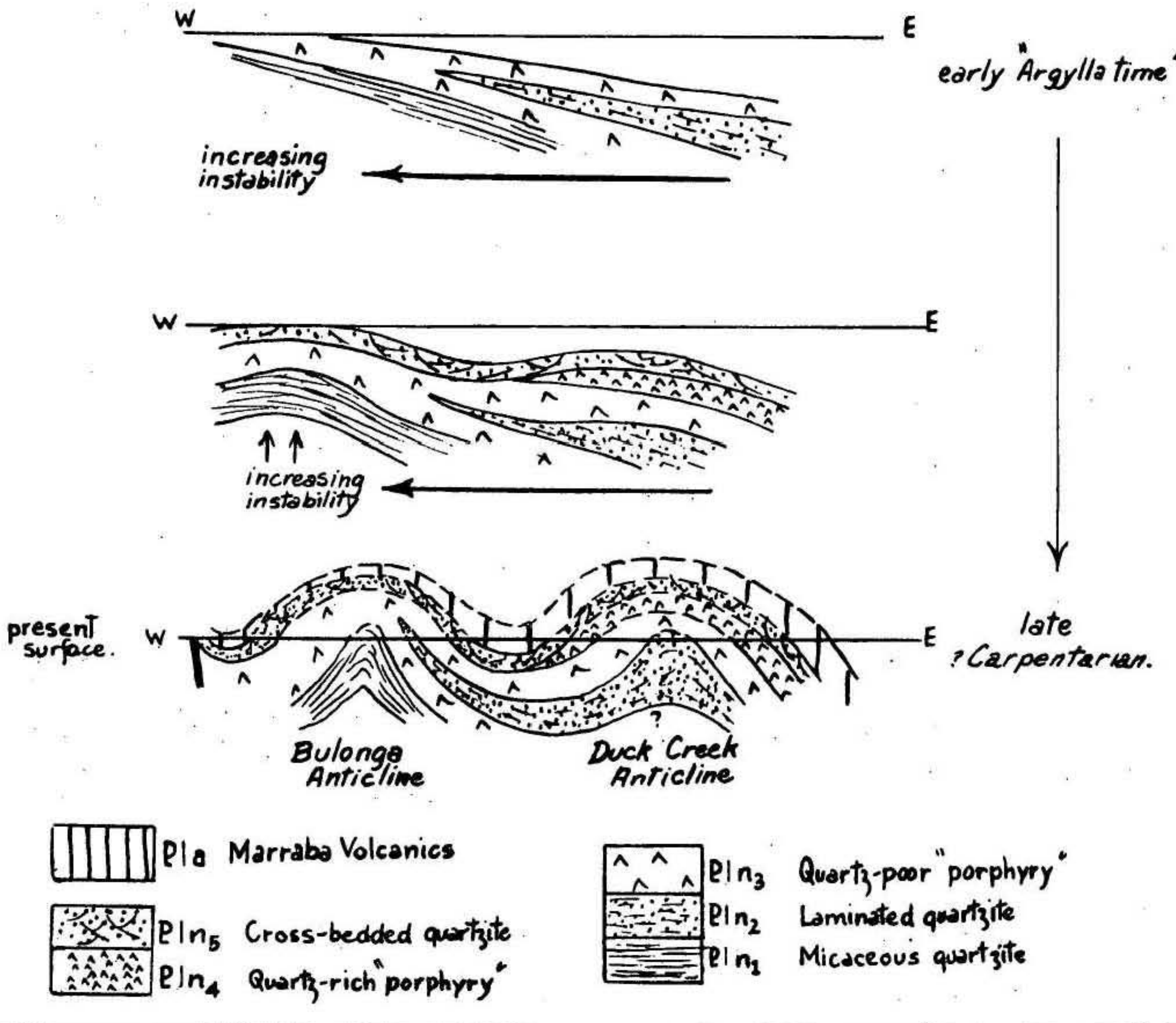


Fig. 17 Embayed quartz phenocrysts in dacite of Argylla Formation M1032/6 GMD

FIG. 18. Diagrammatic sketch of lithological changes and tectonic evolution in Argylla Formation




To accompany Record 1971/56. F54/A2/40

Acid volcanics north and south of Mary Kathleen are more recrystallized than those in the south. They directly underlie, probably unconformably, quartzite and calc-silicate rocks of the Corella Formation, and form an envelope around the Wonga Granite.

## Marraba Volcanics

### Introduction

The Marraba Volcanics, named after Marraba railway siding near the southern boundary of the Sheet area, were formally defined as a formation by Carter et al (1961), but now require redefinition.

The earliest geological work on this formation was near the numerous small copper mines in the Duck Creek and Slaty Creek areas. Jack (1898) described slate and diorite in the Mount Midi lease (west of Timberoo), and Ball (1908) recognized amygdaloidal eruptives, altered slate, and altered calcareous sediments. He found that it was rarely possible to distinguish lavas from sediments in the field because of schistosity and metamorphism. The earliest stratigraphic subdivision of the Precambrian of northwest Queensland by Shepherd (1928, in David, 1932) includes the Marraba Volcanics in the Argylla Series of Archaeozoic age (Table 1). AGGSNA (1937), and Nye & Rayner (1940, Plate 1) show the Marraba area as Soldiers Cap Series overlain by the Mount Isa Series. Shepherd (1946) published his stratigraphic column equating the Argylla Series with the new Soldiers Cap Series, which included the Marraba Volcanics (Table 1).

'Greenstones' now mapped as Marraba Volcanics were covered in an airborne scintillometer survey conducted by Mount Isa Mines Ltd, in 1954, and several anomalies were investigated. Some subsequent work has been done by exploration companies, e.g., detailed work on the numerous copper prospects in the Duck Creek area by Carpentaria Exploration Co. Pty Ltd (1966a, b), and an extensive geochemical survey by Conzic Riotinto Australia (Muceniekas, 1968), results of which are shown on Map 6.

The Marraba Volcanics, covering about 600 km$^2$ are exposed in a complexly folded and faulted arcuate belt in the southern half of the Sheet area. The type section is near the middle of the belt and extends from latitude 20°51' 45"S, longitude 140°13'50"E to latitude 20°53'20"S, longitude 140°15'00"E. Exposure is good to excellent, but there are some areas of poor outcrop in the southeast near Marraba railway siding.

### Stratigraphic Relations

The Marraba Volcanics are conformably overlain by the Mitakoodi Quartzite, and conformably overlie the Argylla Formation in the Duck Creek Anticline.

In defining the formation, we have included the cross-bedded feldspathic quartzite placed at the base of the formation by Carter et al (1961) in the Argylla Formation (member $Bln_5$), because of its lithological similarity and petrogenetic relationship to other quartzites in the Argylla Formation, and the greater ease in recognizing and tracing the base of the basalt member, throughout the Sheet area.

Lithology and Field Occurrence

The Marraba Volcanics consist of basalt, sandstone, siltstone, and minor limestone, agglomerate, and tuff. Three members have been recognized:

$Bla_3$ 'Timberoo Member' up to 730 m thick

$Bla_2$ 'Mount Start Member', up to 120 m thick

$Bla_1$ 'Cone Creek Volcanic Member,' up to 2 800 m thick

Stratigraphic columns of the Marraba Volcanics are shown in Figures 19 a and b. In Section 1, the thickness of the 'Timberoo Member' is probably exaggerated by folding.

Description of Members

'Cone Creek Volcanic Member' ($Bla_1$) - This name is derived from Cone Creek, near the type section at latitude 20°53'20"S, longitude 140°15'00"E to latitude 20°52'40"S, longitude 140°14'28"E. The type section is probably faulted near the top. The member conformably overlies the Argylla Formation, and is overlain conformably by the 'Mount Start Member'.

It consists of blastoporphyritic and massive, cleaved, dark green to black metabasalt which contains regular belts of amygdales (Figs. 20, 21) spaced at 20 to 80 m intervals, some of which contain chalcopyrite. These belts are taken to represent the limits of individual lava flows, and have been used to delineate structure in some areas, but recognition of individual flows near the middle of the member is usually impossible because amygdales are absent.

Brown to black agglomerate or pillow lava near the top of the member is best developed 2 km west of Marraba siding (Fig. 22).

Sedimentary intercalations are rare but include some lenses (100 x 1.5 m) of feldspathic sandstone. The lava flows are cut by numerous dolerite dykes and sills, between 1 and 200 m thick, which are best developed 1 to 10 km northwest of Mitakoodi railway siding.

There was little difficulty in distinguishing between basalt and dolerite where outcrop was adequate, because the dolerite is syn or post metamorphic, and commonly has a blocky outcrop which contrasts with the schistose, flaggy, well cleaved outcrops of basalt. Tuff has not been found in the abundance stated by previous authors, but poorly exposed tuff could have been mapped as lava or sediment in some places. The thickness of the member ranges from 2 800 m in the east to 900 m in the west (Fig. 19b).

Within the basalt, calcite and dolomite veins are commonly associated with large faults. Quartz veins are common along minor shear zones, and contain hematite, actinolite, tourmaline, and copper minerals where dolerite is associated with the veining.

Hydrothermal alteration or metasomatism is commonly associated with these minor veins, giving a granular appearance to the lava, which is then easily confused with calcareous sandy sedimentary rocks in the field.

'Mount Start Member' ($Bla_2$) - The name is derived from the type section at Mount Start, a prominent hill consisting of this member. It overlies the 'Cone Creek Volcanic Member' conformably, and underlies the 'Timberoo Member' conformably. It consists of intricately folded laminated fine-grained calcareous sandstone (Fig. 23). The folding and lamination are diagnostic. Where the member is hill forming, it is strongly leached and silicified, e.g. Mounts Finish, Connor, Brownie, and Sheaffe.

'Timberoo Member' ($Bla_3$) - The name is derived from the Timberoo mine, 8 km north of Mitakoodi siding, where the basal sediments of the member are well exposed, and the type section is near the Banjo and Tambourine mines, from latitude 20°52'40"S, longitude 140°14'28"E to latitude 20°51'45"S, longitude 140°13'50"E. It is 750 m thick in the east, and 50 m or less in the west. Better exposures of the basal beds occur at Mount Start (lat. 20°59'10"S, longitude 140°17'00"E), and north of Timberoo (lat. 20°50'25"S, long. 140° 19'5"E).

The type section is as follows:

(top) grey slate with increasing number of sandstone beds, transitional into Mitakoodi Quartzite

massive dolomitic limestone

ferruginous schistose fine-grained arkosic sandstone

silicified slate and siltstone

grey slate and pyritic slate

grey, slightly calcareous, fine-grained sandstone

buff fissile slate

In the east and north, fine-grained, ripple-marked, labile quartzite with a prominent bouldery outcrop is abundant. At least one basalt flow is present in the member, near Mitakoodi siding, ferruginous sandstone, magnetite-rich sandstone, and calcareous shale are also present in these areas. Numerous dolerite dykes, some with minor copper mineralization, cut the member throughout the Sheet area.

Petrography

'Cone Creek Volcanics:' The metabasalts are fine-grained and show intersertal and pilotaxitic textures. Plagioclase laths (50 - 70 percent) range from albite to andesine, and are intergrown with aggregates of pale brown biotite, chlorite, epidote, and calcite, totalling 15 - 20 percent. In the central and western exposures of the basalt, actinolite is abundant (up to 40 percent). Opaques are mostly (2 - 5 percent) iron oxides and ilmenite, but sulphides may also be present. Accessory minerals are sphene, apatite, zircon, and quartz and the latter forms up to 3 percent of some specimens. Amygdales contain chlorite, biotite, calcite, quartz, and chalcopyrite, plagioclase, and amphibole. The rocks are metabasalt, quartz metabasalt, and minor meta-andesite.

Zones of alteration in the basalt consist of granoblastic aggregates of albite, calcite, limonite, chlorite, subhedral polygonal opaque minerals, and minor quartz. In the alteration, iron and magnesium have been removed, and calcium added.

All rocks show greenschist facies metamorphism; the distribution of the greenschist assemblages is discussed under Metamorphism.

'Mount Start Member:' A fresh sample of this member is a sub-labile quartzite containing minor feldspar. Biotite and chlorite are common; scattered calcite and the heavy minerals apatite, zircon, tourmaline, and epidote are also present. In leached and silicified equivalents, all mafic constituents are leached, leaving a recrystallized quartz mosaic and small flakes of sericite. Tourmaline was the only heavy mineral observed.

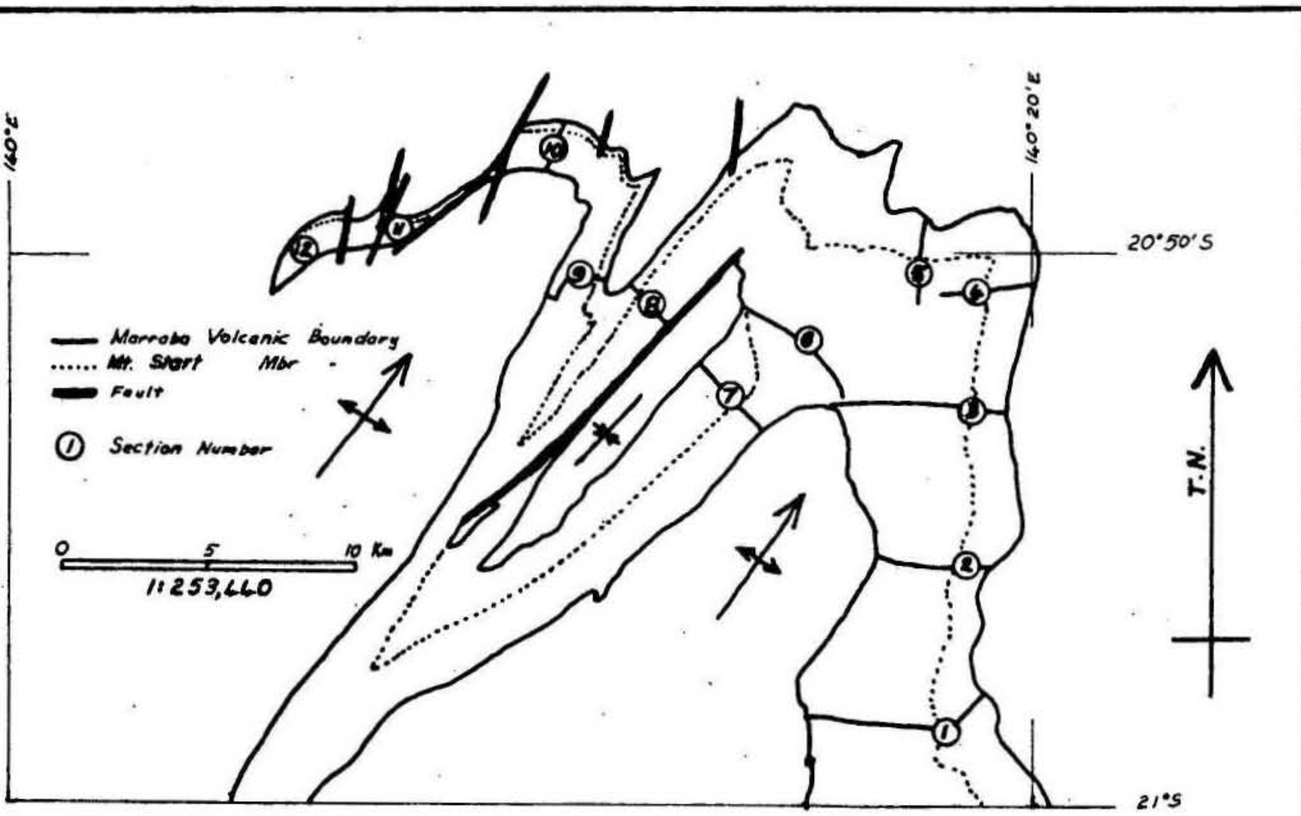
'Timberoo Member:' Modal analyses of sandstone are shown in Table 4. All rocks are highly feldspathic; the feldspars are fresh, and plagioclase is more plentiful than microcline. Chlorite and biotite are the major mafic minerals. Quartz forms subangular grains up to 0.2 mm diameter; calcite is interstitial. Heavy minerals comprise zircon, sphene, apatite, tourmaline, and perovskite?

The feldspar content in the 'Timberoo Member' apparently decreases northwards from the Mount Start area. Scapolite occurs in a limy bed at latitude 20°49'40"S, longitude 140°11'25"E. The textures of the coarser-grained sediments show little evidence of metamorphism apart from the growth of small sericite flakes between the grains, presumably from illite or clay minerals. The finer-grained rocks are more susceptible to metamorphism, and typically show a lepidoblastic texture apparently parallel to bedding.

## Discussion and Conclusions

Most of the metabasalts appear to be subaerial flows on sands of the Argylla Formation, though probable pillow structures indicate some submarine volcanism. The thickness variations, particularly in the upper member, suggest greater subsidence in the east. The Argylla Formation appears to have been the source of nearly all detrital material in the Marraba Volcanics, although epidote and magnetite, common in the upper members, have probably been derived from the lower volcanic member.

Carter et al (1961) correlated the Eastern Creek Volcanics with the Marraba Volcanics plus Mitakoodi Quartzite, and though that the Marraba Volcanics were broadly equivalent to the Soldiers Cap Formation. The latter




LOCALITY DIAGRAM FOR MARRABA VOLCANICS STRAT. COLUMNS

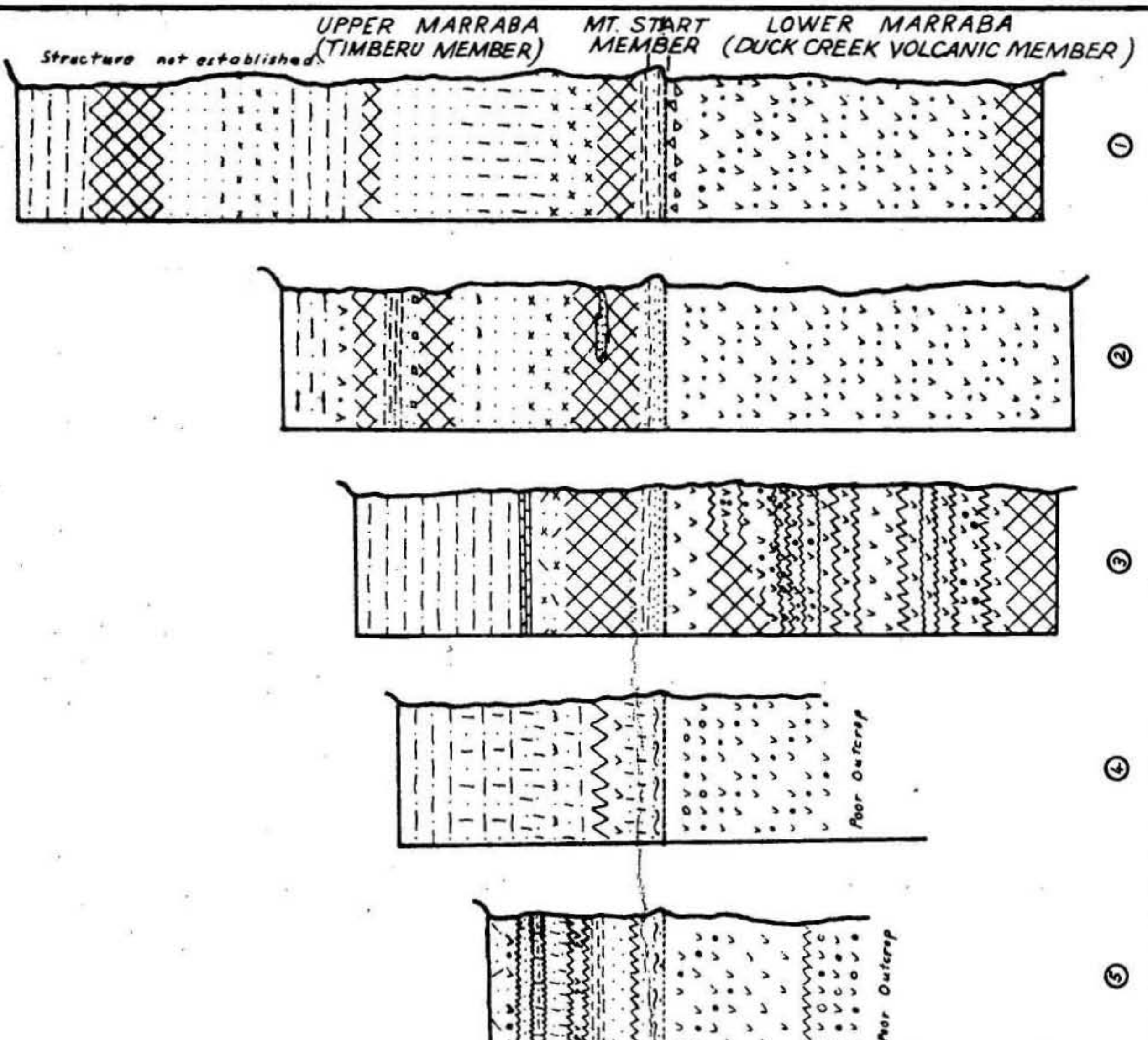



FIG. 19(a). Stratigraphic Columns of the Marraba Volcanics.

To accompany Record No 1971/56. F54/A2/41

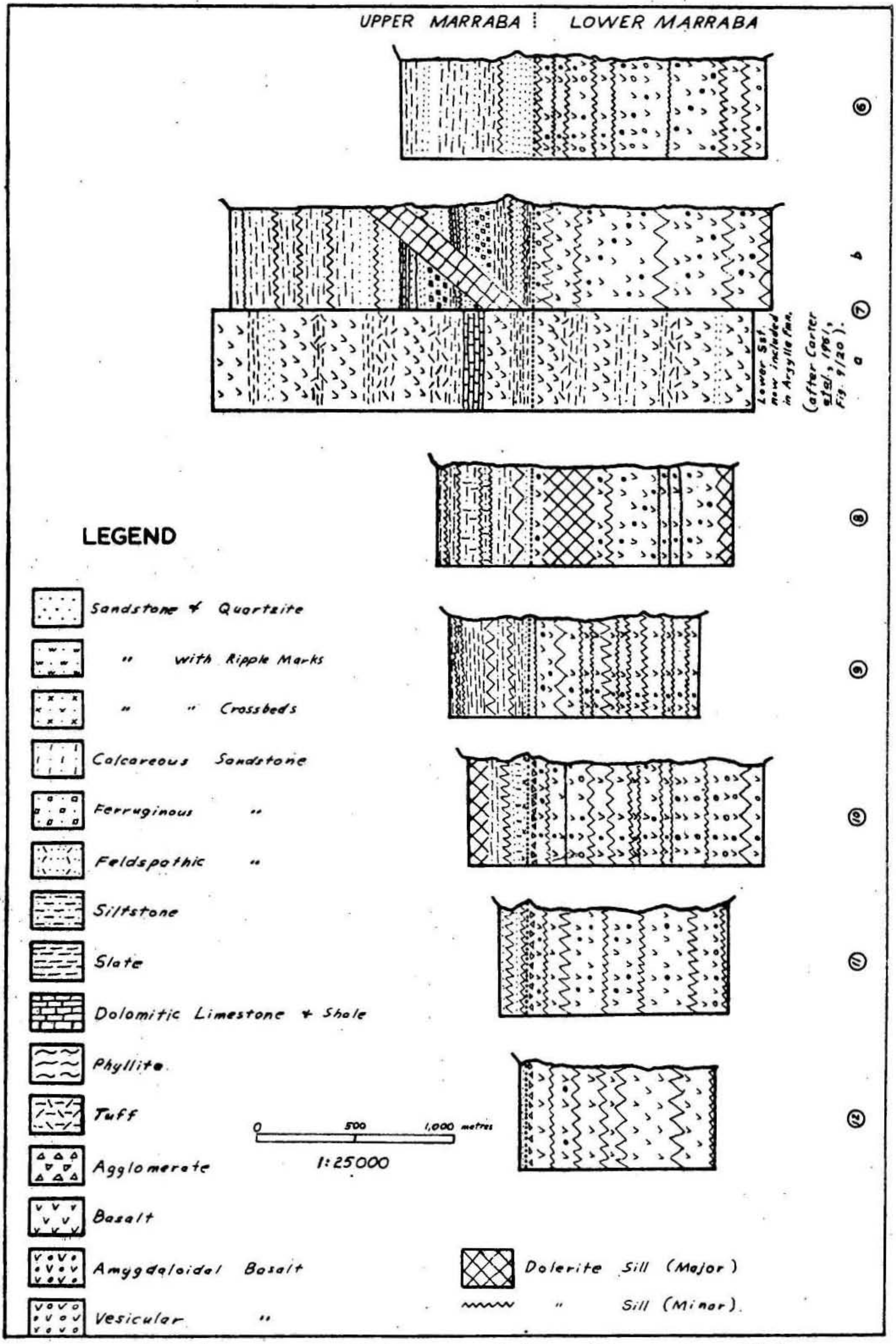


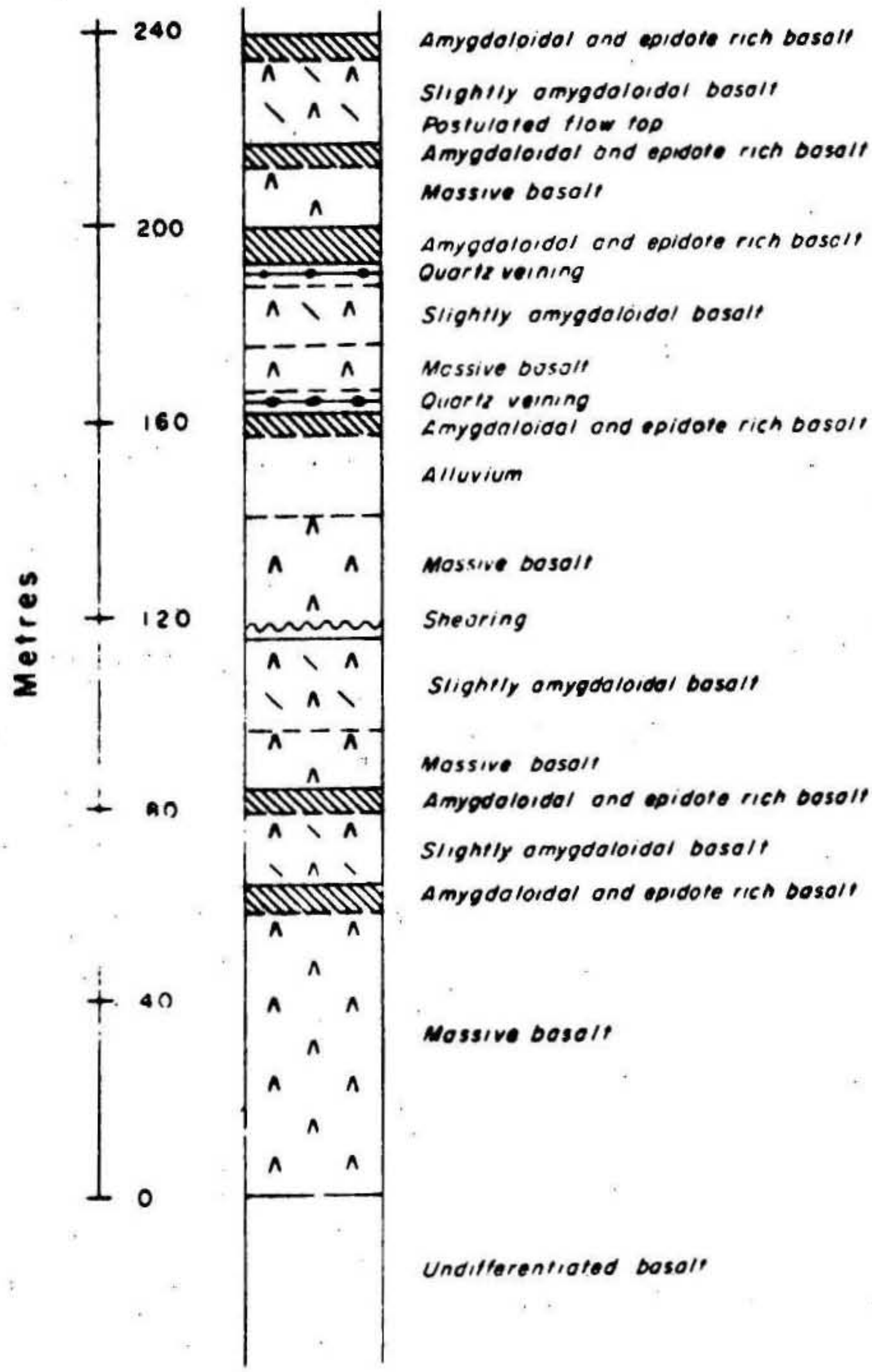

FIG 19(b) Stratigraphic Columns of the Marraba Volcanics.

To accompany Record No 1971/56. F54/A2/42

FIG. 20

# LITHOSTRATIGRAPHIC COLUMN

## of part of Cone Creek Basalt member Marraba Volcanics

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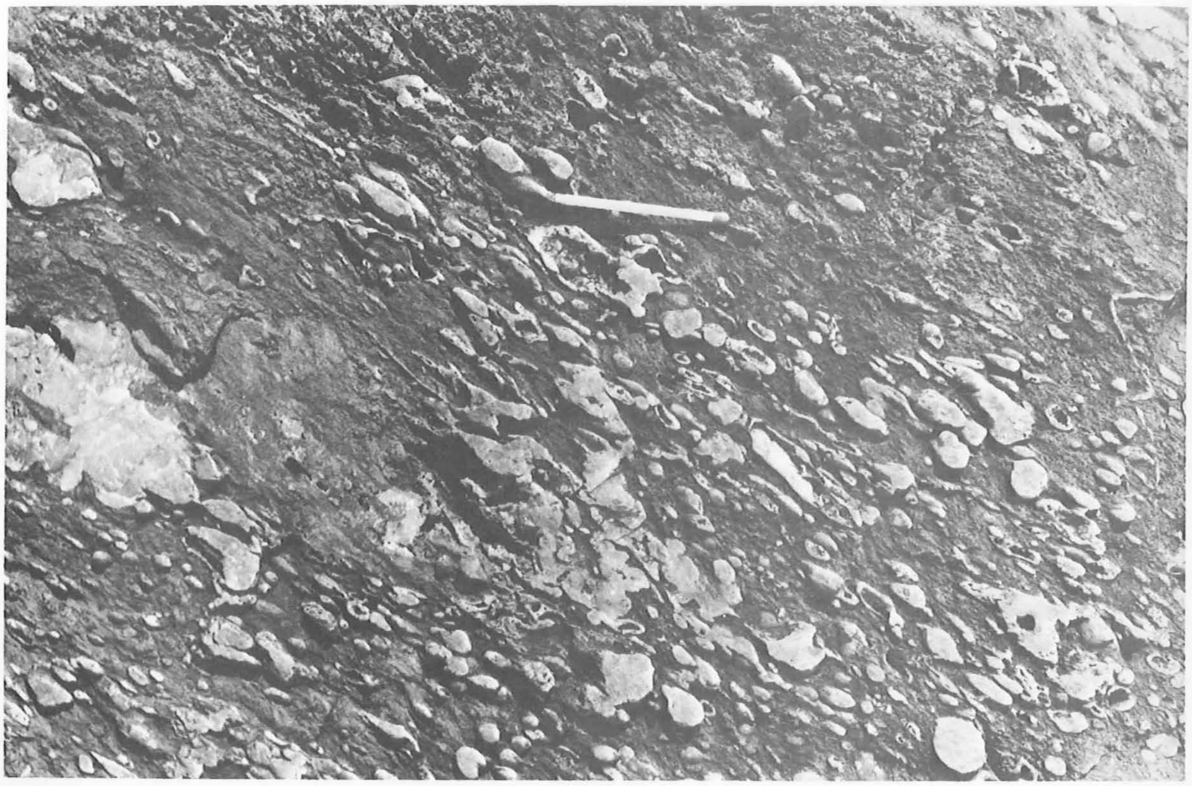


Fig. 21 Amygdales in Marraba Volcanics, 2 km west of Marraba siding M909/26 GMD

Fig. 22 Pillow lave or agglomerate sequence in Marraba Volcanics, 1 km west of Marraba siding, showing blocks of amygdaloidal basalt separated by fine-grained volcanic material. M909/30 GMD

TABLE 4: ESTIMATED MODAL COMPOSITIONS - TIMBEROO MEMBER, MARRABA VOLCANICS

| | 521* | 529 | 530 | 531 | 649 | 648 | 643 | 644 |
|---|---|---|---|---|---|---|---|---|
| Quartz | 65 | 50 | 67 | 66 | 20 | 20 | 48 | 25 |
| Feldspar | 10 | 5 | 5 | 10 | 70 | 60 | 50 | 70 |
| Muscovite | 10 | 15 | 15 | 3 | | | 1 | |
| Chlorite | | | 3 | 1 | | tr | | 1 |
| Biotite | | 20 | tr | 1 | | 15 | tr | |
| Calcite | 13 | | 5 | 15 | 1 | 3 | tr | tr |
| Opaques | 2 | 10 | 5 | 4 | 7 | 2 | 1 | 4 |
| Zircon | tr | | tr | tr | tr+ | tr | | |
| Tourmaline | | | tr | tr | | | | |
| Apatite | | | | | tr | tr | tr | tr |
| Sphene | | | | | 2 | tr | | tr |

*BMR Registered Numbers e.g. 69200521

Rock names (after Crook, 1960):

Feldspathic Labile quartzite/sandstone (649, 648, 643, 644)
Labile quartzite/sandstone (521, 529, 530, 531)

Fig. 23 Tight folds in siliceous beds of 'Mt Start Member', on eastern limb of anticline, 5 km north of Success mine.
M908/5A IHW

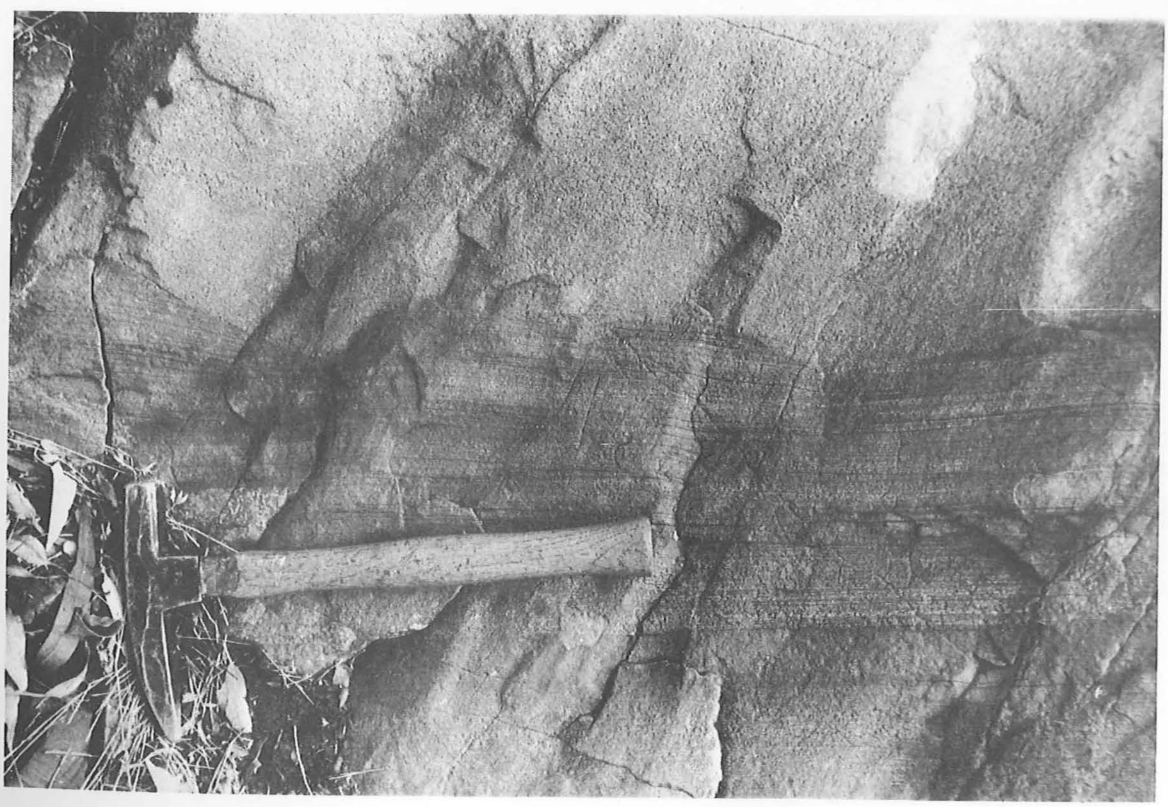


Fig. 24 Truncation of thinly bedded medium-grained sandstone by massive coarse-grained sandstone, in lower Mitakoodi Quartzite, member ($Plt_1$). Locality near Wakeful mine.
M908/32a IHW

are considered submarine by Glikson and Derrick (1970), and are probably a lateral deeper-shelf equivalent of the Marraba Volcanics. Carter et al (1961) indirectly correlated the Eastern Creek Volcanics (near Mount Isa) and Marraba Volcanics on the basis of the cessation of acid volcanicity in both areas. Acid volcanism (Argylla Formation) took place at the same time in the adjoining Mary Kathleen Sheet area, but no major basalt unit post-dating the acid volcanics exists there. Some amygdaloidal metabasalt and quartzite were laid down between the Argylla Formation and the Corella Formation near Lake Corella; their total thickness is about 150 m, and could represent very thin lateral equivalents of the Marraba Volcanics plus Mitakoodi Quartzite. This topic will be discussed further in a future Record on the Mary Kathleen Sheet area.

## Mitakoodi Quartzite

### Introduction

The Mitakoodi Quartzite was defined by Carter et al (1961), and was named after the Mitakoodi railway siding, which is near the type section of the formation at The Gorge. In the Marraba Sheet area the Mitakoodi Quartzite forms an almost continuous belt flanking the Marraba Volcanics; 5 km east of Ballara, rocks mapped by Carter et al (1961) as Argylla Formation are now considered to be Mitakoodi Quartzite. In additions, a small elongate dome of probable Mitakoodi Quartzite occurs in the Fox Mountain-Chumvale area.

The formation is ridge-forming, and hogbacks and cuestas are typical landforms; the silicified and lateritized ridge tops, 350 to 500 m high, are commonly bevelled and indicate an old erosion surface.

### Stratigraphic Relationships

The Mitakoodi Quartzite conformably overlies the Marraba Volcanics over most of the area; in outcrops east of Ballara and near Chumvale it overlies and is faulted against the older Argylla Formation. In most places it is overlain conformably by the 'Overhang Jaspilite' (new unit). The base of the formation is taken to be the base of the first massive quartzite overlying siltstone and calcareous sediments of the upper Marraba Volcanics, and the upper boundary is placed where jaspilite first appears in the topmost silt member of the Mitakoodi Quartzite.

### Lithology and Field Occurrence

Three members are recognisable within the Mitakoodi Quartzite

| | | |
|---|---|---|
| (top) | $Blt_3$ | silt and slate, up to 190 m |
| | $Blt_2$ | metabasalt - 'Wakeful Basalt Member', up to 236 m |
| | $Blt_1$ | feldspathic quartzite, up to 1 300 m |

The numbering does not indicate a strict superposition of members, as member $Blt_2$ is intercalated with members $Blt_1$ and $Blt_3$. On the accompanying maps the symbol Blt indicates undivided Mitakoodi Quartzite.

Member $Blt_1$ is predominantly coarse to medium feldspathic quartzite (about 5 to 30 percent feldspar), and constitutes about 80 percent of the formation. The quartzite is pale buff, cream and brown, with a massive to blocky parting, and thick to thin bedding. Cross-bedding is very common in the lower parts of the formation, south of Butcher Bore, where sets are up to 1 m thick, but ripple-marking is relatively rare; heavy-mineral banding outlines bedding in a number of places. Some bedding characteristics are shown in Figures 24 and 25. The 'Wakeful Basalt Member' is intercalated within this quartzite, and below the basalt the quartzite is massive and ridge-forming; above it, the quartzite is finer-grained and less resistant to weathering, and friable micaceous sandstone and siltstone are increasingly abundant.

The Mitakoodi Quartzite is extensively intruded by dolerite dykes, and less commonly by quartz-feldspar-specularite and quartz-tourmaline veins: massive quartz veins and zones of silicification occur along fault zones. A dyke of biotite lamprophyre over 3 km long intrudes quartzite southeast of Butcher Bore.

Member $Blt_2$ is known as the 'Wakeful Basalt Member', after the Wakeful mine, south of the headwaters of Slaty Creek. North and west from Yoomoo railway siding, only one basalt band is present, but to the south up to three volcanic intercalations occur. Massive and amygdaloidal basalt, chlorite and magnetite schist, tuff, siltstone, slate, and minor chert and limestone are present. Chlorite, quartz, calcite, and epidote are the dominant amygdale minerals in the basalt, which is generally well cleaved and metamorphosed. The minerals listed belong to the greenschist-facies. Pillow lavas have been noted 2 km east of Butcher Bore. Pencil slates are characteristic of beds immediately overlying the basalt, and 'pencils' up to 40 cm long have been observed southeast of Mitakoodi Siding.

A paced section of this member is presented as Figure 26. Dolerite dykes also cut the member in a number of places, and several small high-grade pods of copper mineralization associated with dolerite-basalt contacts occur southeast of Butcher Bore and west of The Gorge.

Member $Blt_3$ is mainly siltstone and slate, characteristically fawn-brown and deeply weathered. It forms a prominent bed up to 190 m thick beneath the 'Overhang Jaspilite', and is best displayed near the Overhang manganese deposit. Both the upper and lower boundaries of this member are transitional. Much of the member west of Butcher Bore is highly cleaved; bedding has been transposed in some places, and obliterated by iron, manganese, and silica enrichment in others.

Undivided Mitakoodi Quartzite (Blt): No members have been differentiated in the westernmost belt of Mitakoodi Quartzite which includes quartzite, phyllite, limestone, basalt, calc-silicate rocks, and some andalusite schist. The rocks are intensely and complexly faulted and more highly metamorphosed than those to

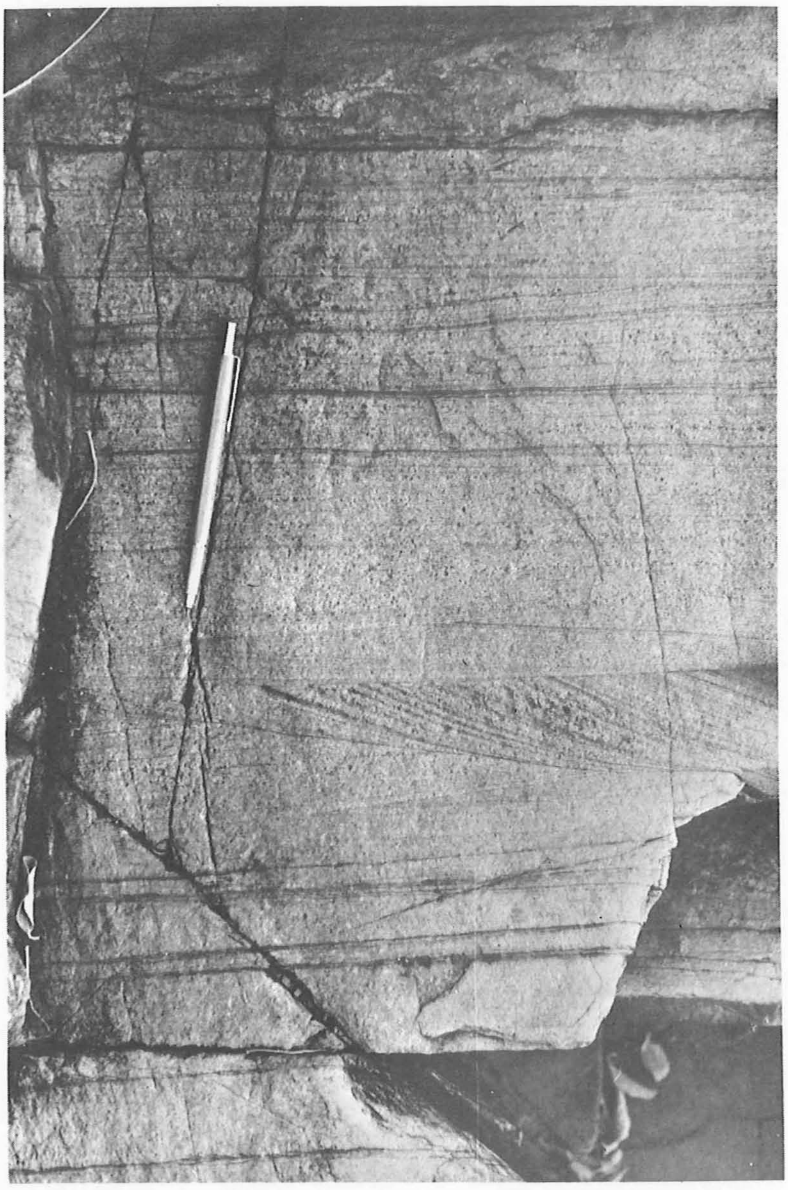


Fig. 25 Cross-bedded sandstone in Mitakoodi Quartzite,
member Elt, 2 km southeast of Mitakoodi siding

M909/18 GMD

to the east. The Mitakoodi Quartzite in the Fox Mountain area is also undivided, and consists of pavements and low ridges of medium to fine feldspathic quartzite which is locally highly fractured.

Structure

The Mitakoodi Quartzite forms a broad anticlinorium affected by cross-folding. A strong radial cleavage characterizes the formation, which is also affected by major faults in the area south of Butcher Bore and near the Corella River. A large elongate body of Mitakoodi Quartzite between Duck and Slaty Creek headwaters is a downfaulted synclinal block which is tightly to isoclinally folded. The repetition of Mitakoodi Quartzite in the Fox Mountain-Chumvale area indicates cross-folding about northwest-trending axes.

Petrography

Member $Blt_1$: Specimens R70200574, 575, 527, 528, 5689, and 5690, have been examined in thin section and their localities plotted on the geological maps and on Figure 27. A summary of their modal compositions is listed below.

TABLE 5

ESTIMATED MODAL COMPOSITIONS - MEMBER $Blt_1$, MITAKOODI QUARTZITE

| Rock Number | 574 | 575 | 527 | 528 | 5689* | 5690* |
|---|---|---|---|---|---|---|
| Mineral | | | | | | |
| Quartz | 70 | 85 | 60 | 86 | 85 | 15 |
| Plagioclase<br>K feldspar | 26 | 12 | 40 | 12 | 12 $An_{10}$<br>3 | 25 $An_{10-25}$<br>6 |
| Biotite, musc. | 3 | | | 1 | tr | 2 ser. |
| Iron ore | | 3 | | 1 | | 2 |
| Accessories | 1 | - | t, zr, r | zr ep | t, zr | 1 zr r am |
| Matrix | | | | | | 49 clay, f.g. qtz, ser. |

*GSQ slide nos.
t = tourmaline
zr = zircon
r = rutile
ep = epidote
am = amphibole
ser= sericite
qtz= quartz

Most of the quartzites are sublabile to labile and feldspathic. The texture is granular, but some flattening of grains has taken place; suturing and cataclasis of grain boundaries is evident in most specimens. Average grain diameter ranges from 0.2 to 1.0 mm. Specimen 5690 is very poorly sorted; grains are angular, and clayey matrix is abundant. Zircon and tourmaline are the most common heavy minerals. In specimen 574 tourmaline forms monomineralic bands up to 2mm thick, and pyrite forms cubes up to 1 cm across in specimen 575.

Member $Blt_2$ ('Wakeful Basalt Member'): Specimens of basalt (Nos 319, 355, 356, 364, 365 and 588) have been examined in thin section, and modal compositions of some of them appear in Table 6. Their localities are plotted on Figure 27 and on the geological map.

TABLE 6 : ESTIMATED MODAL COMPOSITIONS - 'WAKEFUL BASALT MEMBER', MITAKOODI QUARTZITE

| Rock Number | | 365 | 356 | 355 | 364 | 319 |
|---|---|---|---|---|---|---|
| Mineral | Plagioclase | 50 | 66 | 53 | 10 | 72 |
| | Biotite | 40 | 4 | 8 | 90 | 15 |
| | Chlorite | 1 | 20 | 30 | | 2 |
| | Quartz | 5 | 5 | 3 | | 1 |
| | Epidote | 2 | | | | 1 |
| | Iron Ore | 2 | 4 | 5 | | 4 |
| | Carbonate | | 1 | 1 | | 5 |
| | Accessories | 1 | sph, ap. | sph, ap, mu | | sph. |

sph = sphene, ap = apatite, mu = muscovite

All the rocks are metabasalts with spilitic mineral assemblages. Coarsely intersertal textures are moderately well preserved. Plagioclase is fresh and lath-like, and in all cases is albite ($An_1$ to $An_5$). Biotite forms olive-brown decussate aggregates, associated with chlorite and clear interstitial granular aggregates of quartz; accessories comprise apatite, epidote, sphene, ilmenite, and carbonate. Amygdales contain polygonal quartz aggregates associated with biotite, muscovite, and chalcopyrite, and are commonly rimmed by chlorite.

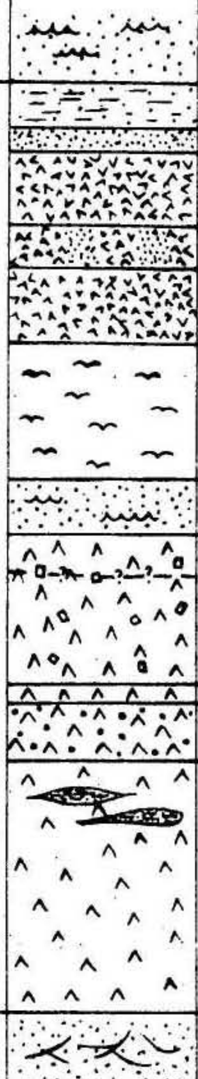
*FIG. 26*

# GEOLOGICAL COLUMNAR SECTION

MAP **Marraba 1·100 000** — **Cameron River** RUN **8** PHOTO **80** POINTS **35-36**

GENERAL LOCALITY: **West of Butchers Bore** GEOLOGIST **G.Derrick** DATE **23.7.69**

AGE **Proterozoic** STRATGRAPHIC UNIT/S **Wakeful Basalt Member** REFERENCE

| SCALE | AGE | GROUP | FORMATION | MEMBER | GRAPHIC LOG | DESCRIPTION | SAMPLES |
|---|---|---|---|---|---|---|---|
| | | | | |  | Feldspathic sandstone, m.g., blocky. | |
| 243 | | | | | | Silty sandstone, dark grey, laminated. | |
| 240 | | | | | | Buff blocky sandstone | |
| 220 | | | | | | Dolerite, fine-grained, subophitic texture. | |
| 200 | | | | | | Dolerite with sandstone rubble | |
| 180 | | | | | | Dolerite, highly chloritised | |
| 160 | | | | | | Alluvium | |
| 140 | | | | | | Felspathic sandstone, ripple marked. | |
| 120 | | | | | | Amyg. basalt with chalcopyrite | |
| 100 | | | | | | Massive basalt with pyrite and scattered amygdales. | |
| 80 | | | | | | Massive basalt | |
| | | | | | | Amygdaloidal basalt | |
| 60 | | | | | | Massive porphyritic basalt with lenses of laminated chert and quartzite | |
| 40 | | | | | | | |
| 20 | | | | | | | |
| 0 | | | | Pct1 | | Feldspathic sandstone, m.g. to c.g.. massive to blocky. | |

M(PF)118 *To accompany Record No 1971/56.* F54/A2/43 SHEET OF

Member Blt₂: One siltstone specimen (284) was examined in thin section. Quartz, muscovite, carbonate, and hematite grains after pyrite are most abundant. Green-brown biotite forms ragged grains, and tourmaline and epidote are the most abundant heavy minerals.

Undivided Blt: Arenaceous limestone and magnetite-bearing quartz-mica schist from the western belt of Mitakoodi Quartzite were examined microscopically. The limestone consists of calcite of average grain dimension 1-2 mm, fragments of feldspathic quartzite, and accessory chlorite, muscovite, zircon, and apatite. The schist consists of lenticles of granular quartz in oriented aggregates of muscovite. Magnetite porphyroblasts (pseudomorphed by hematite) are euhedral and slightly skeletal, and have not deformed the schistosity, which suggests they are due to post-shearing growth.

## Discussion and Correlations

The available evidence suggests that the Mitakoodi Quartzite is a near-shore, moderately well sorted, shallow-shelf, or possibly beach deposit. The abundance of cross-bedding and paucity of ripple-marking suggest deposition below wave base, and some torrential and overturned cross-bedding show that strong currents were locally operative, particularly in middle Mitakoodi Quartzite time. A progressive decrease in grainsize upwards in the sequence indicates either deeper marine (?) shelf sedimentation or maturing of the source areas, or both. A probable source of the sediments was the underlying Argylla Formation. The Argylla Formation (acid volcanics with quartzite) is highly feldspathic, a characteristic reflected in the high feldspar content of the quartzite. Mitakoodi Quartzite in the far southwest of the Sheet area may have received sediments from source areas well to the west. Periodic subaerial and shallow submarine extrusion of basalt provided a source of epidote and magnetite in some of the quartzite.

Carter et al (1961) correlated the Mitakoodi Quartzite with quartzite lenses (Lena Quartzite) near the top of the Eastern Creek Volcanics, in the adjoining Mary Kathleen Sheet area. This presumes that the Eastern Creek Volcanics and Marraba Volcanics are correlatives. The relationship between the Ballara Quartzite (on the Mary Kathleen Sheet) and Mitakoodi Quartzite is problematical. Both underlie Corella Formation and may be equivalent, although Carter et al (1961) considered the Ballara Quartzite to be the older unit.

# 'Overhang Jaspilite'

## Introduction

The 'Overhang Jaspilite' (new name) is a sequence of limestone and argillite containing distinctive beds of jaspilite which were previously included in the Corella Formation by Carter et al (1961). No jaspilite had been recorded in earlier published work. The name is derived from the Overhang manganese mine in the southeastern part of the area. The unit is informally symbolized Blj on the 1:50 000 geological maps, but Bloj on the 1:100 000 map, since the symbol Blj (Judenan Beds) has priority.

The 'Overhang Jaspilite' forms a belt about 80 km long, flanking the Mitakoodi Quartzite anticlinorium. The area of outcrop is broader in the north than elsewhere, because of cross-folding (Fig. 27). The formation crops out as low, dark, strike ridges of limestone and jaspilite, separated by valley-forming argillite, and has a dark grey and soft tone on the air-photographs.

Stratigraphic Relations

The 'Overhang Jaspilite' conformably overlies the Mitakoodi Quartzite, except to the south, in the Bulonga Anticline, where the contact appears disconformable. Relationships with the Mitakoodi Quartzite are described in the section dealing with that formation.

The top of the 'Overhang Jaspilite' is poorly defined, and is generally taken to be the stratigraphically highest bed containing jaspilite. However, in the area near the Overhang mine, pebbly quartzite appears to conformably overlie the jaspilite, and in the extreme southwest near Jimmy Creek, a lens of feldspathic quartzite conformably overlies the jaspilite. These quartzite units are shown as $Blj_q$ on the 1:50 000 geological maps, and are overlain by, or faulted against, the Corella Formation. Elsewhere the jaspilite itself appears to be faulted against the Corella Formation; the quartzitic breccia known as the 'Chumvale Breccia' locally contains jaspilite fragments and is a result of brecciation, decalcification, and silicification of the jaspilite sequence.

Field Occurrence

The 'Overhang Jaspilite' is intensely folded in certain zones along axes which trend northeast, but plunge variably to the north and south owing to cross-folding. On a regional scale cross-folding is indicated by the basin-and-dome structures near Fox Mountain and small-scale folding is best seen in sequences containing abundant jasper or fine-grained quartzite bands (Fig. 28). The quartzite bands tend to fold concentrically, in contrast to interbedded carbonate which display flowage and similar-style folding. Figure 29 shows an idealized cross-folded surface of jaspilite, and Figure 30 large-scale folding west of Dolomite siding. A cross-section of typical small-scale fold is shown in Figure 31. Some bands of specularite thicken in axial zones of the fold, giving rise to saddle-reef structures.

Generalized measured sections of part of the jaspilite are shown in Figures 32 and 33. The locations of the various sections are shown in Figure 27. In the measured section 8 km west of Dolomite (Fig. 33) argillite is especially abundant; it is finely laminated, and possibly varved, with indent structures around angular pebbels up to 5 cm across. Detailed correlations within the jaspilite are not possible because of abrupt lateral and vertical variations in the proportion of limestone and jaspilite. The formation is 300 m to 900 m thick.

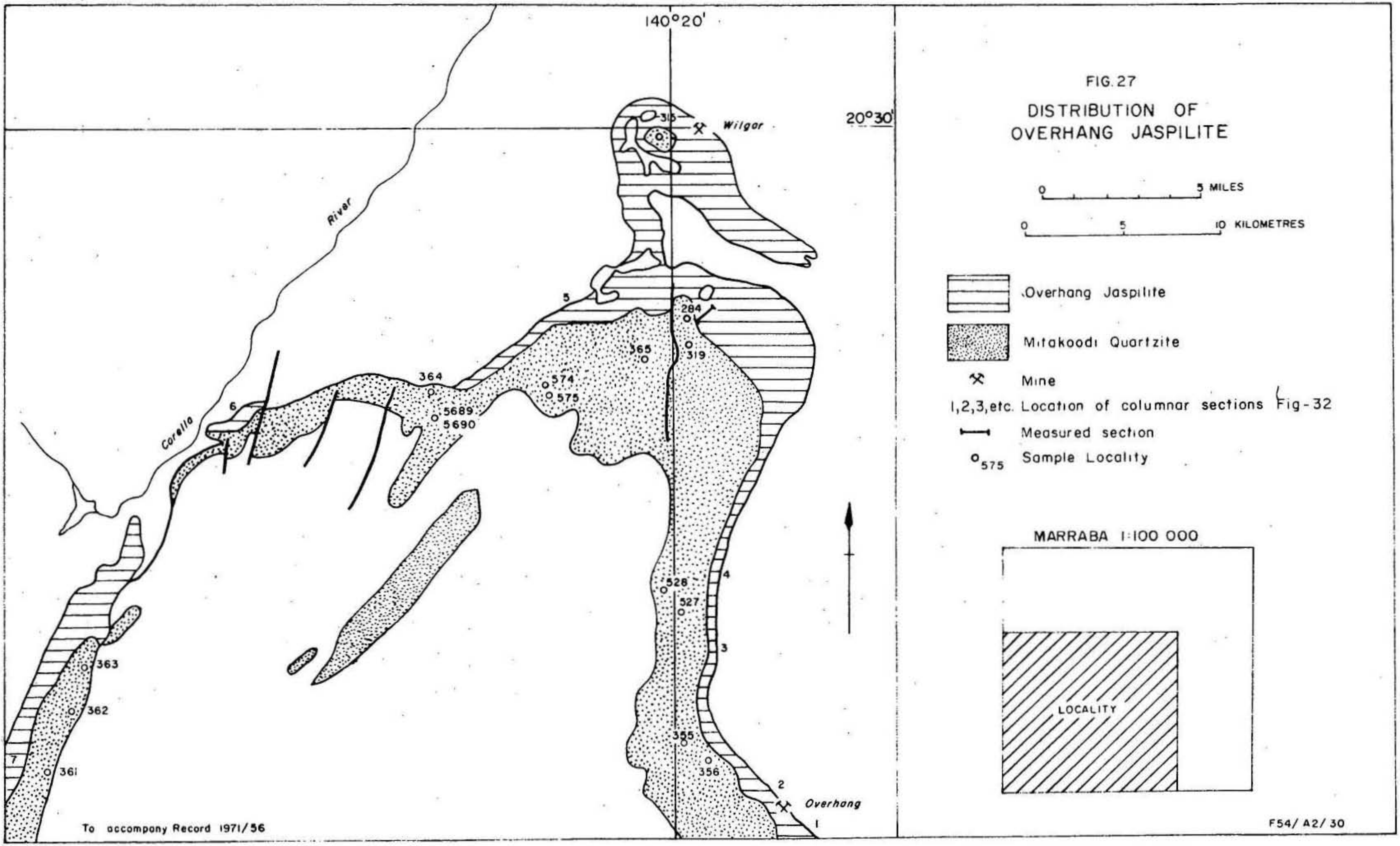
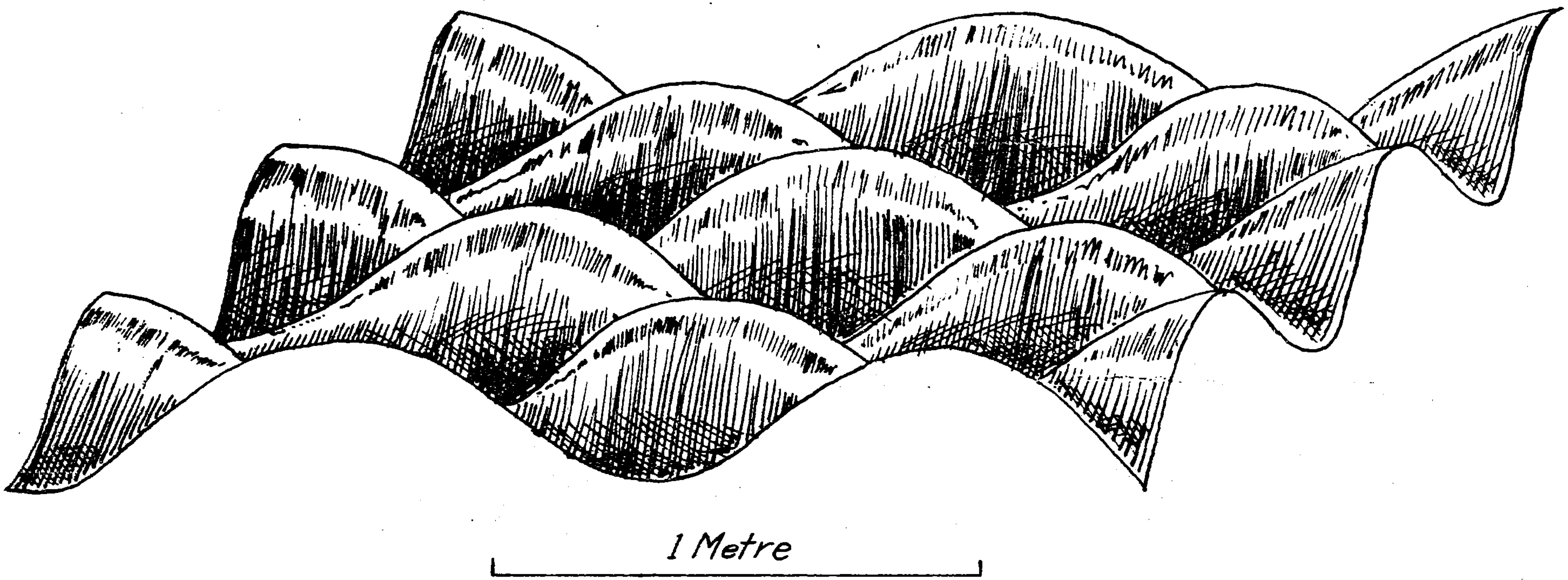



FIG. 27

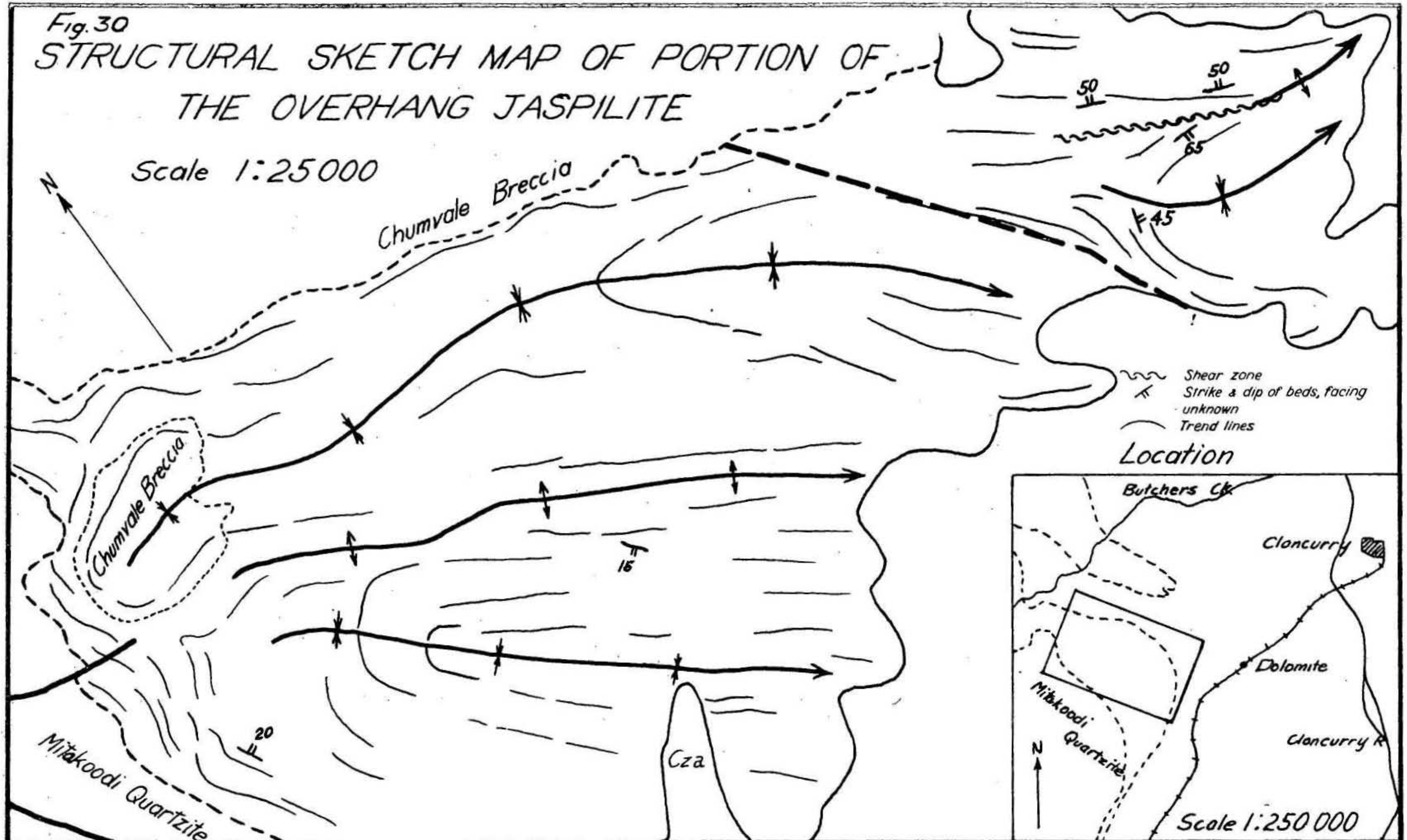
DISTRIBUTION OF OVERHANG JASPILITE

Fig. 28 Bands of cherty quartzite folded with fine-grained red-brown specularitic quartzite, 2 km south of Overhang mine. M909/14a GMD

Fig. 29




IDEALIZED SKETCH of CROSS-FOLDING
in the
OVERHANG JASPILITE




To accompany Record No 1971/56.

F54/A2/45

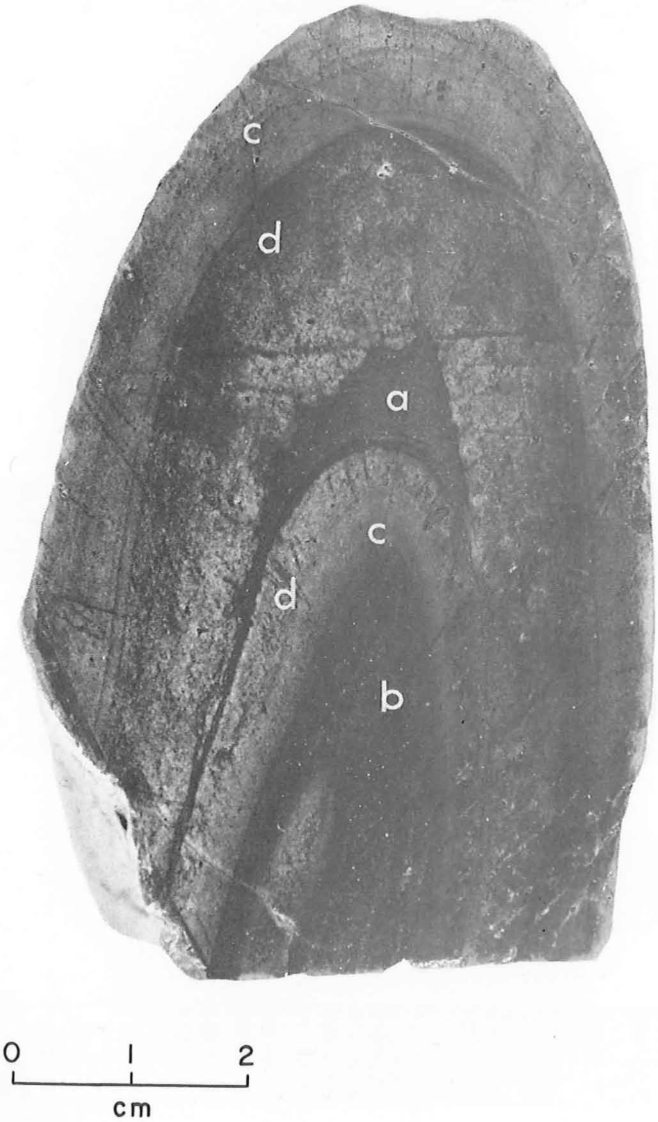



Fig. 31 Detail of small-scale fold in jaspilite;

a. fine-grained specularite showing saddle reef structure
b. fine-grained specularitic quartzite
c. cherry red hematitic quartzite
d. grey fine-grained quartzite

GA3086

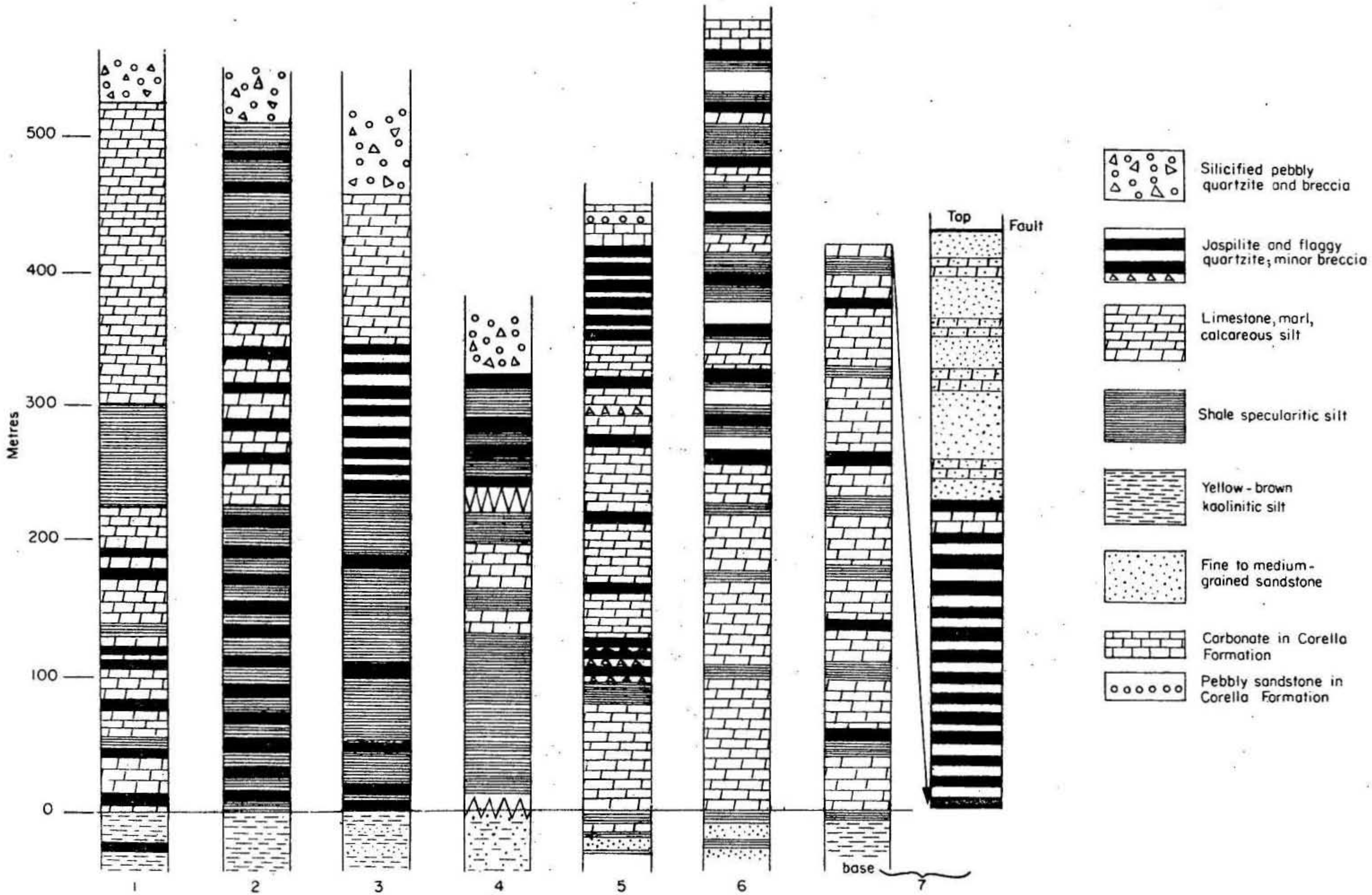



Fig. 32 Lithological columns, Overhang Jaspilite (See Fig. 27 for localities)

*To accompany Record 1971/56*

F54/A2/32

## Fig.33a: GEOLOGICAL COLUMNAR SECTION

MAP: MARRABA 1:100 000; No. 6956  RUN 8  PHOTO 77  POINTS A B.

GENERAL LOCALITY: 8 km West of Dolomite  GEOLOGIST: R.M.H.  DATE 1969

AGE: Proterozoic  STRATGRAPHIC UNIT/S: OVERHANG JASPILITE  REFERENCE:

| SCALE | AGE | GROUP | FORMATION | MEMBER | GRAPHIC LOG | DESCRIPTION | SAMPLES |
|---|---|---|---|---|---|---|---|
| Metres | | | | |  | | |
| 160–155 | | | | | | Top of measured section. Complex folding makes recognition of top of Formation uncertain, but true thickness probably exceeds 300 metres. | |
| 150–140 | | | | | | Argillite, brown to green, finely laminated, alternate dark and light laminae with indent structures in some places; outcrop generally poor; probably varves. | |
| 120–115 | | | | | | Argillite, green, finely laminated, alternate dark and light laminae, rounded pebbles and indent structures, probably varves; more resistant than underlying varves. | A30 |
| 110 | | | | | | Argillite, brown, finely laminated; varves. | A29 |

Scale marks: 160, 155, 150, 145, 140, 135, 130, 125, 120, 115, 110

M(PF) 118

*To accompany Record No 1971/56.*  F54/A2/46 (1 of 3)  SHEET 1 OF 3.

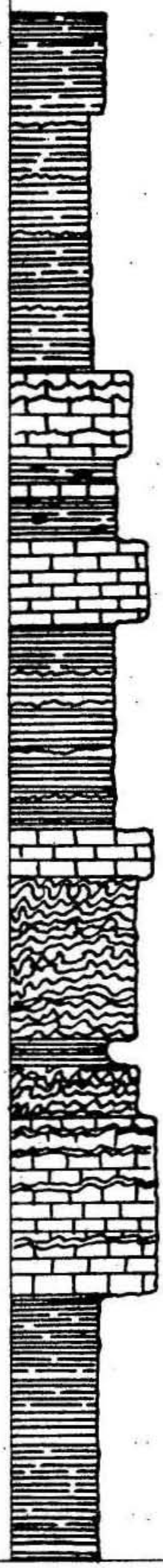
# Fig. 35b: GEOLOGICAL COLUMNAR SECTION

MAP MARRABA 1:100 000; No. 6956  RUN 8  PHOTO 77  POINTS: A B.

GENERAL LOCALITY: 8 km West of Dolomite  GEOLOGIST: R.M.H.  DATE: 1969

AGE Proterozoic  STRATGRAPHIC UNIT/S OVERHANG JASPILITE  REFERENCE:

| SCALE | AGE | GROUP | FORMATION | MEMBER | GRAPHIC LOG | DESCRIPTION | SAMPLES |
|---|---|---|---|---|---|---|---|
| Metres | | | OVERHANG JASPILITE | | | | |
| 110 | | | | | | Argillite, brown, finely laminated, Mn-staining; alternate dark and light laminae, probably varves. | A28 |
| 105 | | | | | | Argillite with very minor jaspilite beds, very poor outcrop. | |
| 100 | | | | | | | |
| 95 | | | | | | Limestone; minor jaspilite, increasing towards top. | |
| | | | | | | Argillite, yellow, calcareous, with Mn concretions. | A27 |
| 90 | | | | | | Limestone, massive. | |
| 85 | | | | | | Argillite with thin jaspilite beds; very poor outcrop. | |
| 80 | | | | | | Limestone, laminated, with resistant laminae. | A26 |
| | | | | | | Jaspilite, complexly cross folded forming small interlocking domes and basins. | A25 |
| 75 | | | | | | Argillite, laminated, gently folded. | |
| | | | | | | Jaspilite, very strongly folded. | A24 |
| 70 | | | | | | Limestone, laminated strongly folded; towards top of unit is increasing amount of very thin resistant laminae and jaspilite. | A23 |
| 65 | | | | | | Argillite, laminated, grey, very poor outcrop. | |
| 60 | | | | | | | |



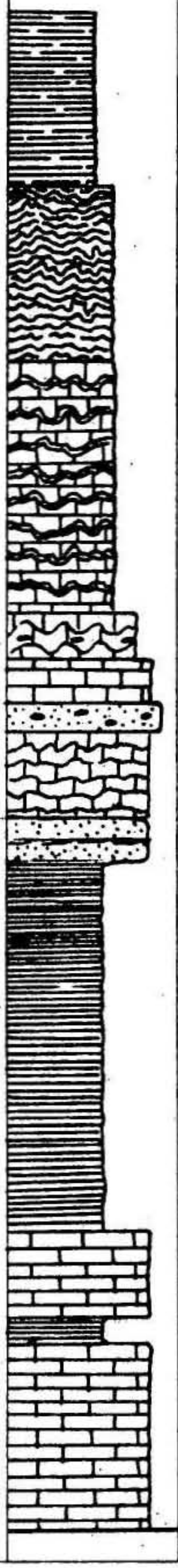
M(PF)118 *To accompany Record No 1971/56.*  F54/A2/46 (2 of 3) SHEET 2 OF 3

# Fig. 35c: GEOLOGICAL COLUMNAR SECTION

MAP: MARRABA 1:100 000; No. 69.. RUN 8 PHOTO 77 POINTS A B

GENERAL LOCALITY: 8 km west of Lolcrite GEOLOGIST [illegible] DATE 1969

AGE Proterozoic STRATGRAPHIC UNIT/S OVERHANG JASPILITE REFERENCE

| SCALE | AGE | GROUP | FORMATION | MEMBER | GRAPHIC LOG | DESCRIPTION | SAMPLES |
|---|---|---|---|---|---|---|---|
| Metres 55–49 | | | OVERHANG JASPILITE | |  | Argillite, laminate, grey, very poor outcrop. | A22 |
| 49–43 | | | | | | Argillite, black, Mn-bearing interbedded with jaspilite and fine-grained calcareous sediments | A21<br>A20<br>A19 |
| 43–34 | | | | | | Jaspilite, tightly cross-folded, with laminate limestone. Striations parallel "a" and "b" directions of folding; magnetite octahedra common along bedding planes. | A18<br>A17 |
| 34–32 | | | | | | Limestone, Mn-bearing | A16 |
| 32–31 | | | | | | Limestone, arenaceous | |
| 31–30 | | | | | | Quartzite, Mn concretions | A15 |
| 30–26 | | | | | | Limestone, with folded resistant laminae of quartzite | A14 |
| 26–24 | | | | | | Quartzite, laminate, dirty. | A12 |
| 24–11 | | | | | | Argillite, felspathic in parts brownish pink to buff; very poor outcrop. | A11 |
| 11–8 | | | | | | Limestone, arenaceous, fine to medium grained; | A10 |
| 8–7 | | | | | | Argillite, brown-buff. | |
| 7–0 | | | | | | Limestone, arenaceous, thin quartzite laminae protrude from weathered surface. | A9 |
| 0 | | | | | | Base: conformable contact Mitakoodi Quartzite | |

M(PF)118 *To accompany Record No 1971/56.* F54/A2/46 (3 of 3) SHEET 3 OF 3.

TABLE 7. **Petrography of 'Overhang Jaspilite'**

| Group | Spec. No.* | Calcite | Quartz | Musc/Ser. | Biot/Phlog | Chlorite | Scap. | Other Access | Opaques | Av. Grain Sz |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 285 | 80 | 10 | 7 | | | | | 3 | 0.45 mm |
| | 279 | 70 | 15 | | | 10 | | | 5 | 0.1 |
| 2a | 321 | 45 | 40 | 5 | 7 | | | | 3 | 0.07 |
| | 287 | 35 | 30 | 15 | 2 | 1 | | Tourm, 10 | 7 | 0.05 |
| | 311 | 20 | 35 | 40 | | | | | 5 | 0.05 |
| 2b | 310 | 30 | 30 | 5 | | 20 | | | 15 | 0.1 |
| | 282 | 25 | 25 | 40 | | | | | 10 | 0.07 |
| | 320 | 15 | 30 | 30 | | 2 | | | 20 | 0.04 |
| 3 | 312 | 15 | 35 | | 35 | | 10 | | 3 | 0.05 |
| | 316 | 1 | 5 | | 30 | 2 | 60 | | 2 | 1.5 |
| 4 | 281 | tr. | 50 | 35 | 10 | | | | 5 | 0.01 |
| | 314 | - | 45 | 55 | | | | | | 0.01 |
| | 286 | - | 40 | 45 | 10 | 1 | | | 4 | 0.01 |
| | 288 | - | 35 | 30 | | | | 10 | 20 | 0.01 |
| 5 | 280 | 7 | 35 | | 15 | | | 3 | 40 | 0.04 |
| | 309 | 5 | 60 | | | | | | 35 | 0.03 |
| 6 | 313 | 60 | | | 15 | | | Trem 20 | 5 | 0.07 |

* BMR Registered Number e.g. 69200285

Sedimentary structures are common in the limestone and argillites. The limestone is laminated to thick-bedded, with interbeds of quartzite, and shows some slumping and micro-cross bedding. Manganese staining and concretions are widespread in fractures and along bedding planes and barite has been found at six widely separated localities in the jaspilite; it forms veins in limestone and fault fracture fillings, and has probably been derived and concentrated from barium-bearing sediments in the formation.

Petrography

The rocks of the 'Overhang Jaspilite' form a continuous spectrum from carbonate-rich rocks, through extremely pelitic rocks to iron and quartz-rich jaspilites, which have been divided into six arbitrary groups for convenience of description. There is a systematic change in grainsize throughout the groups, as shown in Table 7.

Group 1: Chlorite-muscovite-quartz-calcite granofels is yellow brown to grey, weathering to dark brown, fine-grained, and in some places flecked with olive-green chlorite porphyroblasts. In thin section the rocks are granoblastic and consist predominantly of calcite. Quartz is present as sub-rounded elongate grains, and chlorite is closely associated with specks of hematite, with which it generally has a poikiloblastic relationship. The muscovite is roughly aligned.

The rocks have been formed through metamorphism of impure limestones containing detrital quartz and clay minerals.

Group 2: Muscovite-quartz-calcite granofels, which has been divided into two sub-groups on the basis of iron content, is generally finely laminated, grey to brown, with small slump structures, and weathers to a dirty grey-brown; the more resistant laminae form ridges on the weathered surface. Iron-rich varieties are reddish-brown, and rarely contain black manganese-rich concretions.

In thin section, the rocks are granoblastic aggregates of muscovite, quartz, and calcite, and minor biotite, and opaque minerals. Up to 10 percent tourmaline is present in some samples. The opaque minerals tend to be idioblastic, and in the manganiferous sample fine-grained opaques form concentric rings. Laminations are marked by changes in grainsize and the proportions of constituent minerals.

These rocks were formed from impure clay-rich silty limestone, with layers rich in iron oxides, by metamorphism to the greenschist facies.

Group 3: Quartz-biotite-scapolite granofels is grey, laminated to massive and spotted by light grey to round white porphyroblasts of scapolite. The spotting is emphasized by weathering.

In thin section, round poikiloblasts of scapolite with numerous inclusions of biotite, chlorite, and calcite, can be seen in a granoblastic groundmass consisting of biotite, scapolite, plagioclase, and possibly quartz, and minor idioblastic opaque minerals, sphene and zircon. Laminations are due to variations in grainsize and proportions of the constituent minerals.

These rocks have probably formed by metamorphism of evaporitic (?) (halite-bearing) fine-grained impure carbonate sediments. Chlorite was produced early in the metamorphism, and was later converted to biotite, except where protected from reaction within scapolite porphyroblasts.

Group 4: Biotite-sericite-quartz argillite is grey to black, and in some places laminated. Some of the rocks are iron-rich and others contain manganese concretions.

In thin section, rocks of this group consist of very fine-grained aggregates of quartz and sericite, lesser amounts of biotite, and minor calcite, chlorite, and sphene in some. Many are heavily clouded with black dust, others with coarser-grained concentrations of opaque minerals. Hematite staining is common.

The rocks are slightly metamorphosed calcareous shale and siltstone.

Group 5: Jaspilite (biotite-quartz-magnetite-hematite granofels) consists of alternating bands of cherry red and maroon fine-grained iron-rich quartzite. Large numbers of fine fractures cut the rock perpendicular to the bedding, and these have been filled with quartz.

In thin section, the rocks are granoblastic, and consist mainly of quartz and opaque minerals concentrated in the centres of the quartz grains. Some bands consist almost entirely of opaque minerals (including hematite). Calcite is a minor component, and biotite and rounded detrital sphene are also present. Rare large euhedral grains of pyrite have in some cases been pseudomorphed by hematite.

The rocks appear to have been very fine-grained sediments in which the concentric rings of hematite, now the nuclei of recrystallized quartz grains, may be of oolitic origin. Clays in the original iron oxide/silica sediment have been reconstituted during metamorphism to produce biotite.

Group 6: Phlogopite-tremolite-calcite granofels is fine- to medium-grained, grey, with large greenish grey porphyroblasts of tremolite protruding from the weathered surface.

In thin section, large subidioblastic porphyroblasts and smaller acicular prisms of tremolite are in a granoblastic groundmass of calcite, phlogopite, and opaque minerals. The porphyroblasts are poikiloblastic to calcite and phlogopite, but the opaque minerals are concentrated in cleavages and around the perimeters of grains.

The rocks are metamorphosed limestone containing clay impurities.

## Discussion and Conclusions

The 'Overhang Jaspilite' was deposited during a period of quiescene; very fine-grained sediments, consisting predominatly of quartz, clay, and colloidal silica and iron oxide, were deposited in a shallow shelf area below wave base. Carbonate was precipitated from the shallow water, and in some areas of restricted circulation, evaporitic sediments, containing halite, were formed. For at least a part of the period of deposition, sedimentation was controlled by seasonal changes, producing varves. Pebbles forming indent structures indicate the possibility of glaciation at the time of deposition.

Although it is only a small 'banded iron' unit, the 'Overhang Jaspilite' shows many similarities to Precambrian banded iron formations described by Trendall (1968), in that it contains interbedded carbonate, displays varve-like microbanding, and has manganese and barite associated with it.

It is possible that the upper parts of the Mitakoodi Quartzite and the 'Overhang Jaspilite' are time equivalents, the former being a near-shore deposit and the latter a deeper shelf deposit. The basalt interbeds in the Mitakoodi Quartzite could also be partly contemporaneous with the jaspilite environment, as suggested by Trendall (op. cit.) for other jaspilite sequences.

## 'Chumvale Breccia'

### Introduction

The 'Chumvale Breccia' was regarded by Carter et al. (1961) as a problematical quartzite breccia overlying the Corella Formation in the Butcher Bore area. Detailed mapping indicates that the unit requires re-definition (see end of section).

### Field Occurrence

The breccia is best exposed 1 km northeast of Butcher Bore, 6 km west-southwest of Butcher Bore, and in the Fox Mountain area 8 km west of Chumvale homestead. There are smaller exposures south of the Barkly Highway-Butcher Creek crossing, and west of the Cloncurry-Duchess road. A large area mapped as 'Chumvale Breccia' by Carter et al (1961) 2 km northwest of Butcher Bore, is mainly acid volcanics with small areas of quartzite-limestone breccia on the southern and eastern sides of the outcrop.

The breccia forms rugged bouldery ridges and irregular plateaux which are generally the highest points in the Chumvale - Butcher Creek area. It consists mainly of irregular fragments and blocks of quartz and quartzite, 1 mm to 40 cm long, in a friable siliceous, limonitic, and locally calcareous matrix. Vague bedding can be seen in fine-grained quartzite interlayered with zones of quartzite breccia.

Significantly, the breccia is confined to areas of the 'Overhang Jaspilite', a sequence of flaggy fine-grained quartzite, hematitic quartzite, and bedded limestone. Outcrop trends of the breccia generally parallel bedding trends in the associated jaspilite, and iron and manganese enrichment has taken place in some of the breccia zones.

Origin

The 'Chumvale Breccia' probably originated from the 'Overhang Jaspilite' by brecciation and leaching of carbonate, and extensive silicification. A complete transition from jaspilite to 'Chumvale Breccia' has been noted near Butcher Bore, as follows:

a. Interbedded flaggy fine-grained quartzite, hematitic quartzite and laminated limestone

b. Folding and extreme contortion of the sequences, with fracturing of the quartzite interbeds

c. Separation and variable rotation of the disrupted quartzite blocks; these provided most the 'clasts' in the final product

d. Removal of carbonate from the calcareous quartzite breccia by leaching, followed by silicification and iron and manganese enrichment. The product is known as the 'Chumvale Breccia'.

Silicification is related to faulting, folding, and partly to recent laterite profile development. In general the calcareous quartzite breccia is located downslope from the silicified quartzite breccia forming ridges and plateaux. A knife-sharp contact between the two breccia types (with calcareous and siliceous matrices) has been observed 2 km north-northeast of Butcher Bore.

The character of the breccia varies according to the amount of interbedded quartzite in the jaspilite, the thickness of the quartzite interbeds, and sand content of the bedded limestone. Theoretically any sequence of interbedded flaggy quartzite and calcareous beds could provide a suitable starting point for development of Chumvale-type breccia, and it is fortuitous that these rock-types are best developed in the 'Overhang Jaspilite'. Carbonate leaching is widespread throughout the area, and is not confined to the 'Chumvale Breccia'; e.g. in most parts of the Corella Formation the typical gashed and vuggy surface of the calcsilicate rocks is due to selective leaching of small lenses of calcite.

Relation to Previous Work

A number of problems were noted by Carter et al (1961) in their discussion of the 'Chumvale Breccia'. All their anomalies and uncertain stratigraphic relationships can be adequately explained in terms of the processes outlined above.

viz. 1. '.....distribution and mode of occurrence exclude the possibility that it is a fault breccia, except perhaps as a thrust sheet.' (Carter et al., op. cit., p.93).

As noted above, the breccia is related to faulting of various trends; the apparently anomalous distribution of the breccia is explained by its close association with the 'Overhang Jaspilite', a widespread and complexly folded unit in the Marraba 1:100 000 Sheet area.

2. 'The presence of metasediments of the Corella Formation within the core of the arcuate occurrence can hardly be explained without unconformity or faulting.' (Carter et al., op. cit., p.96).

The Corella Formation referred to is actually a calcareous part of the 'Overhang Jaspilite' occurring in a topographic low near Butcher Bore; it is part of the sequence unaffected by lateritization, and away from the influence of faults. The arcuate shape of the breccia reflects cross-folded jaspilite.

Redefinition

The '<u>Chumvale Breccia</u>' is a predominantly quartzitic breccia derived from the 'Overhang Jaspilite' by brecciation, carbonate leaching, and silicification. The type area is immediately north-northeast of Butcher Bore, in the Marraba 1:100 000 Sheet area.

## Corella Formation

Summary

The Corella Formation is subdivided into three broad units - essentially an upper and lower highly calcareous unit separated by a moderately calcareous pelitic-psammitic unit. It appears to conformably overlie jaspilite and unconformably overlie acid volcanics of Argylla Formation. Local facies changes are widespread; in the northwest the topmost unit $Blc_3$ overlaps $Blc_2$ and $Blc_1$ onto basement. Graphitic slate in the sequence is correlated with the Marimo Slate.

Laminated calc-silicate granofels is the most abundant rock type; the most abundant minerals are diopside, hornblende, scapolite, calcite, microcline, quartz, and plagioclase. Other important minerals are garnet, staurolite, vesuvianite, sillimanite, kyanite, and epidote. Monomineralic feldspar bands could represent tuff layers, feldspathized chert bands, or products of local potash-exchange between pelite and limestone.

Other important rock-types include massive, glassy quartzite marker beds, basic tuff, pillow basalt, breccia, schist, and limestone. The formation contains numerous metabasalt and amphibolite intercalations, as well as microgranite sills. The metamorphic grade ranges from high greenschist to amphibolite facies, and at least two periods of metamorphism are recognized.

The calcareous rocks are garnetized near Mary Kathleen. Scapolitization is also widespread in the same area, but in most of the formation scapolite is probably derived from evaporitic minerals (halite (?)) in original marl and limestone. Much limestone in the sequence is mobilized as a result of faulting, accompanied by flowage and recrystallization. The black vuggy surface of much of the Corella Formation is due to calcite leaching.

Some tentative comparisons can be made between the Corella Formation and the near-shore barrier, flat-lagoonal-supratidal environment of Permian carbonates in the Guadalupe Mountains (Kendall, 1969). Detailed studies of the rock types and of scapolite distribution should place comparisons such as this on a much sounder basis.

## Introduction

The Corella Formation is one of the most striking features of the Precambrian in northwest Queensland. It is a metamorphosed carbonate shelf sequence, and its diversity of rock type and abundance of mineral deposits have interested geologists, mining companies, and prospectors for many years.

## Previous Literature (see Table 1)

Vertically dipping slate and sandstone and some crystalline limestone were reported from near Cloncurry by Jack (1898). Several kilometres southwest of the town he described the limestone as thick-bedded, magnesian limestone containing siliceous granules. Ball (1908) listed areas of the older limestone in the Cloncurry Mineral Field and noted that they were lenticular, interbedded with slate and schist, usually ferruginous, and in places replaced by silica. The Cloncurry Series of Dunstan (1913) included calcareous and ferruginous argillaceous slate and schist, rocks containing ferromagnesian silicates, some massive, pure limestone, and impure limestone alternating with slate and schist. He also commented on severely contorted folds with a general northerly trend.

The name Corella Series was first published in David (1932, p32) who used 'Corella Limestone' as a stratigraphic name (p. 29). The Corella Series was described as containing massive marmorized limestone. Mapping by officers of AGGSNA (1937, pl. 4) shows most of the Corella Formation as upper Mount Isa Series limestone. Honman (1939) included the present Corella Formation in his Mount Isa Series, in which he described distinctly bedded and fragmental limestones interbedded with slate and fine-grained mica schist. Quartzite, slate and schist, acid lava flows, and volcanic agglomerate along faults were also reported. Shepherd (1946a) noted that the altered limestone of the Corella Series contains no large intrusions.

Subsequent work concentrated on the petrography of the region. Edwards and Baker (1954) discussed the widespread occurrence of scapolite, and suggested regional sodium and chlorine metasomatism. They also discuss various 'granulite-textured' metamorphic rocks and 'red rocks' which are altered metamorphic rocks. A preliminary systematic account of the petrography of the Cloncurry Complex was given by Joplin (1955), who described pelite and psammite from the present Corella Formation, summarized the work of Edwards and Baker (1954) on the calcareous and calc-silicate rocks, and described some basic intrusive rocks. Walker et al (1960) discussed the difficulties in distinguishing para and orthoamphibolites in areas of higher-grade regional metamorphism, and Carter (1959a, Table 1) briefly summarized the location, topographic expression, lithology, and structure of the Corella Formation. The formation was formally defined and described by Carter et al (1961).

Early in the 1950's activity by exploration companies increased. The early work concentrated on individual prospects, e.g. TAMCO's interest in Yanasinga, Lawler, and Mount Corella (Ivanac, 1953 a, b; 1954, a, b, d). A regional approach was first used in the search for uranium (Carter, 1955 b; Campbell, 1954; Searl and McCarthy, 1958) and at least 60 radiometric anomalies were investigated within the Corella Formation. A similar coverage by an electromagnetic survey produced 106 anomalies, many of which were in the Corella Formation (Rio Tinto Australian Exploration Pty Ltd, 1960). Rio Tinto Australian Exploration also carried out geological mapping near Mary Kathleen (Campana, 1958; Coats, 1958; Matheson, 1959a), and assessed the Milo Uranium Prospect (Searl, 1959b). Geochemical surveys within the Corella Formation were carried out by Conzinc Riotinto Australia Pty Ltd, (Mucenieкas, 1964), Ausminda Pty Ltd, (Ausminda Pty Ltd, 1966), and Kennecott Explorations (Aust.) Pty Ltd, (Fitch, 1967). Informative comments on the geology of the Corella Formation are contained in a report by Kennecott Explorations (Aust.) Pty Ltd, (1968 a and b). Numerous prospect evaluations were carried out by Carpentaria Exploration Co. Pty Ltd, and are held at their Cloncurry office.

The Corella Formation has provided many problems that have been studied by Honours students of the University of Queensland (Derrick, 1963; Hill, 1968; Ramsay, 1968; Barlow, 1969; Bavington , 1969; Clifford, 1969; Rowley, 1969). Most of these areas lie a few kilometers west of the Marraba 1:100 000 Sheet area, north and south of Mary Kathleen, but they provide detailed information relevant to much of the Corella Formation in the Marraba Sheet area.

This preliminary account covers work done within the formation during the 1969 field season; it is a general account, and certain topics will be discussed in more detail in separate reports. For the present it is convenient to retain the definition of the Corella Formation of Carter et al (1961), and to discuss some of the discrepancies that the detailed regional mapping disclosed.

Definition of the Corella Formation (see also Carter et al, op. cit., pp 86-90)

Derivation of Name: The Corella River which flows northeastwards across the formation from its head about 12 km southwest of Mary Kathleen.

Map Reference: Dobbyn, Cloncurry, and Duchess 1:250 000 Sheets, Prospector, Quamby, Mary Kathleen, Marraba, and Cloncurry 1:100 000 Sheets within the Cloncurry 1:250 000 Sheet.

Distribution: In the Marraba 1:100 000 Sheet area the Corella Formation occupies most of the northern half, and extends southward on both sides of the complex north-northeast plunging Bulonga and Duck Creek Anticline.

Type Locality: Carter et al (op. cit.) proposed that the type locality should be along the old Mount Isa/Cloncurry Road from a point a little less than 1 km east of the Federal mine (lat. 20°36'S, long. 140°12'e), to the Wonder Valley turnoff, and then for about 16 km in a westerly direction along a disused Mary Kathleen access track to an outcrop of granite at latitude 20°37'S, longitude 140°4'E.

Thickness: Carter et al, gave the thickness as 1 500 m to perhaps more than 3 000 m. The uncertainty results from the extreme deformation of the rocks, which has resulted in plastic flowage, crenulations, and numerous major faults. The thickness is probably variable; estimates from the present survey are listed in the Stratigraphy Section.

Age: Lower Proterozoic or Carpentarian; age determination work is being carried out, and a minimum age of near 1 500 m.y. is likely.

Stratigraphy

The Corella Formation is underlain by the Mitakoodi Quartzite and 'Overhang Jaspilite'. Contacts appear conformable in areas west of Dolomite, and faulted near the Corella River/Barkly Highway crossing and elsewhere. The Marimo Slate appears to be a lateral equivalent of the middle part of the Corella Formation.

The formation is overlain, apparently conformably or disconformably, by the Roxmere Quartzite near Marimo Siding, and overlain unconformably by the Quamby Conglomerate. The Naraku Granite and the newly defined 'Burstall Granite' intrude the formation but its relationship with the revised Wonga Granite is uncertain. The Corella Formation is cut by numerous basic bodies including large dolerite masses near Morris Creek, the Lunch Creek Gabbro, and the 'Lakeview Dolerite' dyke.

Along the western edge of the Sheet area, the Corella Formation overlies Argylla Formation, but it is not known whether the contact is unconformable or faulted. In a road cutting 2 km south-southeast of the Jubilee mine, schistose and highly weathered acid volcanics and metasediments are overlain by a meta-conglomerate containing cobbles and pebbles of quartzite in a matrix of psammitic schist. This is overlain by massive quartzite of the Corella Formation. Along the western Sheet boundary from south to north there appears to be a progressive onlap of Corella Formation onto Argylla Formation, and in the far north the topmost member of the Corella Formation rests on acid volcanics of the Argylla Formation.

Within the Corella Formation three broad divisions of member status have been recognized. They are generally equivalent to the divisions in the adjacent Mary Kathleen Sheet area to the west, but are less well defined both lithologically and topographically:

| | | |
|---|---|---|
| $Blc_3$ | Black-weathering banded calcsilicate granofels* (with calcite, tremolite, diopside, hornblende, scapolite, and sphene), limestone, marl, calc-silicate breccia, minor quartzite. | 300 -500 m |
| $Blc_2$ | Banded, brown to buff-weathering calcsilicate granofels (with diopside, epidote, scapolite, hornblende, quartz), calcareous quartzite, felds-pathic metasiltstone, slate, basic tuff, and pelitic schist, minor limestone, basalt, and basaltic pillow lava. | |

*Used in the original sense defined by Goldsmith (1959); e.g. medium to coarse-grained granoblastic metamorphic rock without, or with only indistinct, foliation or lineation. The rock may be uniform in mineral composition, or it may contain layers of differing composition in which non-directional minerals predominate.

$Blc_1$ As for $Blc_3$ 0-1 200 m

Field Occurrence

Members $Blc_1$ and $Blc_3$ are similar in all respects except stratigraphic position; they form prominent upstanding black to grey-brown ridges, and are termed colloquially 'black-fella Corella'. Their distribution is shown on the geological map; $Blc_1$ is best exposed along the Barkly Highway in the Corella River area, in an area north of Fox Mountain, as isolated hills southeast and east of Dolomite siding; $Blc_3$ overlies the Marimo Slate, and is very well exposed in the northwest, near the old Mount Isa-Cloncurry track. $Blc_1$ has been displaced from the west to its present position by normal faulting along the Fountain Range fault zone.

The two members contain a wide range of rock types, and differ from $Blc_2$ in containing more free calcite and less pelitic and psammitic sediments. In general the rocks are flaggy, pale quartzitic beds interbedded with less resistant calcareous beds; the distribution of siliceous and feldspathic bands is quite variable, and such bands are altogether absent in places. Spotting due to scapolite, plagioclase, hornblende, or pyroxene porphyroblasts is common (Fig. 34), and many of the rocks have a black crusty vuggy surface ('stewed rhubarb') (Fig. 35) produced by the leaching-out of small calcite veinlets which cut the bedding. A common rock type near the Cameron Fault is 'mobilized' limestone, in which scattered blocks of banded metasediment occur in a coarsely crystalline limestone (marble) matrix (Figs. 36 and 37). These rocks are associated with actinolite masses and nodules and represent a brecciated and completely recrystallized sequence of highly calcareous granofelses. Good examples of this rock type occur on the track between the Cameron Fault and Wollondonga mine, and in the Cameron series of limestone pits 2.5 to 5 km north of Wollondonga.

Massive quartzite lenses north of Mary Kathleen, along and near the Cameron Fault, form high ridges and rough dip slopes. The rocks are coarse to medium-grained, sparsely cross-bedded, and locally ferruginous.

Member $Blc_2$ is probably the most widespread and diverse unit in the Corella Formation. The most abundant rock type is brown to dull green, laminated granofels containing microcline, epidote, quartz, actinolite, garnet, diopside, hornblende, and scapolite in varying amounts. They are best developed in the Mary Kathleen Syncline, where their grade of metamorphism is slightly higher than elsewhere, owing to the contact effects of the 'Burstall Granite'. Typical laminated granofels from this area are shown in Figures 38, 39, and 40. The light-coloured laminae are grey to pink, very fine-grained, cherty in appearance, and consist of potash feldspar and some quartz. The mafic laminae contain scapolite, diopside, hornblende, garnet, quartz, feldspar, and epidote. In areas of higher grade metamorphism veinlets of all the mafic minerals transect the bedding, and large monomineralic segregations and veins are a feature of the Mary Kathleen area, e.g. hornblende crystals up to 10 cm long form aggregates along joints, epidote-tourmaline-prehnite masses occur near the open cut, garnetite veins and dykes ($Blc_{2r}$) intrude and replace country rock east and south of the open cut, and coarse radiating scapolite aggregates are developed along bedding planes, especially near the microwave tower.

Granofelses of lower metamorphic grade occur in the Wonder Valley and Mount Godkin areas, and northeast of Butcher Bore. Some areas of laminated granofels are transitional into thin-bedded, micaceous, feldspathic, and calcareous quartzites 3 to 6 km northeast of the Wollondonga mine. Intricate drag folding is well displayed in these rocks along fault zones (Fig. 41 and geological map). Flaggy to fissile pelitic schists also occur, with scapolite porphyroblasts 1 to 10 mm in diameter (Fig. 42).

'Red rock' is abundant in the area, especially near Lake Corella. It is laminated to massive granofels in which calcium, magnesium, and iron have been leached from the mafic minerals and in which some of the iron has been reprecipitated as fine hematite dust in feldspar imparting a red-brown colour to the rock.

Agglomerate with intermediate to basic fragments crops out 2 km southwest of the Lady Vera mine, near the Corella river. The eruption which produced it appears to have been pre-metamorphic.

A number of 'submembers' of $Blc_2$ have been delineated on the maps:

(a) Black slate ($Blc_{2s}$) crops out in a cross-folded belt 3 - 4 km north of Butcher Bore, and near the Federal mine, where andalusite spotting and carbonaceous and graphitic schist are common. It is interbedded with limestone, and local rapid facies changes are evident. The slate is considered broadly equivalent to $Blm_{1s}$, the oldest slate unit in the Marimo Slate.

(b) Limestone and marl ($Blc_{2l}$) form small lenses in the sequence. The best exposures are in the Mary Kathleen Syncline where garnet-vesuvianite limestone is well exposed (Fig. 43), near the Lalor mine where diopside limestone (Fig. 44) and granofels are most abundant, and 3 km northwest of the Wollondonga mine.

(c) Schist, phyllite, basic tuff ($Blc_{2t}$) The basic tuff is restricted to an area immediately south of the Lalor mine, and is an upstanding sequence of layered basic to intermediate rocks interbedded with garnetiferous schist, amphibolite, and metabasalt (Fig. 54). Some acid agglomerate is also present. Lineated quartz gashes and garnet-quartz-chlorite masses occur in the tuff (?) (Fig. 46).

A narrow persistent belt of biotite schist extends from Lake Corella to north of the Cameron River, and near Jubilee mine sillimanite is present along 1 km of strike.

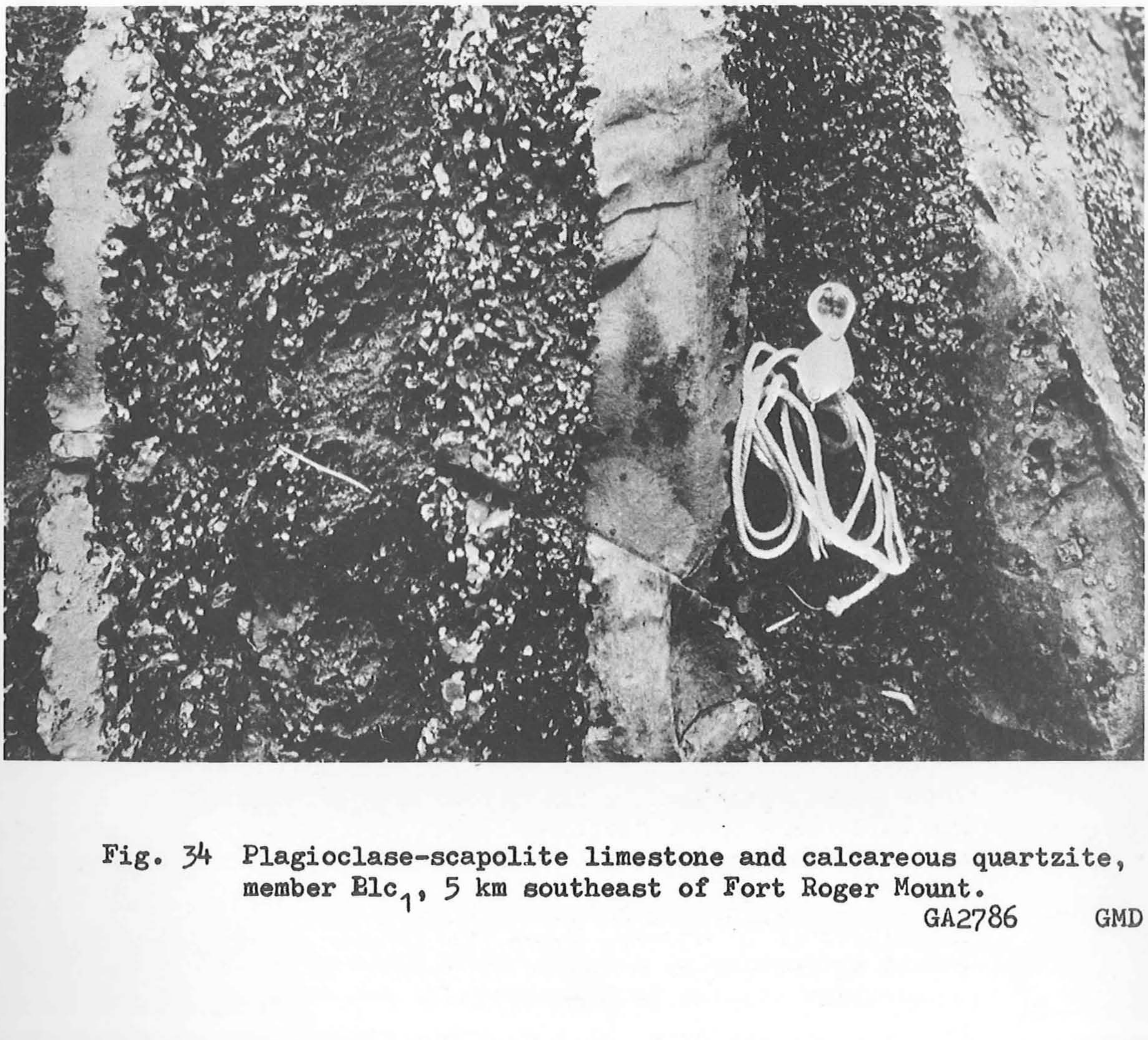


Fig. 34 Plagioclase-scapolite limestone and calcareous quartzite, member Blc$_1$, 5 km southeast of Fort Roger Mount.
GA2786 GMD

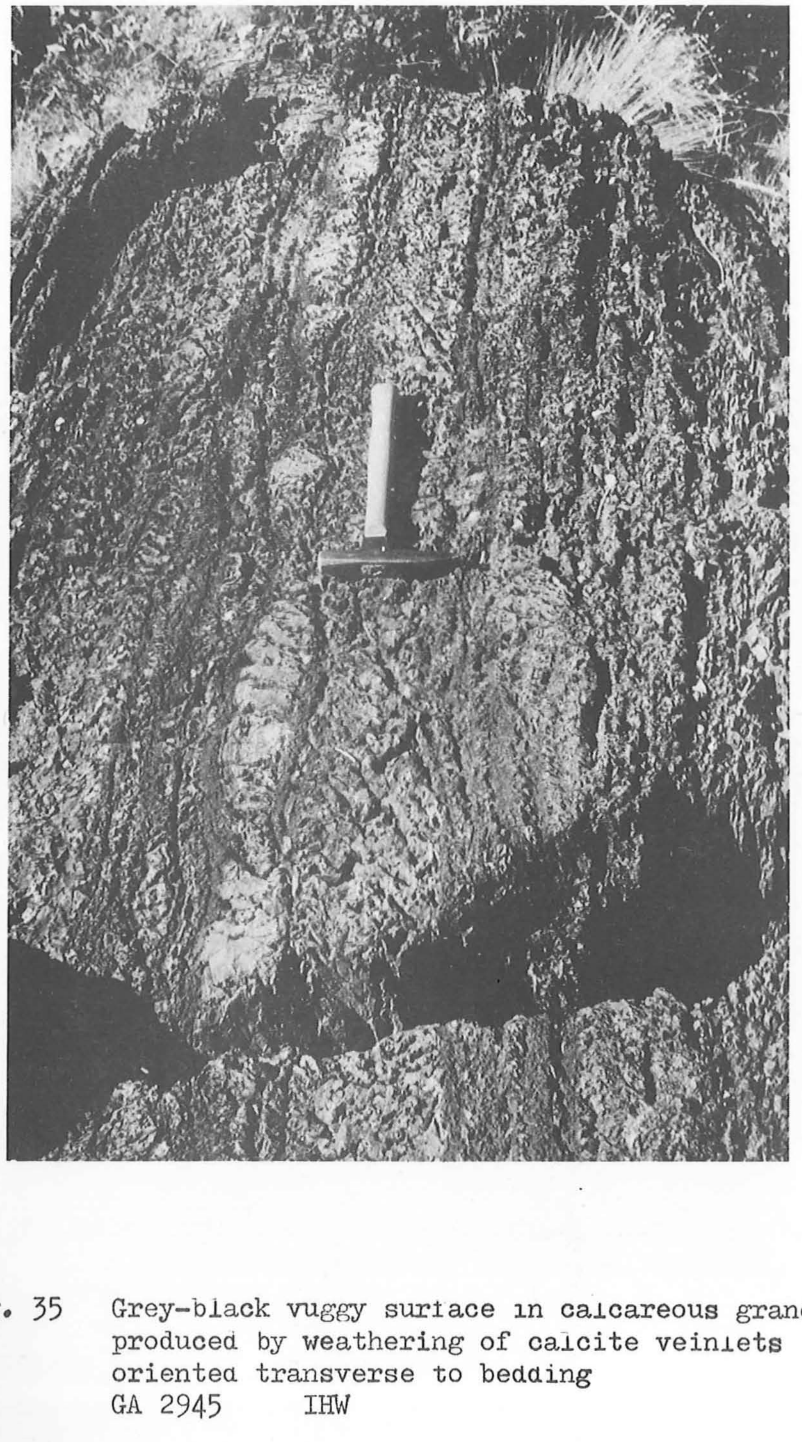


Fig. 35 Grey-black vuggy surface in calcareous granofels, produced by weathering of calcite veinlets oriented transverse to bedding
GA 2945 IHW

Fig. 36 Grey mobilized limestone (Ɇlc3) containing blocks of laminated calcareous sediments, north of Wollondonga mine
GA 2923 IHW

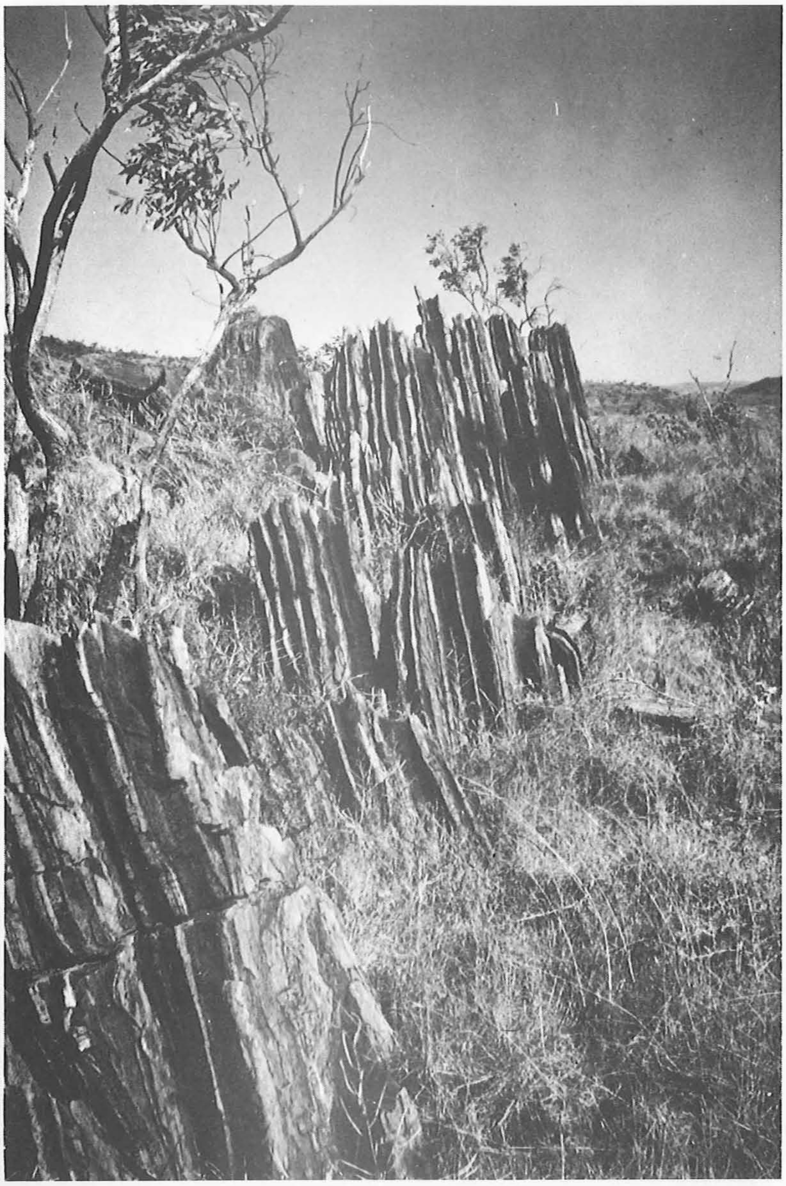


Fig. 38 Laminated feldspathic & scapolitic granofels, $Blc_2$, Mary Kathleen syncline. Beds dip west
GA 4314 GMD

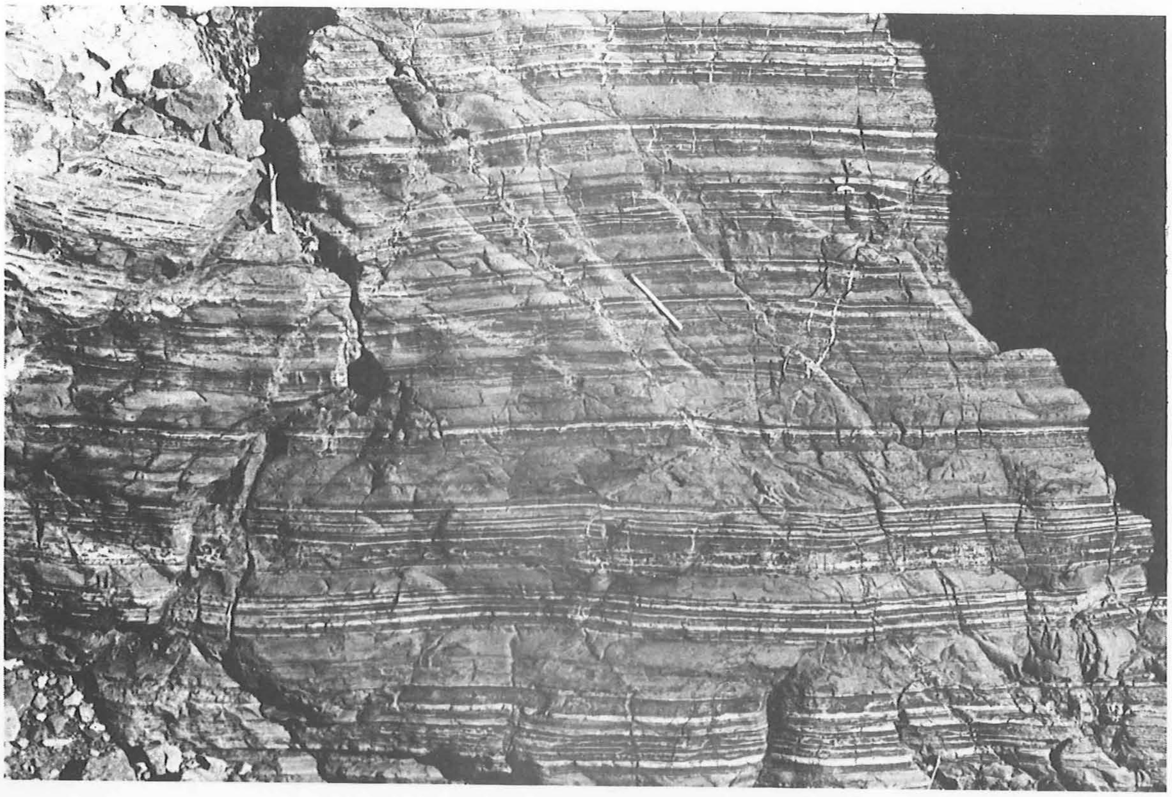


Fig. 39 Laminated feldspathic and mafic granofels, Blc$_2$, Mary Kathleen syncline. M823/11A GMD

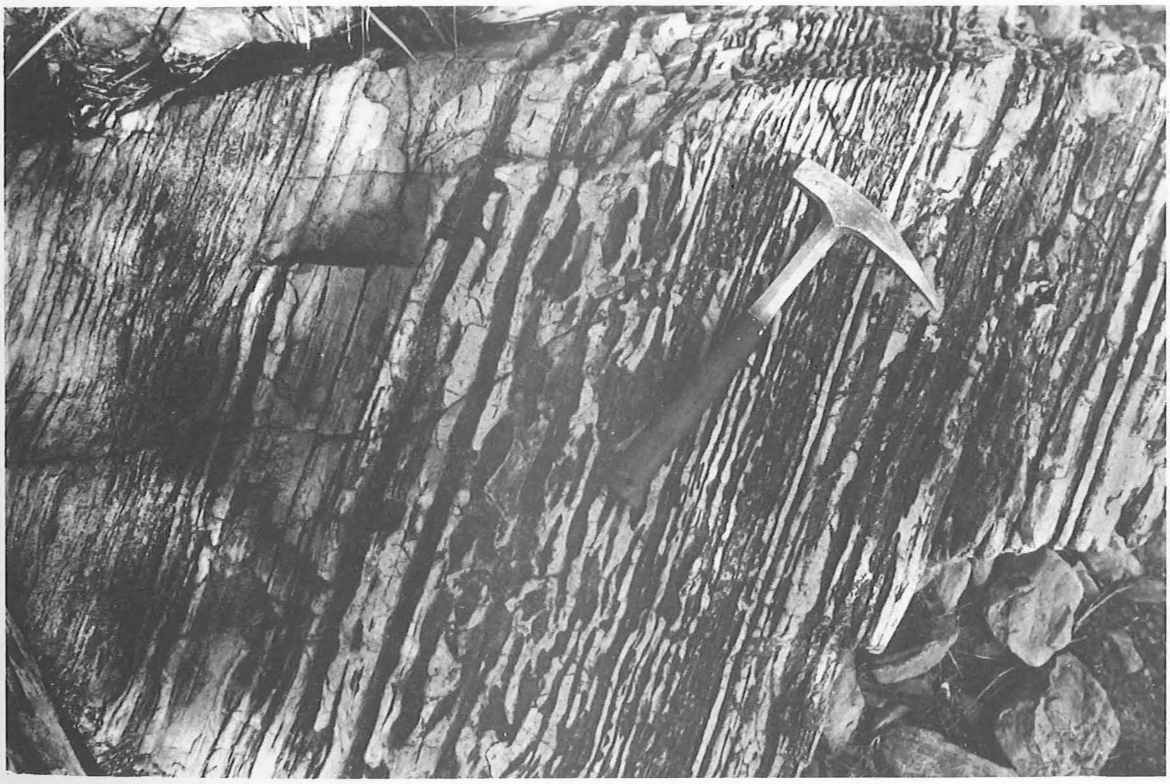


Fig. 40 Convoluted bedding in laminated feldspathic quartzite and granofels, Mary Kathleen syncline M 824/1 GMD

Fig. 41 Intricate crenulation in laminated feldspathic granofels, near Wonder Valley. GA3066 JM

Fig. 42 Rounded scapolite porphyroblasts in biotite schist, 3 km northwest of Wollondonga GA2704 GMD

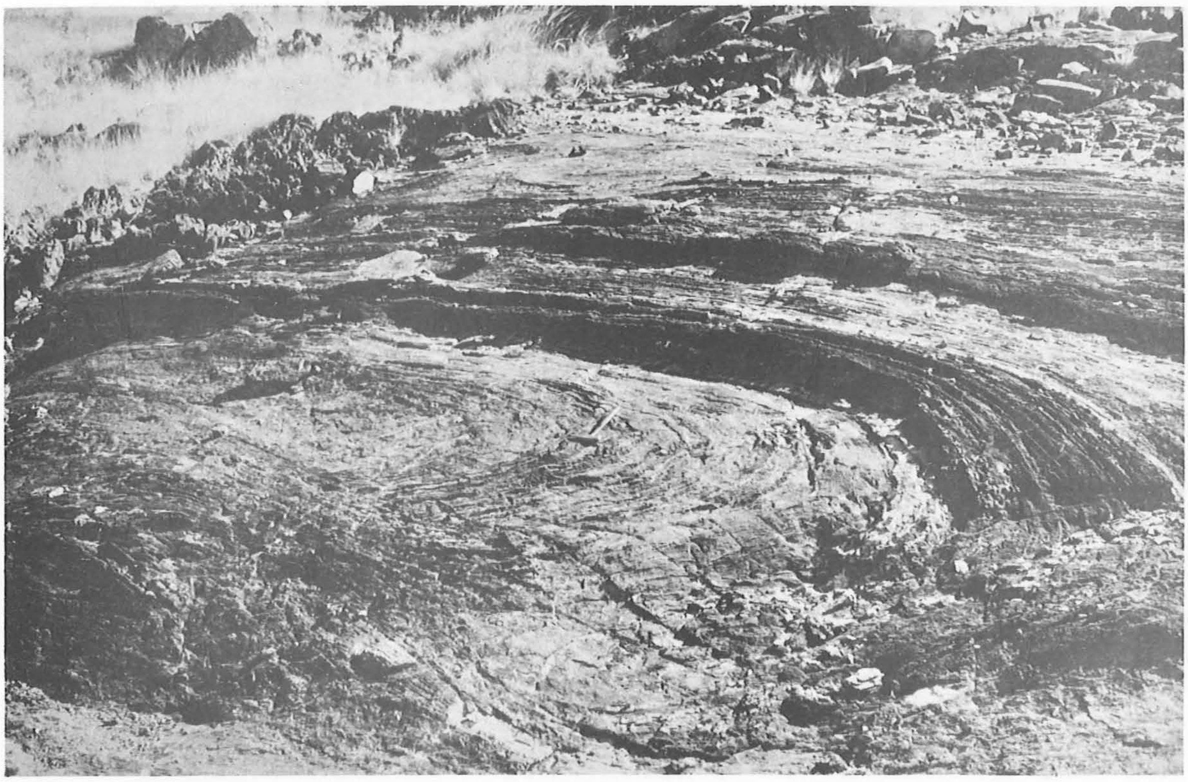


Fig. 43 Bedded limestone in Corella Formation, with vesuvianite and garnet locally; 1.5 km east of Jubilee mine GA3041 JM

Fig. 44 Lineated diopside crystals in limestone, 1 km west of Lalor mine. GA2744 GMD

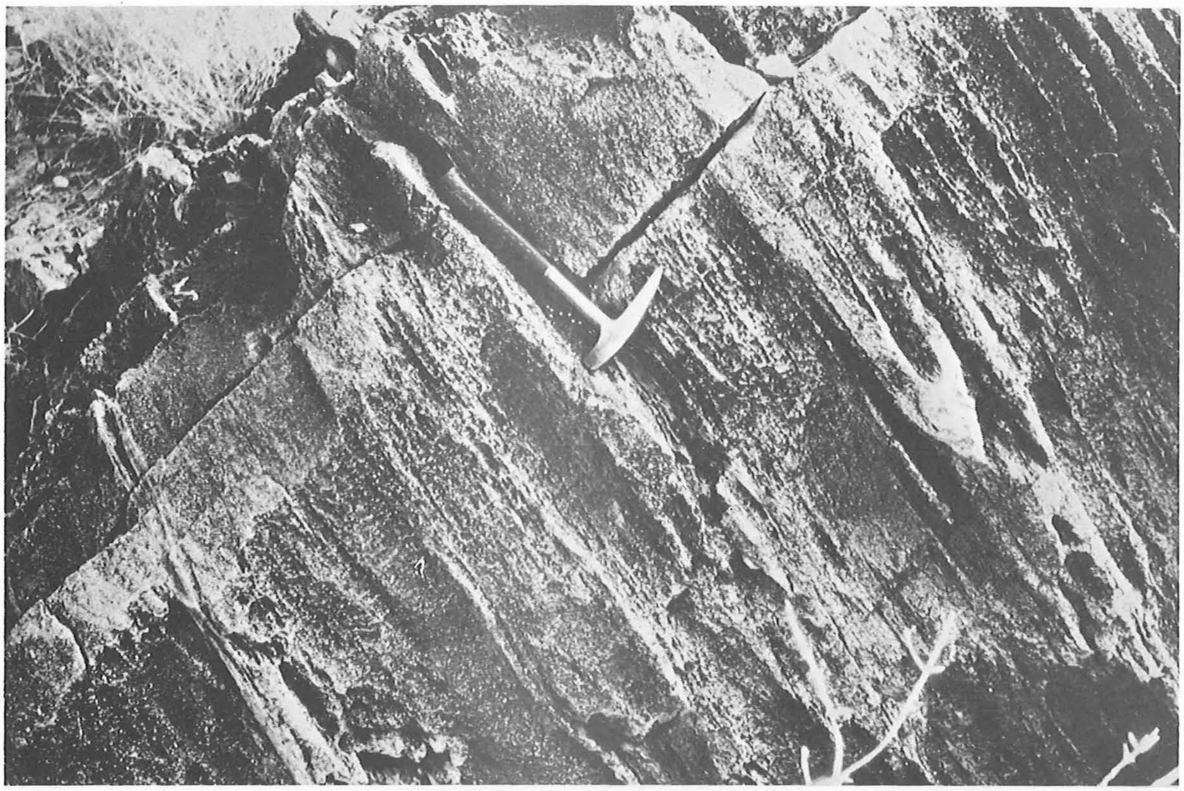


Fig. 45 Layering in basic to intermediate ?tuff, parallel to hammer handle, 0.5 km south of Lalor mine. GA2758 GMD

Fig. 46 Garnet-quartz masses with chlorite aureoles in banded basic ?tuff, 1 km south of Lalor mine M929 GMD

Fig. 47 Pillow lava sequence, Cameron River, 6 km north-northwest of the Wollondonga mine. Roots of pillows indicate top to left (east) of photo. GA2796 GMD

(d) **Metabasalt** ($Blc_{2b}$). Small bands of metabasalt are widely distributed in the Corella Formation, but only one has been shown on the map. It forms a prominent belt in the northwest of the Sheet area, and consists of amphibolite, metabasalt, and amygdaloidal basalt, some showing excellent pillow structures (Fig. 47) which are in zones up to 50 m thick towards the base of the basalt unit, which is about 800 m thick. The top of the unit is to the east, as determined from the pillow lavas.

(e) **Quartzite** ($Blc_{2q}$). Most of the quartzite is massive to blocky, and forms discontinuous lenses in the calc-silicate rocks. A large body of glassy green-grey quartzite, 380 m thick, occupies the southern part of the Mary Kathleen Syncline, and contains variable amounts of diopside and hornblende.

(f) **Conglomerate** within and north of the Mary Kathleen open cut contains cobbles and boulders of quartzite and meta-acid volcanics. Most of the clasts show narrow rims of potash feldspar up to 1 cm wide. Drape and scour structures are present, and imbricate arrangement of the clasts suggests sorting by wave or current action.

## Petrography

The following descriptions generally follow the subdivisions listed on the geological maps. Some distinctive rocks within the broad divisions, e.g. slate in granofels of $Blc_2$, will be treated separately.

## Calc-silicate granofels and limestone ($Blc_1$ and $Blc_3$)

These show a porphyroblastic granular texture, with prominent banding. Porphyroblasts are scattered through the rock, and comprise actinolite, scapolite, quartz, calcite, epidote, garnet, diopside, and plagioclase. Calcite replaces actinolite, and actinolite encloses quartz and plagioclase. Average grain dimension is 0.2 to 0.9 mm. A possible order of crystallization, form early to late, is plagioclase-quartz-tremolite-epidote-garnet-calcite-iron ore. Hornblende and scapolite are common porphyroblasts in the Cameron River area, and garnet occurs in the Slaty Creek area.

Fine-grained bands consist of sodic plagioclase, quartz, and microline, with average grain dimension 0.04 mm. Accessories are sphene and poikiloblastic iron ore.

Tremolite limestone contains euhedra of tremolite, up to 1 cm long, faintly oriented in a granoblastic groundmass of calcite. Biotite and phlogopite flakes are present, and abundant hematitic alteration imparts the dark brown colour to the rock; iron ore is a rare accessory. Plagioclase limestone (0018, 5656) is also common, the plagioclase ($An_{30}$) forming subhedral laths 1-5 mm long. Tourmaline inclusions are abundant in the feldspar.

<u>Assemblages $Blc_1$ and $Blc_3$:</u>

| | | |
|---|---|---|
| 570* | : | <u>light bands</u>: tremolite-calcite-epidote-clouded feldspar granofels<br><u>mafic bands</u>: epidote-tremolite-quartz-calcite-plagioclase-garnet granofels |
| 571 | : | actinolite-quartz-calcite-plagioclase granofels |
| 586 | : | poorly sorted pebbly quartzite; accessory muscovite, iron ore, and ?sphene |
| 590 | : | calcite-iron ore-biotite-plagioclase granofels |
| 595 | : | biotite-tremolite limestone; accessory muscovite, limonite |
| 598 | : | plagioclase ($An_{10}$) limestone; accessory biotite, apatite, sphene, iron ore |
| 613 | : | sphene-bearing scapolite-calcite-hornblende-quartz-microcline granofels |
| 615 | : | sphene-bearing phlogopite-scapolite-hornblene (Z = deep green) - quartz-calcite granofels |
| 633 | : | tremolite-carbonate granofels |
| 636 | : | para-amphibolite: albite-quartz-hornblende (Z = blue-green) bands, with quartzofeldspathic bands |
| 5650+ | : | biotite-hornblende-plagioclase-quartz-calcite-scapolite granofels |
| 5642 | : | diopside-plagioclase-actinolite-scapolite granofels |
| 5666 | : | chlorite-epidote-actinolite-microcline-calcite-andesine granofels |
| 5641 | : | biotite-calcite-scapolite granofels |
| 5671 | : | scapolite-biotite-plagioclase granofels with bands of biotite-quartz-scapolite-plagioclase-calcite granofels |

*BMR registered No's 69200570, etc.
+GSQ registered slide nos.

TABLE 8 : Estimated Modal Compositions, Corella Formation ($Blc_1$, $Blc_3$)

| Rock number / Mineral | 613 | 615 | 636 | 590 | 593 | 595 | 5642 | 5666 | 5641 | 5681 |
|---|---|---|---|---|---|---|---|---|---|---|
| Quartz ) | 40 | 25 | 25 | | | | | | 7 | 63 |
| Microcline ) | | | | | | | | 5 | | 5 |
| Plagioclase | | | 10 | 80 | | | 1 | 75 | | |
| Calcite | 15 | 50 | | 5 | 93 | 82 | tr. | 5 | 22 | 15 |
| Diopside | | 3 | | | | | 1 | | | 5 |
| Scapolite | 10 | 10 | | | | | 59 | | 58 | |
| Hornblende | 30 | 10 | 60 | | | | | 5 | tr. | |
| Tremolite | | | | | 6 | 10 | 35 | | | |
| Epidote | 2 | | | | | | | 3 | | |
| Phlogapite/biotite | 3 | | | 10 | 2 | 5 | | | 12 | |
| Iron ore | | | 5 | 5 | | 3 | 4 | 3 | 1 | 2 |
| Accessory* | | 2 sp to op | | | | | 1 sp | 1 sp ap | | |
| Chlorite | | | | | | | | 3 | | |
| Muscovite | | | | | | | | | | 10 |

* sp = sphene to = tourmaline ap = apatite op = opaques

Pink-green calc-silicate granofels ($Blc_2$)

(Mary Kathleen area)

Texture in these rocks is granoblastic; pink bands are microcline granofels showing intense clouding, particularly adjacent to diopsidic bands. Minor quartz and plagioclase accompany the potash feldspar. The bands are almost monomineralic, and could represent feldspathich tuff, chert/quartzite bands affected by potash addition, or a product of local metasomatic exchange of potassium between pelite and limestone bands. Further work is required on this problem.

Mafic bands contain diopside, scapolite, plagioclase, calcite, hornblende, garnet, prehnite, epidote, and sphene. All minerals are granoblastic, diopside showing strong apple-green body colour, with refractive indices of NY=1.688 to 1.692 in some specimens. Scapolite is strongly poikiloblastic, with average grain dimension 0.5 to 2 mm. In the east limb of the Mary Kathleen Syncline replacement phenomena are widespread, generally parallel to bedding. Some bands of scapolite are coarsely radiating structures, especically parallel to bedding, otheres are very fine-grained and granoblastic; scapolite has partly or completely replaced both microcline and diopside-rich bands. Garnet aggregates cut and replace all types of original sedimentary bands. Sphene and tourmaline are common accessories, but apatite is scarcer.

Other areas of $Blc_2$ contain similar assemblages, but generally show an absence of prehnite, an increase in biotite, and a decrease in the abundance of scapolite.

Assemblages

1. Mary Kathleen Syncline

| | | |
|---|---|---|
| 563* | : | mafic bands: epidote-feldspar-prehnite-garnet-diopside |
| | | light bands: granoblastic quartz-clouded K feldspar |
| 564 | : | sphene-bearing diopside-scapolite granofels interlayered with fine-grained microcline granofels ('feldspathic quartzite') |
| 624 | : | calcite-scapolite-quartzite with bands of quartz-calcite-scapolite granofels |
| 626 | : | garnet-diopside-calcite-quartz-scapolite-hornblende granofels with bands of fine-grained biotite-feldspar quartzite |
| 629 | : | sphene-bearing epiodite-calcite-quartz-microcline-amphibole (Z = blue-green)-scapolite granofels |

2. Butcher Bore area

| | | |
|---|---|---|
| 592 | : | microcline granofels, with bands of epidote-biotite-quartz-feldspar granofels; accessory sphene, iron ore, muscovite, calcite |
| 602 | : | quartz-plagioclase ($An_{30}$)-feldspar-diopside granofels, with minor calcite, sphene, epidote, and iron ore, accessory apatite and zircon |
| 129 | : | sphene-quartz-scapolite-diopside granofels |
| 132 | : | quartz-diopside-calcite-hornblende-plagioclase granofels |
| 133 | : | tremolite-biotite-quartz-diopside-calcite-plagioclase ($An_{30}$) granofels. |

3. Cameron River area

| | | |
|---|---|---|
| 5676+ | : | granitized calcite-quartz-actinolite-microcline granofels |
| 5690 | : | hornblende-diopside-scapolite granofels |
| 5661 | : | garnet-sphene-microcline-quartz-actinolite granofels |
| 5654 | : | banded scapolite-quartz-diopside and hornblende-microcline-scapolite granofels |
| 5656 | : | tremolite-plagioclase ($An_{30}$) - calcite granofels |

*BMR registered nos. 69200563
+GSQ registered slide nos.

TABLE 9 : Estimated Modal Compositions, Corella Formation ($Blc_2$)

| Rock No. / Mineral | *629 | 631 | 129a | 129b | 132 | 138 | 139 | 5676+ | 5663 | 5662 | 5653 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Quartz | 10 | | 3 | 60 | 2 | | | 10 | 77 | 29 | 10 |
| | | 20 | | | | | | | | | |
| Microcline | 7 | | | | | | | 50 | | | 15 |
| Plagioclase | | | | | 50 | 5 | | | 10 | | 55 |
| Calcite | 7 | 1 | | | 13 | | | 7 | | 30 | |
| Diopside | | | 75 | | 10 | 30 | 25 | | | | |
| Scapolite | 48 | 9 | 20 | 5 | | 40 | 55 | | | 10 | |
| Hornblende | 25 | | | | 20 | | | | | | 12 |
| Tremolite | | | | | | 15 | 25 | 25 | | | |
| Epidote | 2 | 30 | | | | | | | | | |
| Phlogopite/Biotite | | 40 | | 35 | | | 15 | | 2 | 7 | |
| Iron Ore | | | | | 5 | 8 | | 3 | 1 | 3 | 5 |
| Sphene | 1 | | 2 | | | 2 | | 4 | | | 3 |
| Accessories | to | to | | | sp | | | 1 ap | 2 zr | 1 to | |
| | ap | | | | ap | | | | ap | | |
| Muscovite | | | | | | | | | 8 | 20 | |

Amphibolite-basic tuff sequence ($Blc_{2t}$) - Butcher Bore area

The rocks are variably banded, coarse-to medium-grained, with porphyroblasts of plagioclase ($An_{15-25}$) and large pale red glassy garnet. Biotite is the most abundant mafic mineral, forming discontinuous schistose bands, and hornblende is common (Z = blue-green mostly). Matrix is a granoblastic plagioclase aggregate with minor quartz; apatite, epidote, and iron ore are abundant accessories. In general the coarse plagioclase crystals (1-4 mm) are pre or syn-tectonic, and garnet (4-15 mm) is syn to post-tectonic. In the latter, iron ore trials are continuous with iron ore trails in the matrix (Fig. 48).

*BMR registered nos. 69200581

TABLE 10 : Estimated Modal Compositions, Corella Formation ($Blc_{2t}$)

| Rock No. / Mineral | *581 | 587 | 589 | 591 | 146 | 147 | 150 | 154 |
|---|---|---|---|---|---|---|---|---|
| Quartz | | | 3 | 65 | | | 20 | 5 |
| Plagioclase | 20 | 18 | 60 | 30 | | | 5 | |
| Hornblende | 70 | 70 | | | | | 40 | |
| Garnet | | | 4 | 2 | 20 | 10 | 15 | 25 |
| Sericite | | | | 1 | 5 | 22 | 5 | 15 |
| Biotite | | 10 | 30 | | 30 | 55 | 1 | 40 |
| Calcite | | | | | 40 | | 10 | |
| Tremolite | | | | | 3 | | | |
| Iron Ore | 3 | 2 | | | 2 | 10 | 3 | 10 |
| Epidote | 7 | | | | tr. | 3 | | |
| Accessory | | | | | | | 1 sp zr | 2 to |
| Chlorite | | | 3 | 2 | | | | 3 |

Assemblages

| | | |
|---|---|---|
| *605 | : | ?agglomerate: ?plagioclase porphyroblasts in matrix of staurolite-garnet-chlorite-biotite-quartz-plagioclase; accessory apatite, iron ore |
| 577 | : | hornblende (Z - deep blue green)-biotite-plagioclase-garnet gneiss; accessory iron ore, apatite |
| 579 | : | garnet-plagioclase-quartz-K-feldspar-biotite schist |
| 580 | : | garnet-plagioclase-biotite-schist |
| 581 | : | epidote-quartz-plagioclase-amphibolite (Z = blue-green) |
| 582 | : | quartz-garnet-plagioclase-biotite amphibolite |
| 144 | : | sphene-bearing garnet-calcite-plagioclase-quartz-biotite gneiss |
| 146 | : | tremolite-sericite-garnet-biotite-calcite gneiss |

Mafic quartzite ($Blc_{1q}$, $Blc_{2q}$, $Blc_{3q}$)

These rocks show granoblastic textures, and contain 5 to 15 percent mafic minerals, mainly tremolite, hornblende, and diopside. Fresh and clouded plagioclase and microcline (up to 45 percent) form elongate patches and bands. Accessories are apatite, iron ore, and sphene. Average grain dimension is 0.3 to 1 mm. Quartzites in the Mary Kathleen area are notably glassy in appearance.

*BMR Registered Nos 69200581
+GSQ registered slide nos.

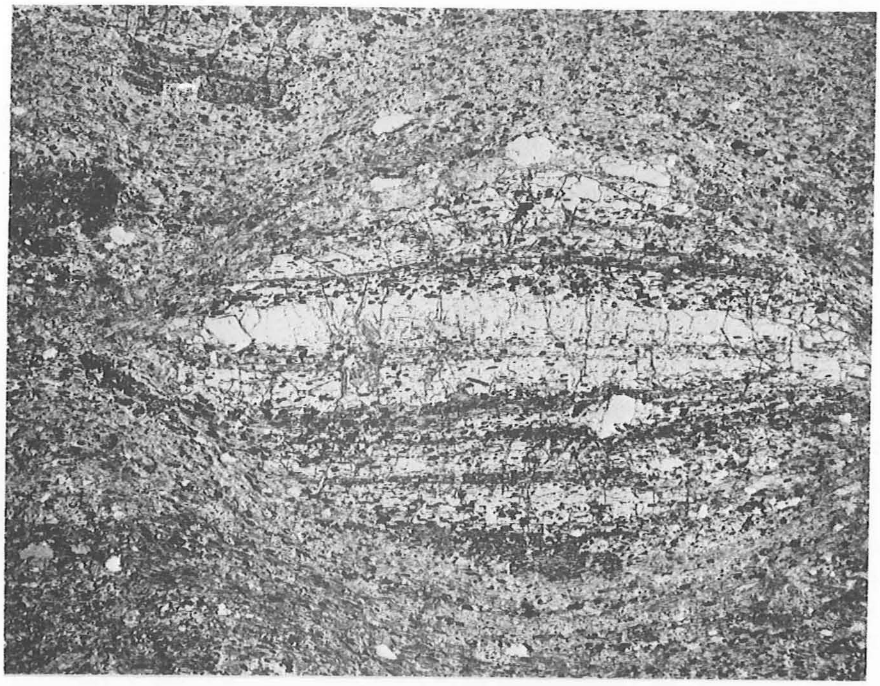


Fig. 48 Photomicrograph of post-tectonic garnet porphyroblast in basic ?tuff, Butcher Bore X10

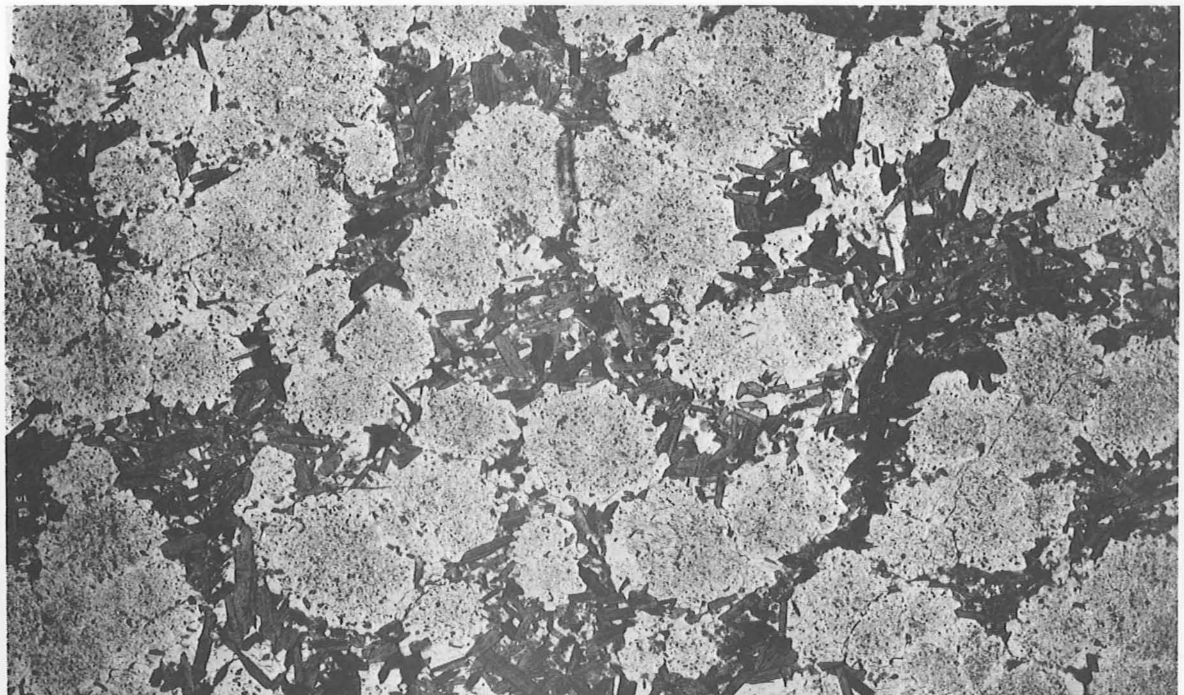


Fig. 49 Photomicrograph of scapolite-biotite schist, Cameron River area X10 GA4404

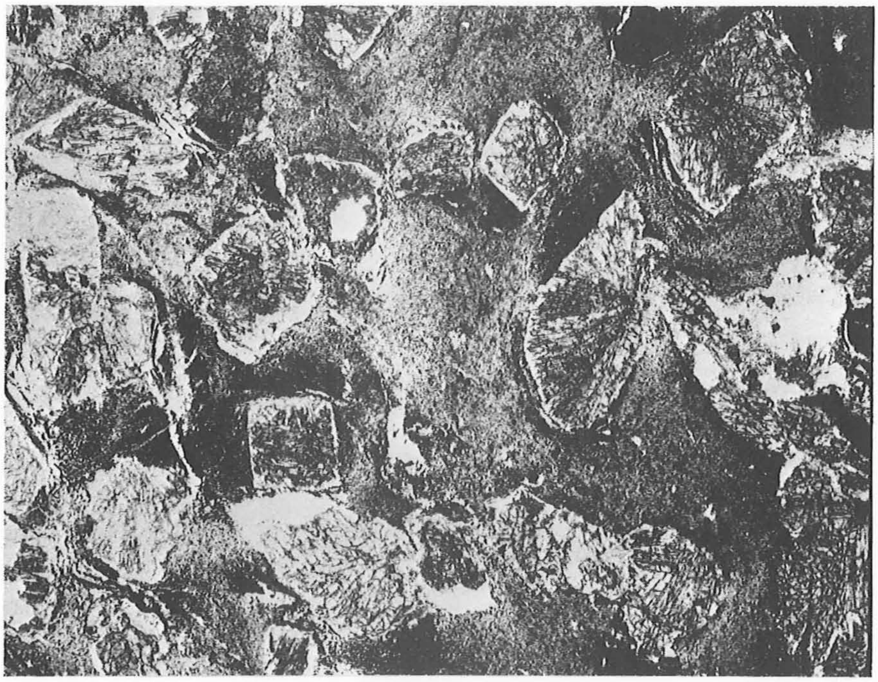


Fig. 50 Photomicrograph of kyanite porphyroblasts after andalusite in graphitic slate. X10

Assemblages

| | | |
|---|---|---|
| 614 | : | diopside feldspathic quartzite |
| 623 | : | diopside-tremolite feldspathic quartzite |
| 627 | : | strained biotite-bearing quartzite |
| 628 | : | ferruginous quartzite |
| 637 | : | clayey feldspathic quartzite |
| 5665 | : | microcline-rich sandstone |

Limestone, $Blc_{21}$

Diopside limestone (201) contains large euhedra of diopside in a calcitic matrix. The diopside is highly altered to sericitic aggregates. Vesuvianite limestone (270) contains idioblastic vesuvianite showing faint pleochroism e = pale yellow, o = colourless, and rare garnet poikiloblasts, with abundant calcite inclusions. Diopside forms small scattered granules, and microcline is accessory in a matrix of deformed crystalline calcite. All the metamorphic minerals appear to be post-deformation, and the order of crystallization, form early to late, is calcite-microcline-garnet-vesuvianite.

Diopside-calcite granofels (137), and tourmaline-bearing quartz-calcite-biotite microline granofels (594) occur in the Butcher Bore area.

Schists ($Blc_{2b}$), Mary Kathleen area (620, 630, 634, 227, 228)

Sillimanite schist occurs in a restricted section of biotite schist near Jubilee mine. The matrix is a flattened aggregate of biotite, muscovite, quartz, and rare apatite and tourmaline. Knots in the schist are decussate aggregates of coarse-grained muscovite and prisms of sillimanite and fibrolite, which post-date the muscovite.

Post-tectonic magnetite and ilmenite occur in schist at the head of Lake Corella.

Psammitic schists contain flakes of brown to yellow biotite, and granoblastic microcline, clouded albite and quartz. Apatite and green tourmaline are accessories. Scapolite-biotite schists are also widespread (Fig. 49).

Cordierite-anthophyllite schist (227, 228) contains 1 cm poikiloblasts of anthophyllite (10 percent) in a granoblastic groundmass of 0.4 mm cordierite (30 percent) and quartz (30 percent). Biotite (30 percent) forms subparallel laths, with some minor chlorite. Accessories include coarse-grained apatite, iron ore, zircon and tourmaline.

Black slate, Butcher Bore area ($Blc_{2s}$)

Rocks from this unit are black to grey and fine-grained, containing porphyroblasts of andalusite, kyanite (after andalusite) (fig. 50), and garnet. ?Graphite is abundant, and most rocks mark paper readily; other opaques or accessories include hematite and rutile. Very fine-grained quartz, feldspar and muscovite also occur in the matrix. Some of the porphyroblasts of kyanite are rimmed by calcite, quartz, and in one case, plagioclase.

TABLE 11 : Estimated Modal Compositions, Corella Formation ($Blc_{2s}$)

| Number / Mineral | 142 | 143 | 153 | 608 |
|---|---|---|---|---|
| Kyanite | | | 40 | 12 |
| Andalusite | | | | 1 |
| Garnet | | 3 | | |
| Rutile | | | | 3 |
| Opaques | 45 | 45 | 25 | 80 |
| Quartz | 25 | 20 | 25 | 3 |
| Calcite | | 2 | | |
| Sericite | 30 | 30 | | 1 |
| Plagioclase | | | 10 | |

Discussion and Comments

In the Marraba 1:100 000 Sheet area, the following facies changes are evident. The basal part of the Corella Formation consists of carbonate rocks, apparently transitional from fine-grained siliceous and ferruginous sediments of the 'Overhang Jaspilite'. From the Butcher Bore area westwards to Mary Kathleen, a shallowing of the depositional shelf is indicated by a change from fine detrital-chemical(?) sediments (slate, limestone, jaspilite) to fine-grained calcareous psammitic and pelitic sediments with coarse-grained quartzite interbeds, algal structures, and local probably wave-sorted conglomerates. Progressive onlap westwards in the area north of Mary Kathleen suggests a shoreline broadly coincident with the western Sheet boundary.

The overall fine-grained nature of the formation indicates that the source area was of low relief, and that the environment could well have provided broad zones of evaporite-rich carbonate, which, it is suggested, leads to extensive scapolite development during metamorphism.

A Permian evaporite/carbonate shelf sequence in the Guadalupe Mountains (U.S.A.) has been described by Kendall (1969), and contains many features displayed by the Corella Formation, taking age and metamorphic differences into account. In the Permian rocks the carbonate muds are laminated, with rare micro-cross-bedding, and form part of a barrier flat-lagoonal environment; evaporitic and dolomitic carbonate silt and mud occur in a supratidal zone; beds of quartz siltstone and sandstone inter-bedded with evaporites are considered to be wind-blown sub-aerial deposits, because of a lack of traction-current structures. These features are particularly comparable with the postulated nearshore facies in the Corella Formation along the western margin of the Sheet area. Some granofels at Mary Kathleen contains layers rich in fine-grained scapolite, which could be metamorphic equivalents of evaporite-rich layers, such as those described from the Guadalupe area e.g. overburden caused the intrastratal movement of some of the evaporite, producing the coarsely crystalline gypsum which flowed along bedding planes and into fissures. However, the Corella Formation shows no massive reef development typical of most Phanerozoic carbonate provinces, and comparisons such as those above are still tentative. Detailed plotting of the distribution of scapolitic granofels in the Corella Formation will be undertaken to elucidate the dispostion of possible evaporitic facies throughout the Sheet area.

## BRECCIA IN THE CORELLA FORMATION

### Introduction

Brecciation of calc-silicate rocks is a characteristic of the Corella Formation. Honman (1939, p.9) regarded these breccia as agglomerate, and Carter et al (1961) considered that most of them were of sedimentary origin, though he thought that some could be fault-breccias and others the result of intense folding.

### Field Occurrence and Lithology

The breccia is generally well exposed, forming ridges or isolated hills. The fragments are subrounded to subangular, and consist of grey chert, pale pink, fine-grained quartzite, calcareous and dolomitic quartzite, laminated marl, possibly dolomitic, calc-silicate granofels, and minor scapolite limestone, vein quartz, and iron ore. Some fragments are up to 2 m in diameter, but most are 3 to 20 cm. The matrix is generally a pink to brown quartz-feldspar-calcite aggregate with some hematite. Typical examples of breccia are shown in Figures 51 and 52.

Breccia is widespread in the Marraba Sheet area, but appears to be associated mainly with the more calcareous units ($Blc_1$ and $Blc_3$) of the Corella Formation. It forms in linear synclinal fold belts e.g. in the Butcher Creek area, and along major fault lines, e.g. Corella River area a few kilometres north of the Barkly Highway crossing. Dolerite, basalt, and amphibolite are intimately associated with some areas of breccia, e.g. northeast of the Wollondonga mine, basic rock appears to form large fragments in the breccia, however, it is more likely that it postdates the breccia, and has been intruded along the weakened strata. The intrusion of dolerite may have further contributed to brecciation. Calcite and quartz-calcite veins intersect the breccia in some areas.

Breccia types

Three types are distinguished on the basis of relationship to the enclosing rock:

(a) intraformational breccia

(b) chaotic breccia

(c) fault breccia

(a) Intraformational breccia is well displayed near the Butcher Creek - Barkly Highway crossing, where the breccia forms zones parallel to bedding and is 1 to 20 m thick. Relict discontinuous bedding is usually present, and the fragments in the breccia represent slightly disrupted blocks of the more competent strata. The degree of brecciation locally decreases upwards and downwards in the sequence.

(b) Chaotic breccia contains randomly distributed clasts in a pulverised calcareous groundmass (Figs. 51 and 52), and shows sharp contacts with regularly bedded and folded Corella Formation. Breccia pipes and irregular steep-sided masses and veins are common; an excellent exposure of this type, about 5 km southeast of Fort Roger Mount is sketched in Figure 53. Some parts of the bedded Corella Formation have been intraformationally deformed near the contact with chaotic breccia.

(c) Fault breccia is chaotic in form and occurs along major fault zones in the area e.g. Cameron Fault.

Origin of breccia

Detailed mapping of breccia indicates that tectonic processes were probably responsible for the development of the three types. A regional association with tectonism is suggested by the presence of breccia in linear fold and fault zones; the smaller-scale evidence for tectonic origin is described below, and illustrated diagrammatically in Figure 54.

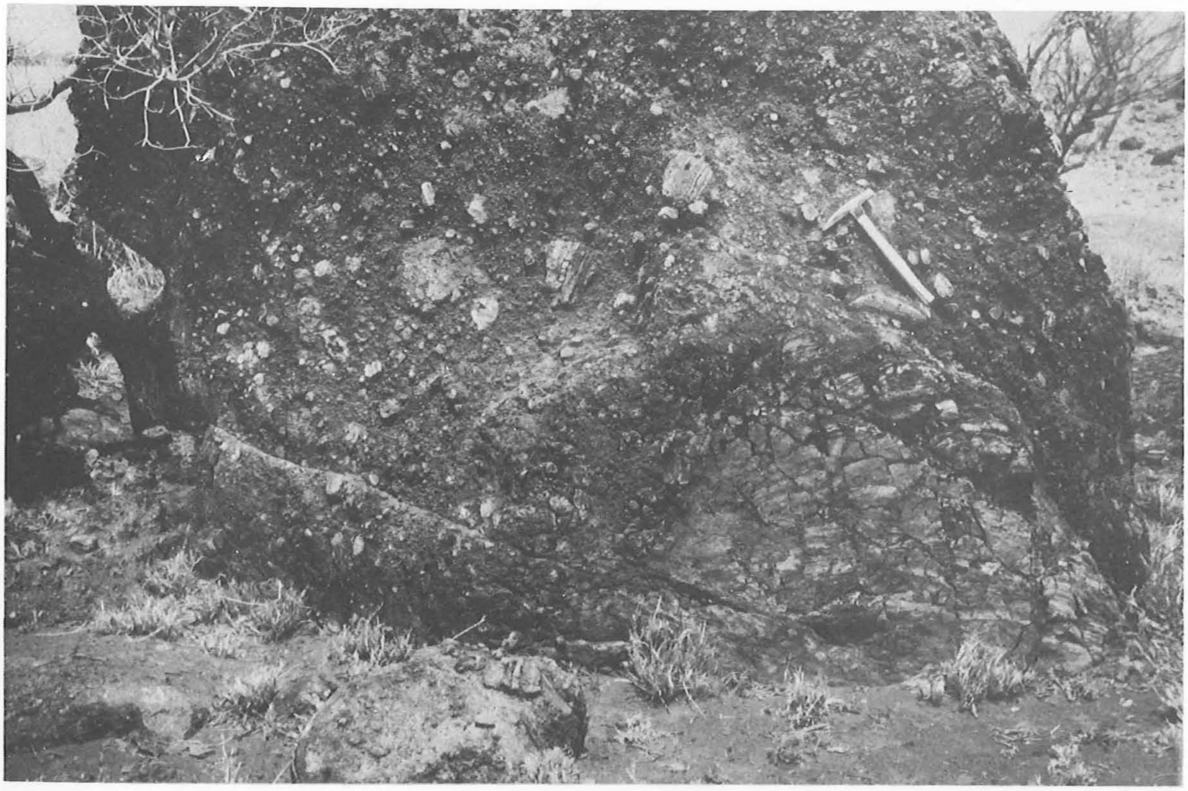
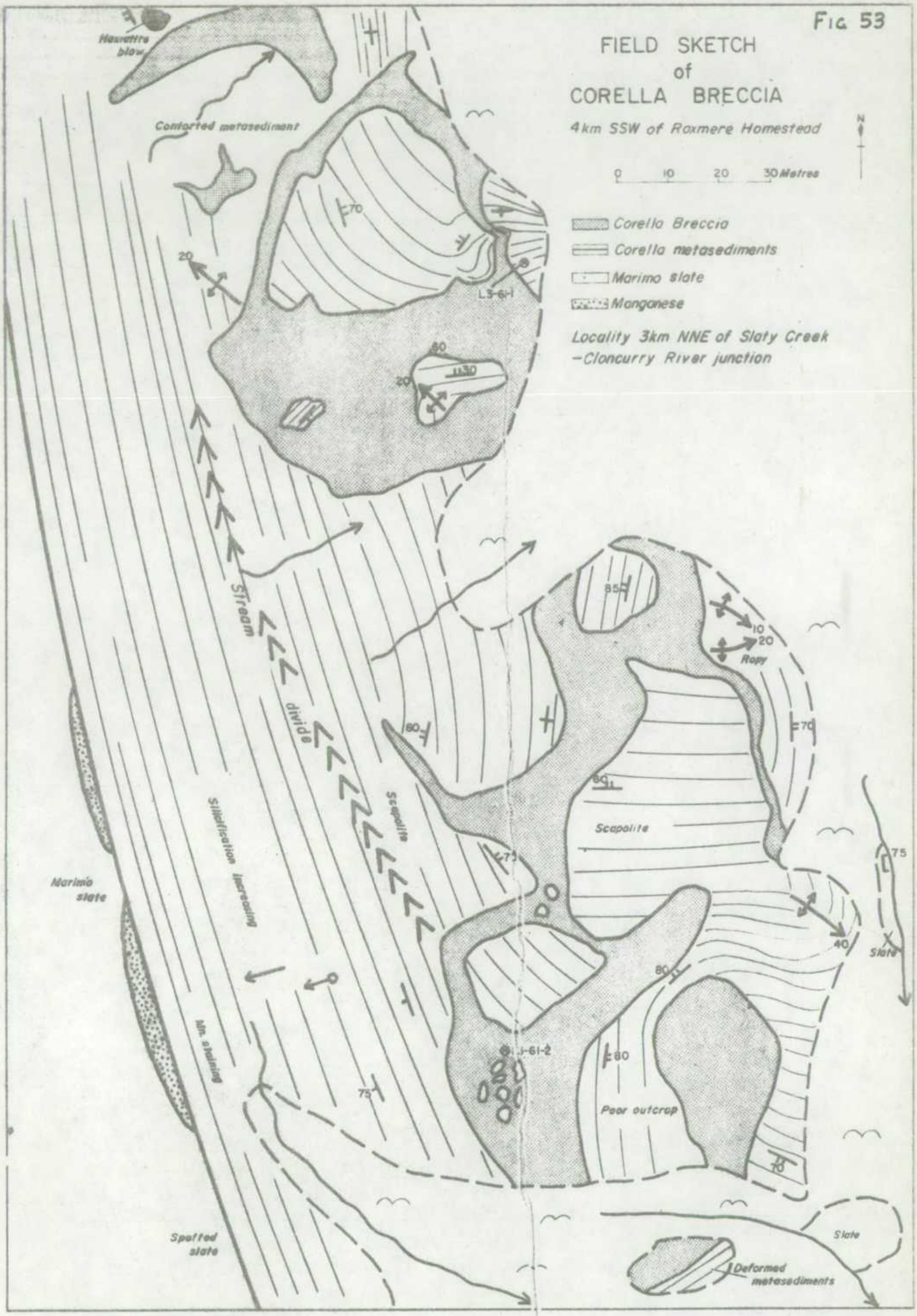


Fig. 51 Calc-silicate breccia; note the laminated fragments and the fractured zone surrounding the largest fragment below the hammer. Locality 2 km east of Corella Park.
GA2952 IHW

Fig. 52 Calc-silicate breccia, 8 km southeast of Dolomite siding M895/1
GMD

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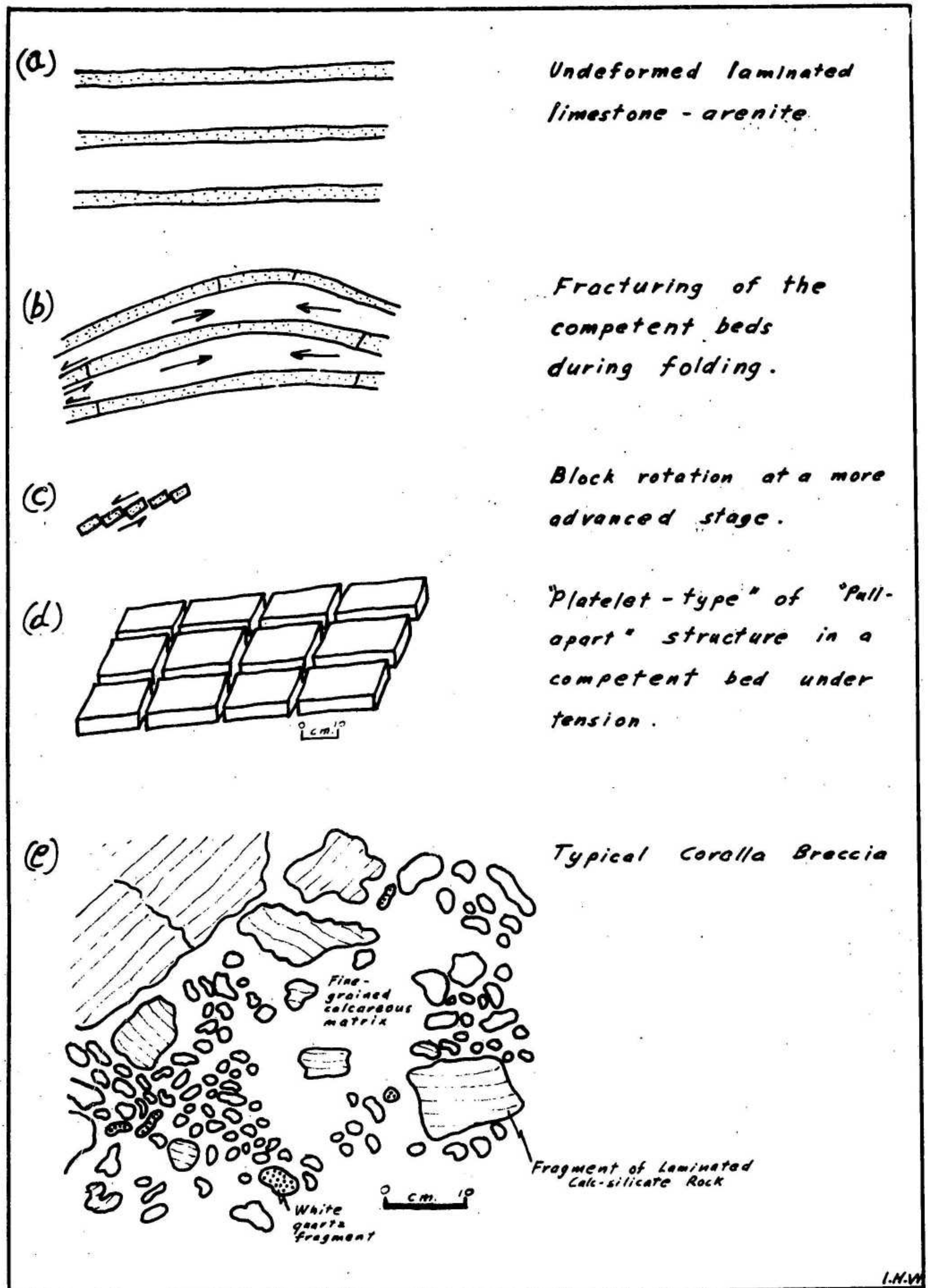


Fig 54 Deformation and brecciation of the Corella Formation

To accompany Record No 1971/56.

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Fig. 55 Fracturing of more competent beds and slight block rotation accompanying deformation of interbedded calcareous or siliceous rock types. Locality 2 km southeast of Lake Corella. GA2970 IHW

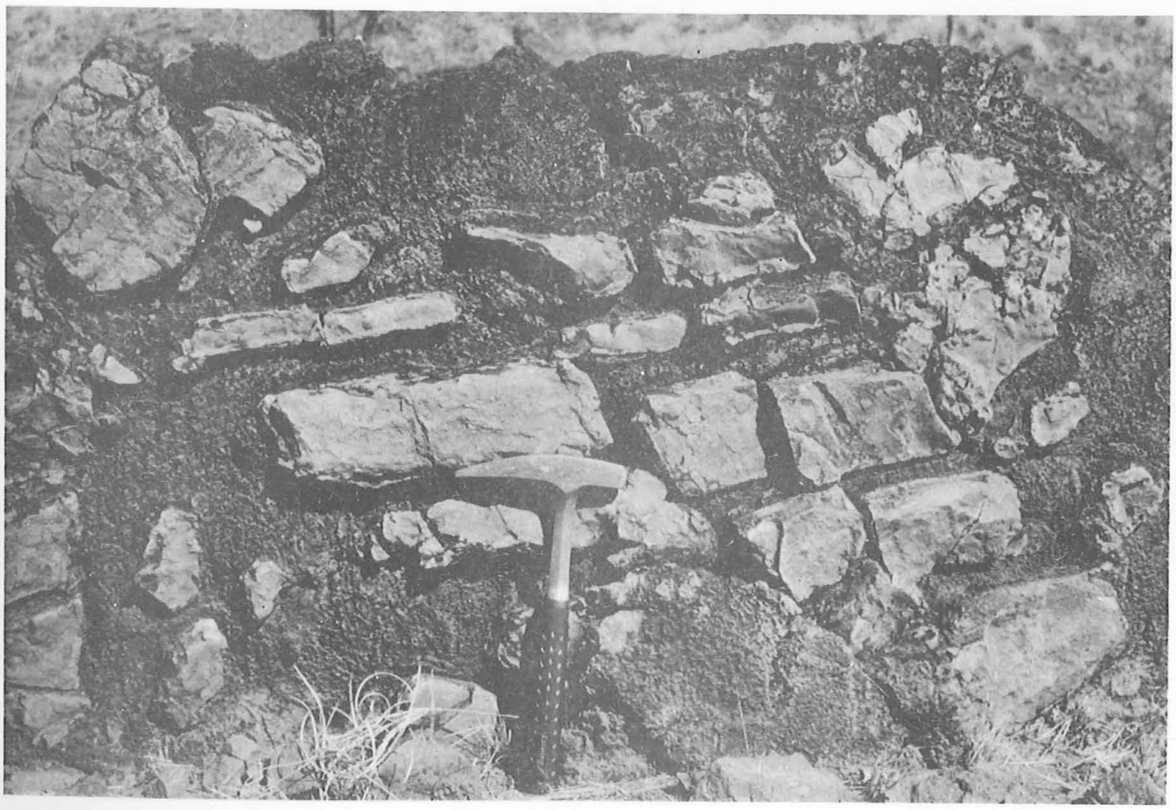


Fig. 56 Platelet development in more competent feldspathic quartzite, interbedded with calcareous granofels. Bedding parallel to plane of page. Locality 3 km west-northwest of Lalor mine. GA2733 GMD

Brecciation was initiated by folding, during which the more competent beds, generally flaggy to blocky, laminated calcareous and dolomitic quartzites, were fractured. Continued deformation along these fold-axial plane fractures caused block rotation (Fig. 55) and the development of 'platelet' structures (Fig. 56) in the competent strata. The resultant breccia is of the intraformational type.

Further deformation resulted in complete rotation and separation of competent blocks, and increased plastic flowage and recrystallization in the incompetent (generally carbonate-rich) beds which ultimately formed the breccia matrix. This breccia is typical of both chaotic and fault varieties (Figs. 51 and 52). Pipes and veins of breccia resulted when continued deformation caused piercement or injection of relatively unbrecciated strata by the chaotic breccia. Extensive tracts of breccia were formed when the stresses of folding eventually were relieved by faulting.

In the adjoining Cloncurry Sheet area similar breccia and megabreccia are also considered to be products of tectonism, mainly folding (Glikson & Derrick, 1970).

A similarity has been observed between the Corella Formation breccia and brecciated dolomitic rocks found in diapirs in the Flinders Ranges of South Australia (Coates, 1964, Figs. 8 and 9; Leeson, 1970). It is not suggested that diapirism on a large scale has been the cause of brecciation in the Marraba Sheet area, but it is believed that tectonic deformation can produce large areas of similar breccia.

Carter et al (1961) thought that most breccias were formed by slumping and density current action at or near the foot of a slope below wave base. Some fringing reefs, with associated breccias, may have existed. The present work indicated an overall lack of submarine relief, including reefs, during deposition of the Corella Formation; there appears to be no relationship between breccia and probable shore-line areas, and no slumping was observed. These facts, plus the observed relationship of breccia to structural elements, favourable rock type, and intrusive rock, indicates that a syndepositional origin for the breccias is unlikely.

## Metamorphic and Metasomatic Processes Affecting Mainly the Corella Formation

### (A) Scapolite Development

Scapolite is widespread throughout the Mount Isa/Cloncurry area. It forms mainly in metasediments, basic igneous rocks, and meta-acid volcanics; in particular it is abundant in calc-silicate granofels in the Corella Formation, where its distribution is generally controlled by bedding (Fig. 34) or it forms small veins. In the Mary Kathleen area scapolite forms 10 cm diameter rosettes on bedding planes (Fig. 57), and thin granoblastic, monomineralic bands in granofels. Elsewhere the most common forms of scapolite are euhedral crystals in limestone, similar in size and shape to stubby matchsticks, and sieve-textured porphyroblasts (Figs. 42 and 49) in biotite schist.

Scapolite composition ranges from the NaCl-rich end member marialite (Ma) to the $CaCO_3$-rich member meionite (Me). Some scapolite compositions expressed as molepercent Me for the Mary Kathleen area are as follows (after Hill, 1968; Ramsay & Davidson, 1970):

| | |
|---|---|
| scapolite limestone | $Me_{42}$ |
| vein-forming aggregates | $Me_{40}$ |
| biotite schist | $Me_{52}$ |
| hornblende-biotite schist | $Me_{52}$ |
| hornblende-pyroxene granofels | $Me_{32}$ |
| hornblende-pyroxene granofels | $Me_{36}$ |
| metadolerite | $Me_{20}$ |
| acid metavolcanics | $Me_{21, 35, 27}$ |
| basic metavolcanics | $Me_{20, 28, 29}$ |

These show that scapolites from metasediments are moderately marialitic, i.e. NaCl-rich, and those from metadolerite are highly marialitic.

In other areas, Edwards & Baker (1954) recorded $Me_{25}$ from the Duchess area; van de Kamp (1968) recorded the following from Ontario:

| | |
|---|---|
| para-amphibolite | $Me_{73}$ |
| carbonate-silicate gneiss | $Me_{65}$ - $Me_{75}$ |
| pyroxene-scapolite gneiss | $Me_{57, 68, 43, 72, 63, 38}$ 60, 53, 58, 49, 50, 66 |

i.e. considerably more meionitic than scapolites from the Mary Kathleen area.

In South Australia, White (1959) recorded $Me_{60}$ to $Me_{65}$ for pyroxene-scapolite-sphene rocks and scapolite marbles, and $Me_{56}$ for vein-forming scapolite.

Discussion and Comments

Scapolite development in the Mary Kathleen area is a result of either metasomatic introduction of elements (Na, Cl, etc) or isochemical metamorphism of calcareous shales, etc., which contained some halite for instance. Edwards & Baker (1954) invoked regional metasomatism in their study of the Mount Isa/Cloncurry area, and calculated that a minimum of 100 000 000 tonnes of chlorine had been introduced during regional metamorphism. White (1959) concluded that scapolite in metasediments is an isochemical metamorphic product, as did Ramsay & Davidson (1970). Hietanen (1967) calculated that as little as 2 percent halite in a calcareous shale would be sufficient to produce considerable scapolite (up to 30 percent) isochemically. Van de Kamp (1968) showed scapolite was possibly isochemical in low grade rocks, but postulated chlorine addition from magmatic sources for scapolite rocks of higher metamorphic grade. He also considered scapolite formation involved decarbonatization.

We tentatively agree with the results of Ramsay & Davidson (1970), which are summarized below.

a. The origin of the scapolite in the metasediments of the Corella Formation is fundamentally different from that in the adjacent metadolerites and metavolcanic rocks

b. The primary control on the composition of the crystallizing scapolite was the local abundance of chlorine. Thus the calcareous shales, which contained considerable halite, recrystallized to form marialitic scapolite ($Me_{32}$ - $Me_{52}$), whereas the low calcium equivalents formed a meionitic scapolite ($Me_{50}$ - $Me_{61}$). The relative abundance of CaO and $Na_2O$, and their availability in the chemical system, appear to have been secondary controls effective within each rock type. The $Al_2O_3$ content of the original shale had little or no direct control on the scapolite composition.

c. The comparatively marialitic scapolite in metadolerites and metavolcanics originated metasomatically by recrystallization of the igneous rocks in the presence of volatile-rich pore fluids derived from the adjacent sediments.

d. The relative abundance of the volatiles in the various environments of scapolite formation may be of considerable significance in determining scapolite composition. This may be controlled by the value of $P_{Cl_2}$ : $P_{CO_2}$ in a system which can furnish the other required constituents ($Na_2O$, CaO, $Al_2O_3$) in whatever amounts are prescribed by the ratio of the volatiles.

To these conclusions we can add:

e. Where plagioclase and scapolite coexist in a rock it appears that it is the facies of metamorphism rather than the composition of the rock which controls the composition of the scapolite.

f. Vein-scapolite is similar in composition to that in adjacent scapolite metasediments, from which it has been derived by local metasomatic transport.

It is possible that Ramsay and Davidson overlooked the effect of the 'Burstall Granite' on scapolite occurrences in the Mary Kathleen area. Van de Kamp (1968) shows that 0.1 percent chlorine is required for scapolite development in low-grade rocks, but that higher-grade scapolite-bearing rocks contain 0.8 percent chlorine. He postulates addition of chlorine from a magmatic source to explain this increase, and a similar situation could exist at Mary Kathleen.

Future work will attempt to clarify this point; a detailed study of scapolite composition over the whole Sheet area will be undertaken, together with further chemical studies, in particular the determination of the amount of chlorine in the rocks, and studies of whole-rock composition in relation to scapolite composition.

(B) Garnetization

Garnet in veins, dykes, and irregular masses is widespread in the Sheet area. On a small scale, garnet-quartz veins 3 km west-northwest of Butcher Bore are associated with garnet schist and garnet amphibolite (Fig. 58). Large masses of garnet are associated with the Mary Kathleen uranium deposit, where they are considered precursors of rare earth and uranium mineralization. They are well developed along the southeastern margins of the open cut, at the Elaine Dorothy prospect to the south, and in a belt 2 km southeast of the open cut where the garnet masses appear to have preferentially replaced a limestone-clacareous granofels sequence.

Most garnetite masses are monomineralic, consisting of fine-to medium-grained, subhedral to anhedral garnet. Euhedral to subhedral diopside occurs with garnet at Elaine Dorothy and in the Mary Kathleen open cut, and crystals measuring up to 8 cm are common. Skarns also occur in the open cut (Fig. 59). Minor garnet veins in granofels in the Mary Kathleen sycnline, have preferentially formed in small-scale fold axial regions.

The compositions of garnet in the Mary Kathleen area have been determined by Whittle (1960) using the graphs of Wincehll (1958). Garnets from skarn, dykes, and metasediments were examined and the range of composition was 50 to 70 percent andradite, and 50 to 30 percent grossularite, i.e. the average composition is $An_{60}Gr_{40}$, an iron-calcium-aluminium garnet.

In thin section the garnet is red-brown, generally free of inclusions, slightly zoned, and locally associated with minor calcite, diopside, epidote, chlorite, biotite, and pools of albite which appear to vein and incorporate the garnet.

Origin of the Garnetite

The close association of secondary iron-rich garnetite and calcareous, iron-poor metasediments suggests that garnet has formed by addition of iron to the latter. As garnetization is restricted to the Mary Kathleen area, and is associated with mineralization, and garnet is found in late-

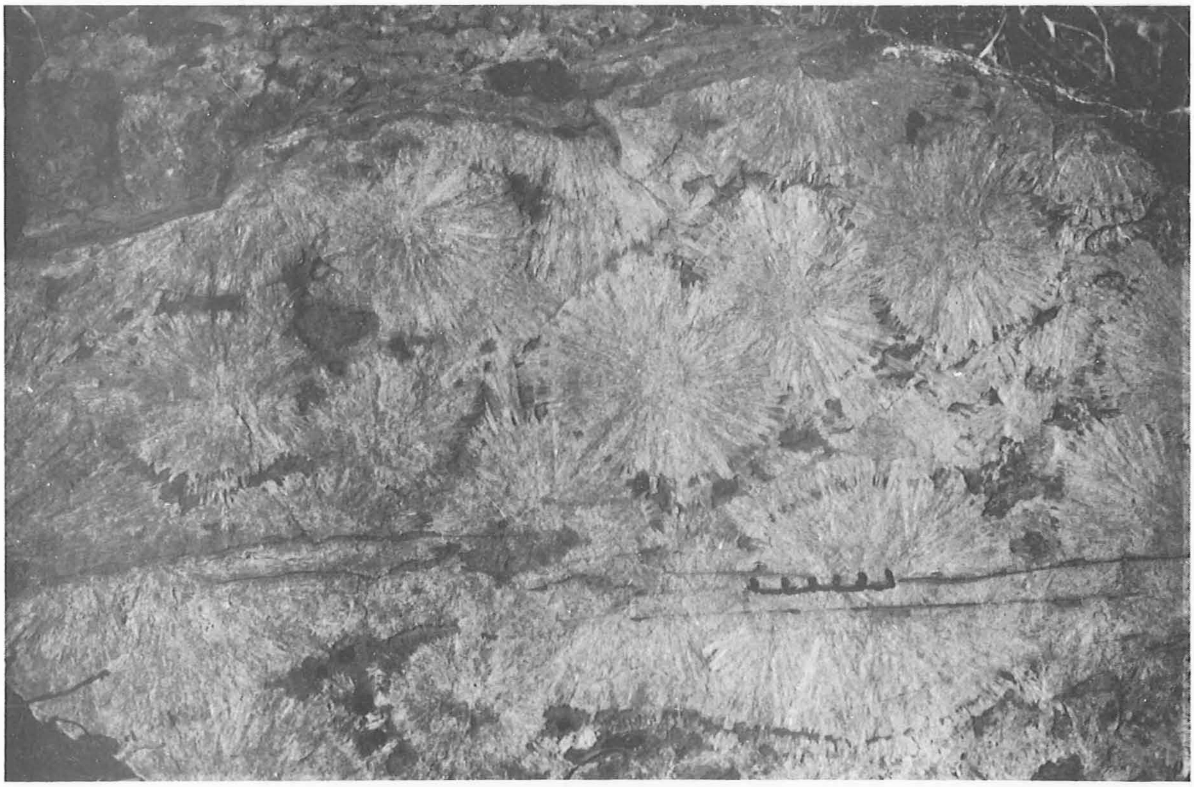


Fig. 57 Radial aggregates of scapolite on bedding planes, in calc-silicate granofels; locality 400 m east of microwave station. (Scale in cms) GA4299 GMD

Fig. 58 Quartz-garnet aggregates in garnet gneiss, 4 km west-northwest of Butcher Bore. M929/32 GMD

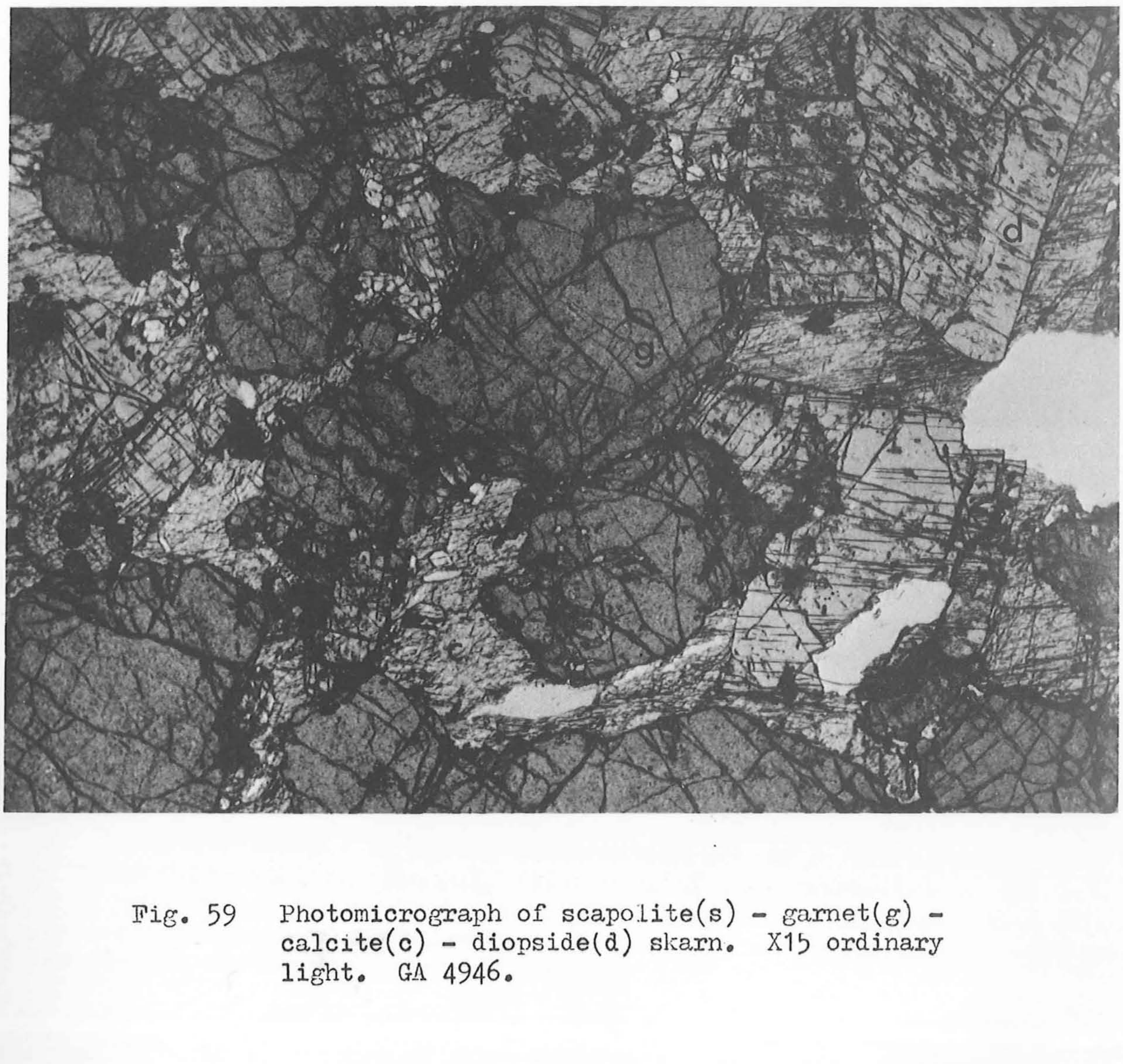



Fig. 59 Photomicrograph of scapolite(s) - garnet(g) - calcite(c) - diopside(d) skarn. X15 ordinary light. GA 4946.

stage porphyry, the introduction of iron is probably related to the 'Burstall Granite' and its associated dykes. However, there is no indication of a late stage iron-rich fluid phase derived from the granite itself and an alternative source for the iron is from granofels containing zones of 'red rock' and clouded feldspar-rich bands. These rock types contain finely dispersed hematite, and redistribution of iron along temperature gradients created by granite intrusion could provide sufficiently iron-rich fluids to form garnetite masses from limestone. A skarn-forming reaction such as $3CaCO_3 + Fe_2O_3 + 3SiO_2 \rightarrow Ca_3Fe_2Si_3O_{12} + 3CO_2$ is possible; in the event of insufficient silica being present, some magnetite may result.

This simple hypothesis of garnetite development is not wholly applicable to the garnetite development within the open cut where there are no highly calcareous beds from which garnet could be developed en masse by simply iron addition. There are, however, abundant coarse-grained veins of calcite with diopside, and it appears that in this zone of intense local metasomatism, iron, calcium, and magnesium have been freely available in metasomatic fluids derived from external sources.

## (C) Potash Metasomatism and Granitization

Carter et al (1961) described examples of potash metasomatism and granitization from the Argylla and Corella Formations, and the Ballara Quartzite which occurs only in the Mary Kathleen Sheet area. The metasomatism is manifested by microcline porphyroblasts, microcline veins, etc. in volcanics and quartzite. Probable metasomatic porphyroblasts have been noted in acid volcanics and schist 1 km west of Lake Corella, and similar rocks occur along the western margin of the Marraba Sheet area. Many of these could, however, be sheared porphyritic acid volcanic rocks of the Argylla Formation (Fig. 16), as many unsheared porphyries elsewhere are coarsely porphyritic.

Local migration of potassium is suggested by extensive biotite development in altered amphibolite adjacent to zones of mineralization. Many older dolerite dykes likewise are almost wholly converted to biotite schist.

A further example of potash metasomatism occurs on the northern margin of the Mary Kathleen open cut, where rims of pink microcline up to 2 cm thick have formed around acid metavolcanic cobbles and boulders (Fig. 60). A narrow depression around many quartzite boulders in the conglomerate represents a preferentially weathered microcline rim.

In the rim the microcline forms fine-grained granoblastic, turbid aggregates, similar to patches of microcline developed in the conglomerate matrix. The rim material is also identical to monomineralic pink bands of microcline granofels forming in the east limb of the Mary Kathleen Syncline. These latter rocks are problematical; similarity of the feldspar 'beds' to the cobble rims suggests a common origin.

Origin of the rims: There is little doubt that the microcline rims are secondary, and have formed by metasomatic addition of potassium to the rocks, or by metasomatic exchange of potassium between clast and matrix. The source of potassium is uncertain, but is possibly the 'Burstall Granite'. Relatively large scale 'streaming' or diffusion of potassium ions outwards from the pyrometasomatic zone exposed in the open cut is a possible mechanism leading to the development of rims. The relative permeability of the conglomerate and the feldspathic nature of the cobbles possibly facilitated the movement and concentration of potassium in the rock. The monomineralic bands of potassium feldspar in granofels in the Mary Kathleen syncline could also be a result of local metamorphic differentiation in which potassium and other elements are exchanged between laminae of carbonate and pelite in the original sequence (Sweet, 1968; Vidale, 1969).

(D) Diopside development

Large crystals of diopside associated with garnetite and skarn, and veins of diopside cutting biotite schist and amphibolite in the Mary Kathleen open cut, could be of metasomatic origin. As the metasediments elsewhere in the Mary Kathleen Syncline contain abundant diopside, there is no need to postulate any major regional introduction of elements; recrystallization and local redistribution of material, particularly calcium and magnesium, probably account for its formation. Diopside forms granoblastic masses localized along microfractures, where it appears to have replaced hornblende, and zones depleted in mafic minerals are found 1 to 2 cm either side of the diopside-filled microfractures. Some magnesia derived from red-rock leaching may have contributed to secondary diopside formation.

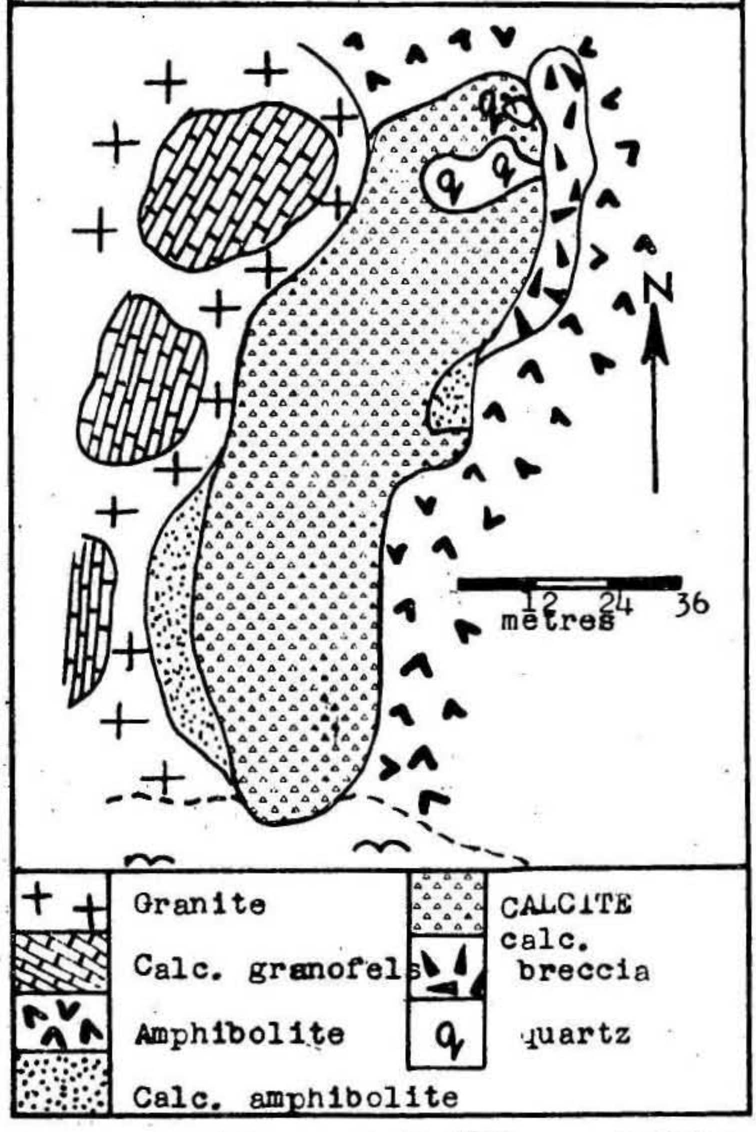
(E) Soda Metasomatism

Edwards & Baker (1954) postulated that soda (and chlorine) metasomatism, contemporaneous with regional metamorphism, has formed most of the widespread albite-bearing rocks in the Mount Isa-Cloncurry area. No detailed study of albitic metasediments has yet been made in this investigation. However, patches of albite replace potassic microgranite in dykes 1 km east of the Mary Kathleen open cut. The albitite masses show sharp contacts with microgranite and form clouded aggregates with a distinctive, ragged, interlocking prismatic texture, which contrasts with the fine hypidiomorphic granular texture of the dyke. Similarly texture albite occurs sporadically in some granofels in the Mary Kathleen Syncline, and presumably is also metasomatic in origin. The example of albitite cited above supports the suggestion of Joplin (1956) that some albitite represents a late differentiate of granitic magma.

(F) Calcite Veins and Masses

Large masses of coarsely crystalline calcite are common in the Marraba Sheet area. They consist mainly of calcite, but rare masses are dolomitic (Appendix Table B). Economic deposits are mainly in the Corella

Fig 61 Sketch map of calcite lens 2km SE of Lime Creek




To accompany Record No 1971/56.

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Fig. 60 Microcline rims formed metasomatically around acid volcanic cobbles and boulders in conglomerate north of Mary Kathleen open cut. GA2763 GMD

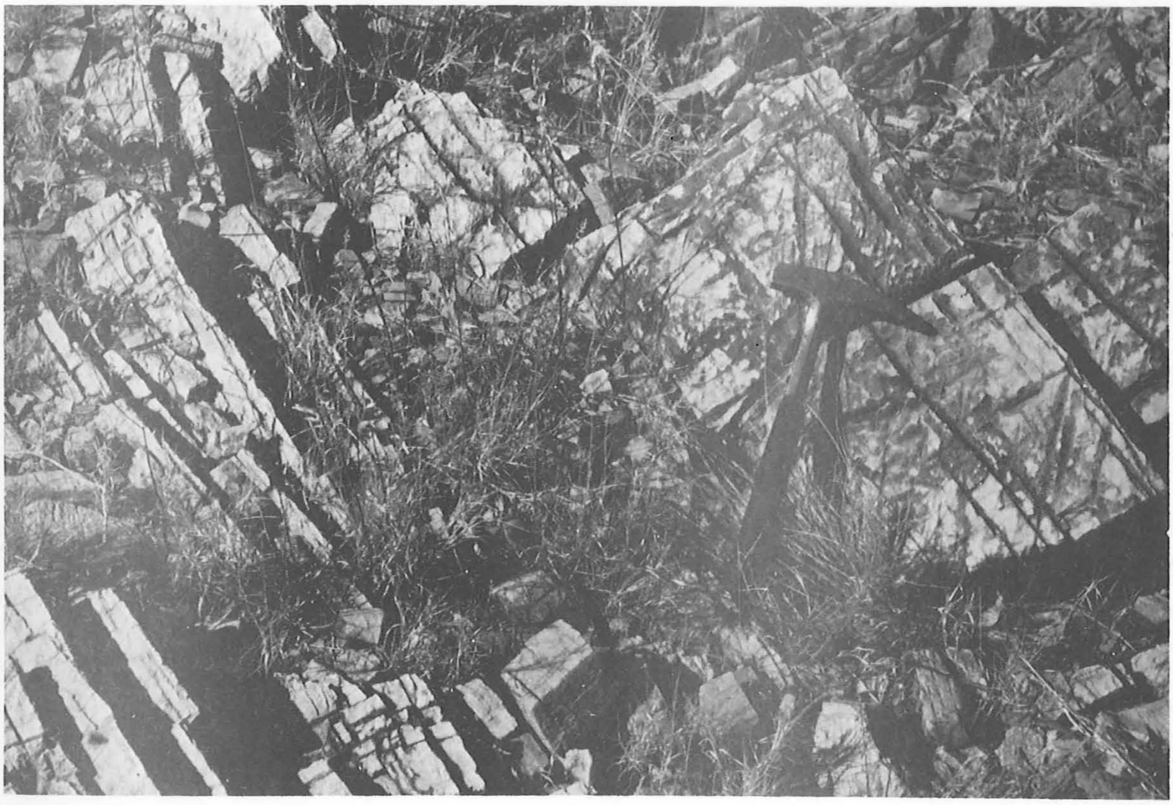


Fig. 62 Coarse-grained euhedral rhombs of calcite, 2 km southeast of Lime Creek mine, Cameron River area. GA2719 GMD

Formation (i.e. Kuta, Dolomite, Cameron) and in the Argylla Formation (Lime Creek); minor deposits of calcite occur in these formations and in basalts of the Marraba Volcanics and Mitakoodi Quartzite, and numerous dykes of coarse-grained granular calcite intrude metabasalt along the track immediately west of the Cameron Fault. These extend for 1 to 2 km, are up to 4 m wide, and contain sporadic chalcopyrite and malachite. At Lime Creek, chalcopyrite, pyrrhotite, molybdenite, biotite and quartz, form veins and segregations in the coarse-grained calcite. Figure 61 is a detailed sketch map of a large calcite lens, and Figure 62 shows the large calcite rhombs characteristic of this type of deposit. A large dyke of coarse-grained carbonate intruding the Marraba Volcanics is nearly pure dolomite. (Appendix 2 Table B)

Origin: Most of the calcite bodies have three features in common:

1. They lie in or near highly calcareous metasediments
2. They occur near fault zones
3. Dolerite and/or amphibolite is a ubiquitous associate.

The calcareous host rocks have probably been the ultimate source of calcium and magnesium carbonate. The mechanism of concentration is not known in detail, but deformation during regional metamorphism appears to have mobilized large amounts of calcite which recrystallized under favourable pH conditions in structural sites such as fold axial zones. Calcite-actinolite breccia is associated with pure crystalline calcite in some deposits.

In addition to faulting, and also where faulting is not evident, dolerite intrusion appears to have caused the mobilizing, migration, and recrystallization of calcium carbonate from metasediments. Copper sulphides in the calcite deposits were probably derived from the dolerite.

The calcite dykes in dolerites and amphibolites are probably late-stage crystallization products of basic magma, which has been enriched in calcite-forming elements derived from the intruded sediments.

The Lime Creek deposit seems anomalous; it is situated in acid volcanics cut by numerous sheared dolerite dykes and quartz veins. Gneiss and foliated granite veins are included in the sequence. No large dolerite body is associated with the mass, and the nearest calcareous sediments lie 600 m to the southeast. Molybdenite in the deposit suggests that nearby granite and granite pegmatite, as well as the sheared dolerite dykes, may have played a part in the formation of the deposit. Further work is required in the area. The quartz veins in and near the deposit show rhombohedral crystal faces, indicating pseudomorphous silicification of calcite.

Preliminary geochemical investigation of the calcite masses shows no carbonatite affinities, despite their intrusive habit (Appendix 2 Table B).

(G) Silicification

Silicification has taken place on both regional and outcrop scales. Regionally, the best example is the 'Chumvale Breccia', which is a silicified carbonate breccia, but throughout the Corella Formation the replacement of calcite by chalcedonic silica is common, particularly near mines and prospects. The replacement is mostly pseudomorphous; at Lime Creek, rhomb-structured quartz crystals up to 10 cm have been found, but more commonly chalcedony forms a polygonal aggregate after calcite, with average grain dimension of about 1 cm. The rhomb structure of the replaced calcite is outlined by fine opaques, probably manganese, in the chalcedony. Good examples can be seen at the Mount Linsay, Wollondonga, and Rainbow mines.

## Marimo Slate

### Introduction

The Marimo Slate occupies the southeastern part of the Sheet area. It is only moderately well exposed, and forms a mature and extensively dissected physiographic block (Figs. 5 and 63).

### Previous Literature (see Table 1)

Slate was mapped by Jack (1898) near Slaty Creek to the southwest, and along the Cloncurry River to the south of Cloncurry. Ball (1908) reported schists with lenticular quartz veins and 'saccharoidal' north-trending limestone east of the Gorge Hotel along Slaty Creek, and noted manganese concentrations in slate south of the Gorge Hotel. In the Hampden area Ball (op. cit.) noted slate, pyritic slate, and schist in what is presently known as the Kuridala Formation (Carter et al 1961). Other slates were recorded by Ball in what is now called the Corella Formation.

The earliest stratigraphic subdivision of the Precambrian (Shepherd, 1928) included the slate in the Mount Isa Series. AGGSNA (1937, Pl. 4), and Nye & Rayner (1940, Pl. 1) included the slates of the Hampden-Kuridala area in the Soldiers Cap Series (equivalent to the Argylla Series), but they included those in the Slaty Creek area and the limestone to the north and northwest in the younger Mount Isa Series. In 1946, Shepherd published his original classification with some notes on the significance of the work by officers of AGGSNA and as their maps were the most detailed available their classification remained popular until the results of regional mapping by BMR and GSQ became available (Carter, 1959; White, 1957; Carter et al 1961).

The discovery of lead-zinc anomalies in carbonaceous shale north and south of Mount Isa, and in similar rocks in the Dugald River area, by geochemical surveys carried out by BMR (Debnam, 1953) induced Titanium Alloy Manufacturing Co. (TAMCO), a division of National Lead Company, to take out an Authority to Prospect covering the areas of outcrop of the Corella Formation and Marimo Slate known to contain carbonaceous shales. Their activities centred around a number of prospective areas which were mapped in detail. Geochemical and geophysical surveys were carried out (the latter in conjunction with BMR) and some diamond drilling was done (Ivanac, 1953 a and b; 1954 a, b, c, and d; Horvath & Langron, 1956).

In 1954 Mount Isa Mines Ltd took up an Authority to Prospect (12M) which covered some of the eastern part of TAMCO's authority, and extended south to Malbon. Several prospects were examined, but little was added to the geology of the slate unit (Allen, 1956). Evaluation of copper prospects was continued by Carpentaria Exploration, especially in the Marimo Slate in the Mount McCabe area, a few kilometers south of the Marraba 1:100 000 Sheet area (Carpentaria Exploration Pty Ltd, 1963). However, most of their geological information was derived from mapping done by TAMCO.

The search for uranium in the mid-1950's brought with it further regional exploration. Rio Tinto Australia Exploration Pty Ltd used a helicopter in their survey of 5 100 $km^2$ of the Corella Formation and the Marimo Slate in 1955, but no anomalies were located in the Marimo Slate (Searl & McCarthy, 1958). Another geophysical survey of the area, using airborne electromagnetic detectors was undertaken and the anomalies were investigated on the ground (Rio Tinto Australia Exploration Pty Ltd, 1960). The Marimo Slate was covered by an extensive stream-sediment sampling program conducted by Kennecott Explorations (Aust.) Pty Ltd from 1965 to 1967. Copper, lead, zinc anomalies were investigated in the Marimo Slate, and some notes on the lithology are included in the final report for Authority to Prospect 362M (Kennecott Explorations (Aust.) Pty Ltd, 1968). Part of the Marimo Slate has more recently (1967-1969) been examined by Western Nuclear, whose program involved geological mapping and stream-sediment geochemistry for the whole of the area, soil sampling in more prospective areas, and costeaning and diamond drilling of several prospects (Mathews & Woods, 1969).

Formal definitions of the Answer Slate, Staveley Formation, and the Kuridala Formation (which occur in the Kuridala area), and the Marimo Slate and Corella Formation nearer Cloncurry are in Carter et al (1961), who pointed out that there is no evidence that these are sedimentary sequences of different age. We have not been able to correlate the Marimo Slate succession with the stratigraphic sequence in the Kuridala area (White, 1957), but an area between Kuridala and the Marraba 1:100 000 Sheet area remains to be mapped in detail; until this mapping has been done, a comprehensive account of the relationships of the various slate units cannot be given. The following descriptive account covers that part of the Marimo Slate lying in the Marraba Sheet area. Slates within the Corella Formation are discussed with that formation.

Definition

Derivation of Name : Marimo siding, 15 km southwest of Cloncurry.

Map Reference : Cloncurry and Duchess 1:250 000 Sheet area; Marraba, Cloncurry, Malbon, and Mount Angelay 1:100 000 Sheet areas.

Distribution : The Marimo Slate, as defined by Carter et al (1961), is restricted to a meridional belt about 44 km long and up to 18 km wide extending from 12.5 km southwest of Cloncurry to 12 km northwest of Kuridala. The overall structure of the belt is synclinal, although faulting, cross-folding, and major drag folds have produced a complicated pattern.

Structure : We have had difficulty in resolving the structure of the Marimo Slate but detailed work in a number of areas has shown a consistent vertical succession.

Type Section : A new type section in two parts is proposed to replace the type section of Carter et al (1961). The lower part runs for 1.5 km east of a small rock hole 3 km north of the Eight-Mile Rock Hole (lat. 20°56'50"S, long. 140°25'12"E to lat. 20°56'35"S, long. 140°26'00"E). The upper part runs in a northeasterly direction from the Mount McNamara copper mine for 1.5 km (lat. 20°55'22"S, long. 140°25'10"E to lat. 20°54'35"S, long. 140°25'38"E).

Thickness : The total thickness of the sequence defined here as Marimo Slate is about 2 000 m.

Age : Lower Proterozoic or Carpentarian.

Relationships with other units : The Marimo Slate overlies the Corella Formation, 'Overhang Jaspilite', and Mitakoodi Quartzite to the west, with either conformity or disconformity. This contact is probably faulted in part. To the north, the Marimo Slate is apparently faulted against a block of laminated, fine-grained sandstone, calcareous, dolomitic, and pyritic in part, which has been mapped as Roxmere Quartzite. A complex faulted contact with thin-bedded calc-silicate rocks and calc-silicate breccia occurs east of the Marimo Slate (Fig. 53). To the south the Marimo Slate is separated from the Answer Slate by an arbitary Fault (Carter et al, op. cit., p.80). The relationship between the Marimo Slate and the above formations will be further discussed in the following section.

## Field Occurrence

In the field the Marimo Slate is characterized by a series of north-northwest-trending ridges of silicified slate, with scree of grey to black, fissile to flaggy slate on the flanks of the ridges. Vegetation is sparse, and characteristically consists mainly of gidyea and wattle scrub. Outcrop on the ridges is virtually continuous, but because of extensive soil creep, little reliable structural information can be gained. Outcrop in the valleys is usually poor, being restricted to stream beds and low ridges. The central area of the major synclinal structure is covered by a five to six kilometre-wide black to grey soil alluvial plain crossed by Slaty Creek, Eight-Mile Creek, and the Cloncurry River. The rocks usually found in the valleys include siltstone and minor shale, ferruginous sandstone, dolomitic sandstone, 'antbed conglomerate', and calcsilicate rock.

The following stratigraphy has been established:

| Symbol | | Thickness |
|---|---|---|
| $Elc_3$ (top) | calcsilicate rocks, limestone, para-amphibolite and ferruginous (specularitic) calcareous and dolomitic conglomerate/breccia ('antbed conglomerate') | 200 m + |
| $Elm_2$ | ferruginous siltstone, fine-grained sandstone | Up to 380 m |
| $Elm_{2q}$ | rare marl and calcareous sandstone | |
| $Elm_{1s}$ | grey slate and black carbonaceous slate | 400 m |
| $Elm_{1a}$ | marly siltstone, limestone and 'attenuated' | 280 m |
| $El_{11}$ | siltstone | |
| $Elm_{1t}$ | phyllite, mica schist, and siltstone | 380 m |
| $Elm_{1q}$ | clean fine to medium-grained feldspathic sandstone | 820 m |

The slate-silt-limestone sequence ($Elm_{1s}$, $Elm_2$, $Elc_3$) is most characteristic north of Mount McNamara; south of this area the sequence is less clear, but a number of units are present which are older than the slate ($Elm_{1a}$, $_{1t}$, and $_{1q}$). The members $Elm_{1q}$ and $Elm_{2q}$ have been informally named the 'Toby Barty Sandstone Member', and 'Mick Creek Sandstone Member', respectively, the latter unit occurring mainly in the adjoining Cloncurry 1:100 000 Sheet area. The limestone unit occupying synclinal keels in the silt-slate sequence has been designated $Elc_3$, the top-most member of the Corella Formation; this means that the Marimo Slate is broadly equivalent to $Elc_2$, the middle unit of the Corella Formation.

A small pod of diorite has been mapped 1.5 km southeast of the Black Slate copper mine south of Slaty Creek, and a small pod of leucogranite occurs 3 km north-northwest of the Black Slate mine. There are far fewer basin intrusives in this formation than in other Lower Proterozoic formations.

Low greenschist facies regional metamorphism has affected the whole of the Marimo Slate. The cleavage in the slate is due to folding which accompanied the metamorphism, and a lepidoblastic texture is usually developed. Spotting in the slate could be due to the growth of porphyroblasts. A narrow contact-metamorphic aereole, about 20 m wide, containing mica schist and amphibolitic schist, surrounds the diorite.

Lithological Description

Unit $Blm_{1q}$ - Feldspathic sandstone ('Toby Barty Sandstone Member'): Clean fine-grained feldspathic sandstone crops out in a series of domal structures along the axis of the anticline north of Eight-Mile Rock Hole, and as an apparently undeformed mass 1.5 km to the west, extending from the Toby Barty mine south to the Sheet boundary. It is fine-grained, thick-to thin-bedded, cross-beds and ripple marks are abundant, and grainsize decreases from north to south. Some minor conglomerate occurs 1 km south of the Toby Barty mine.

Unit $Blm_{1t}$: A characteristic of this phyllite-schist-siltstone unit is the rapid alteration of rock types. Individual beds rarely exceed 10 mm, and lensing of the siltstone beds is common.

Unit $Blm_{1a}$: 'Attenuated' siltstone is used to describe the characteristic bedding of this unit, which consists of alternations of fine- and coarse-grained siltstone, and minor sandstone. The two latter rock types are extremely lenticular (Fig. 64) giving the appearance of a drawn-out, boudinaged bed. The lenticles are finely cross-bedded. Ripple marks and minor slump structure have been noted.

Grey and buff to orange marl limestone, and marly siltstone beds occur irregularly through this unit ($Blm_{1l}$). They are 1 to 200 m thick and vary widely in their lateral extent. In some cases they develop a knobbly black weathered surface. Calcareous sandstone 400 m north of the Toby Barty mine (Fig. 65) shows cross and convoluated bedding.

Unit $Blm_{1s}$: Grey and black slate has received a great deal of attention from companies because of its possible equivalence to the shales of the Mount Isa Group, and hence a prospective unit for copper, lead, and zinc mineralization. The lowest part of this unit is poorly exposed at Mount McNamara and is complicated by severe faulting, silicification, and introduction of iron. It consists of a dark grey, very fine-grained, fissile slate. Stratigraphically higher in the unit, the slate gradually becomes coarser-grained. The unit has beds of siltstone 30 to 100 mm thick near the top. Primary structures within the finer slates are absent except for rare laminations, but bedding is common in silty slate near the middle of the unit. Bedding, cross-bedding, and very rare ripple marks have been noted in the siltstone beds near the top of the unit.

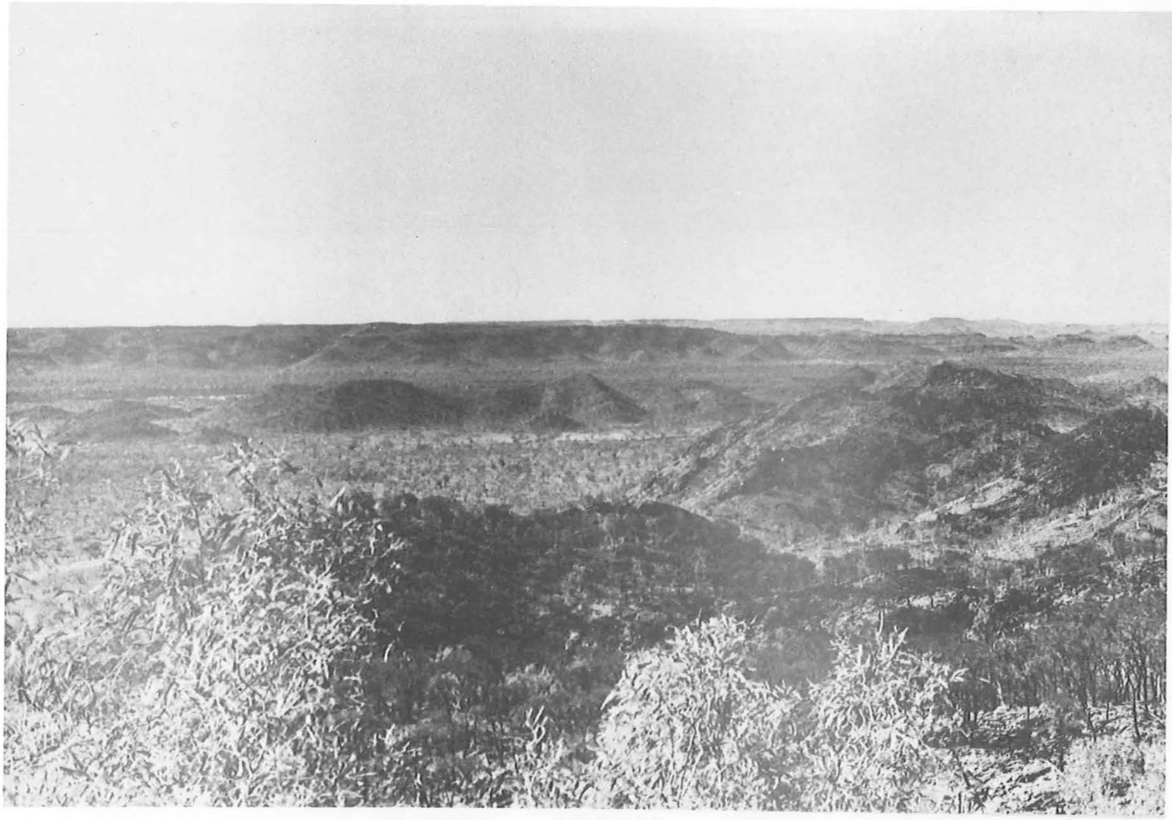


Fig. 63 Panorama in the Marimo Slate, looking south and east of Helafels. Black slate is hill-forming, and contains resistant quartzite interbeds. M895/12a GMD

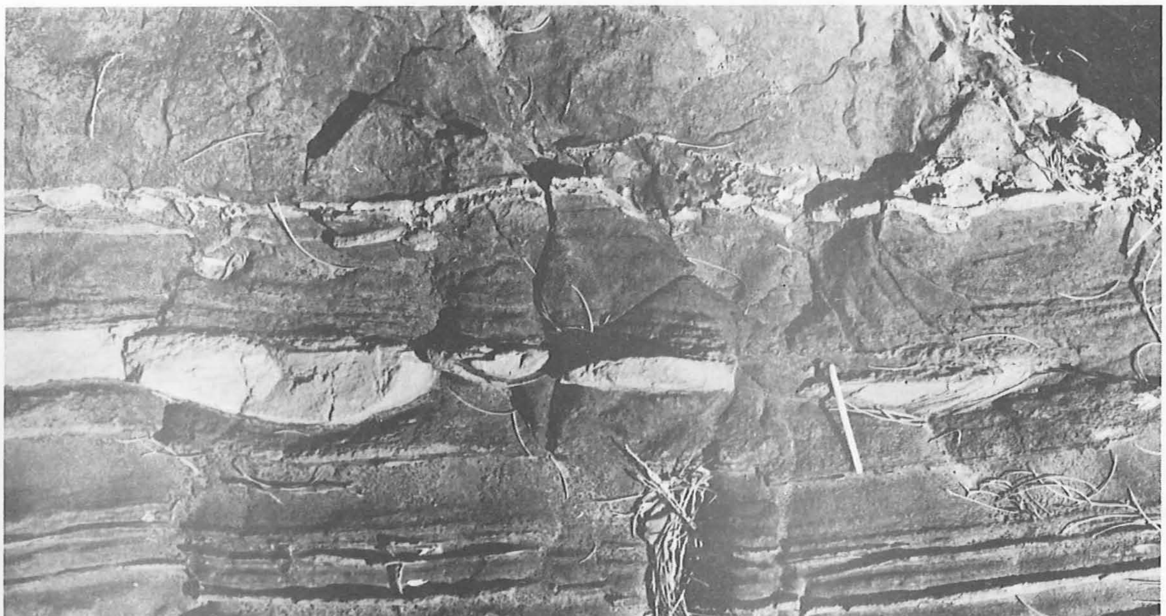


Fig. 64 Lenticles of finely cross-bedded fine-grained sandstone in laminated calcareous siltstone sequence of $Blm_{1a}$; locality 2.5 km south-southwest of Mount McNamara M909/0 GMD

Fig. 65 Truncated convoluted bedding in calcareous sandstone ($Elm_{11}$), 400 m north of Toby Barty Mine. M909/3a GMD

'Holey slate' is characteristic of the lower half of this unit, although it is not well exposed in the type section. It is a black to medium grey carbonaceous slate, with well developed, uniform spherules, 1 to 3 mm in diameter, making up 5 to 50 percent of the rock. The spherules are filled with quartz, sericite, and opaque minerals, and have rims richer in aggregated opaques. Relics of an unidentified mineral have been observed as optically continuous patches with low birefringence. The origin of these structures is not understood, but it is likely that they represent altered porphyroblasts of either andalusite or feldspar, or less probably sedimentary structures, gas bubbles, diagenetic sulphide spherules, or organic structures. Slight flattening of the spheres in the plane of the cleavage has taken place.

Several beds, up to 30 cm thick, in the upper part of the slate unit contain extensively sericitized euhedral porphyroblasts of andalusite up to 7 mm in cross-section and 40 mm long. Cubic casts presumably after pyrite, and angular casts filled with goethite after carbonate minerals, have been reported (Kennecott, 1968).

Excellent exposures of stromatolitic chert have been found 2.8 km east-northeast of Marimo siding. Individual stromatolite are up to 0.5 m long and 8 cm diameter, and form a colony up to 2 m thick and 0.7 km long.

The structure of the Marimo Slate is in a later section. The sequence is strongly cleaved and locally drag-folded about north-trending axes, and some cross-folding about east-northeast trending axes is evident (Fig. 66). This later folding may be related to the development of a fracture cleavage nearly perpendicular to the slaty cleavage in some areas.

Strike-slip faulting is common, and is accompanied by minor brecciation, intense folding, and zones of silicification up to 50 m wide in which bedding is usually undisturbed. Minor copper mineralization is localized along small cross-faults with 1 to 20 m displacement. The relatively few joints in the sequence are coated with clays, ironoxides, carbonates and phosphate minerals (e.g. crandaliite and milliste). Veins of quartz, dolomite, calcite, and feldspar-specularite-quartz are also present.

<u>Unit $Blm_2$, $Blm_{2q}$</u> ('Mick Creek Sandstone Member'): Unit $Blm_2$ overlies $Blm_{1s}$ and is composed mainly of siltstone, which has lower relief than associated slate. In the lower part, siltstone and interbedded slate predominate, but the rock type changes towards the top to feldspathic fine-grained sandstone with minor pebble and mud-flake conglomerate. Slate interfingers with siltstone about 2 km south-southeast of the Black Slate mine. Lenticular marl beds are numerous within the unit, as is 'gashed siltstone', presumably caused by the leaching of carbonate minerals concentrated in small cross-cutting lenses up to 1 cm thick. Sedimentary structures within this unit include well defined bedding, cross-bedding, graded bedding, lamination, micro-slumping, and mudballs. In the southeast, near the Cloncurry River, fine-grained micro-cross-bedded sandstone and red and white striped siltstone are common. Holes similar to those found in the 'holey slate' unit occur sparsely in the finer-grained rock type.

Along the eastern margin of the Sheet area the 'Mick Creek Sandstone Member' ($Blm_{2q}$) overlies black slate: it is brown, fine-to medium-grained, blocky, thick to thin-bedded, with abundant heavy-mineral laminae. Tight folding in siltstone immediately west of the Cloncurry River, south of Slaty Creek, probably defines a major synclinal axial zone. Minor drag folds are associated with faulting about 1.5 km south of the Black Slate mine, and zones of breccia in the unit north of Slaty Creek, consist of silt, shale, and sandstone fragments in a specularitic sandstone matrix.

Incomplete paced measured sections of unit $Blm_2$ are listed below:

Section of $Blm_2$, 2 km north-northwest of Black Slate mine

(top) calc-silicate granofels, epidote quartzite, marl - $Blc_3$

| Thickness (m) | |
|---|---|
| 6 | friable sandstone breccia, micro-crossbedded |
| 66 | flaggy calcareous silt, shale, minor sandstone laminae, and minor limestone |
| 60 | specularitic quartzite breccia |
| 30 | fine-grained sandstone and coarse-grained siltstone, with thin slate intercalations. Abundant micro cross-bedding, convoluted bedding, and ripples |
| 4.5 | fine to medium-grained quartzite |
| 4.5 | intraformational conglomerate |
| 27 | white to pale grey, flaggy laminated siltstone |
| 4 | brecciated quartzite |
| 10 | silicified, grey to orange-brown cherty quartzite |
| 9 | flaggy to blocky, white to pale grey siltstone and fine-grained sandstone. |
| 221 | light to grey to black slate, $Blm_1$ |

Section of $Blm_2$, 1 km southwest of Black Slate mine

(top) Calcareous breccia - $Blc_3$

| Thickness (m) | |
|---|---|
| 150 | fine-grained sandstone, grey, massive, interbanded with phyllite laminae; minor chert bands |
| 90 | shale and siltstone, with some interbedded pale red-brown fine-grained sandstone |
| 15 | limestone, massive in parts, with fragments of pale pink quartzite |

| | |
|---|---|
| 75 | siltstone with discontinuous shale laminae; lenticular ?tuffaceous beds. |
| 330 | quartzite breccia, silicified slate, $Blm_1$ |

A problematical rock type at or near the top of this unit, $Blm_2$, is 'ant-bed conglomerate'; the name is derived from its deep brown colour and rubbly nodular outcrop. Clasts 10 mm to over 20 cm across are subrounded to angular, with low to moderate sphericity, and consist of laminated calcareous siltstone and quartzite. The matrix contains 50 percent of rounded quartz grains, 20 percent calcite, and small quantities of microcline, chlorite and specularite. On weathering the calcite is removed, and hematite forms limonite, leaving honeycombed ferruginous material between the unweathered iron-stained clasts. This rock type has been termed scoriaceous agglomerate by Carter et al (1961), and rhyolitic agglomerate by Honman (1939) and Invanac (1954b); we think it is either a fault breccia, similar to breccia in the Corella Formation, or a sedimentary breccia associated with turbidity currents and slumping. Sedimentary structures such as micrograding, cross-bedding and scour-and-fill favour the latter origin.

Petrography

Slate, $Blm_1$: The slate consists of a lepidoblastic framework of muscovite, chlorite, some biotite, and abundant quartz and feldspar grains; the whole rock is dusted by fine-grained opaque minerals. Quartz (30 to 80 percent) is most abundant, and albite (30 to 60 percent) is common in the upper parts of the slate unit. The rock also contains up to 5 percent andalusite and epidote and accessory limonite, tourmaline, sphene, zircon, and monazite. Fluffy opaque aggregates are commonly elongated parallel to foliation, and rare hexagonal plates, possibly graphite or hematite, were noted. Feldspar, hematite, and quartz have been identified by X-ray diffraction in the very fine-grained slates.

Slate, silt, and sandstone, $Blm_2$ (523, 524, 525, 526, 536): The slate is similar to that of $Blm_1$. The siltstone is laminated, and consists mainly of quartz, feldspar, sericite, and hematite, with average grain dimension 0.05 to 0.2 mm. Subrounded grains of coarse feldspathic quartzite up to 1.5 mm long are found in sample 523. Opaque red-brown to black minerals probably consist of hematite, pyrite, and graphite. Sericite defines a fracture cleavage at varying angles to bedding. Spots in some samples consist of chlorite, hematite after ?pyrite, and scapolite.

The sandstone (average grain dimension 0.2 to 0.4 mm) has a quartzitic texture, and contains up to 30 percent feldspar and 10 to 20 percent opaque minerals. Lenticles of biotite, muscovite, and chlorite are present and some heavy mineral laminae contain tourmaline, hematite, and at least two different kinds of zircon.

The marl consists of carbonate beds alternating with pelitic-psammitic beds. Assemblages of quartz (20 to 30 percent), calcite (50 to 60 percent), limonite and opaques (8 to 10 percent), and minor sericite, chlorite, and scapolite are typical.

## Geochemistry

Geochemical examination of the various slates in the district was undertaken in 1969-70. The data are presented in Appendix 2, and include carbon analyses and major-and trace-element analyses. It is noteworthy that the graphitic carbon content of slate (ranging up to 16.7 percent) shows a general decrease at higher stratigraphic levels accompanied by a lightening in colour.

## Discussion and Conclusions

Uniform bedding in black slate, fine grainsize, relatively high carbon content, lack of ripple marks, the presence of convolute bedding and micro-cross-bedding, and interbedding of slate, siltstone, sandstone, and calcareous sediments, all suggest a marine, shallow to moderately deep, shelf environment. There is little or no evidence for turbidite-type deposition or near-shore intra-tidal deposition.

The only indications of current direction within the Marimo Slate suggest a sedimentary source to the southwest. Detritus was probably derived from most of the underlying rock units, including uplifted parts of the Marraba Volcanics, which may have been the ultimate source of the plentiful manganese mineralization, e.g. Overhang and Mount McNamara.

Hardly any detrital material was being deposited when the banded iron beds of the 'Overhang Jaspilite' (adjacent to the Marimo Slate) were laid down. Somewhat similar conditions prevailed when the carbonaceous slates and carbonate beds of the Marimo Slate were being laid down, and it is possible that the jaspilite, characterised by red hematitic quartzite and chert and interbedded carbonate, is a nearshore time equivalent of the Marimo Slate (Fig. 67a).

The present limits of exposure of the Marimo Slate and the Kuridala Formation south of the Sheet area indicate that deposition took place in a broad north trending trough bounded by the older blocks of Soldiers Cap Formation to the east and Argylla Formation/Mitakoodi Quartzite to the west. Figure 67 shows possible detailed cross-sections of part of the Marimo Slate from the Overhang to the Toby Barty mine (Fig. 66 and geological map).

In Figure 67, Section (a) infers a facies change from nearshore jaspilite and limestone to the deeper-water black slate in the east, an interpretation which is favoured in this report.

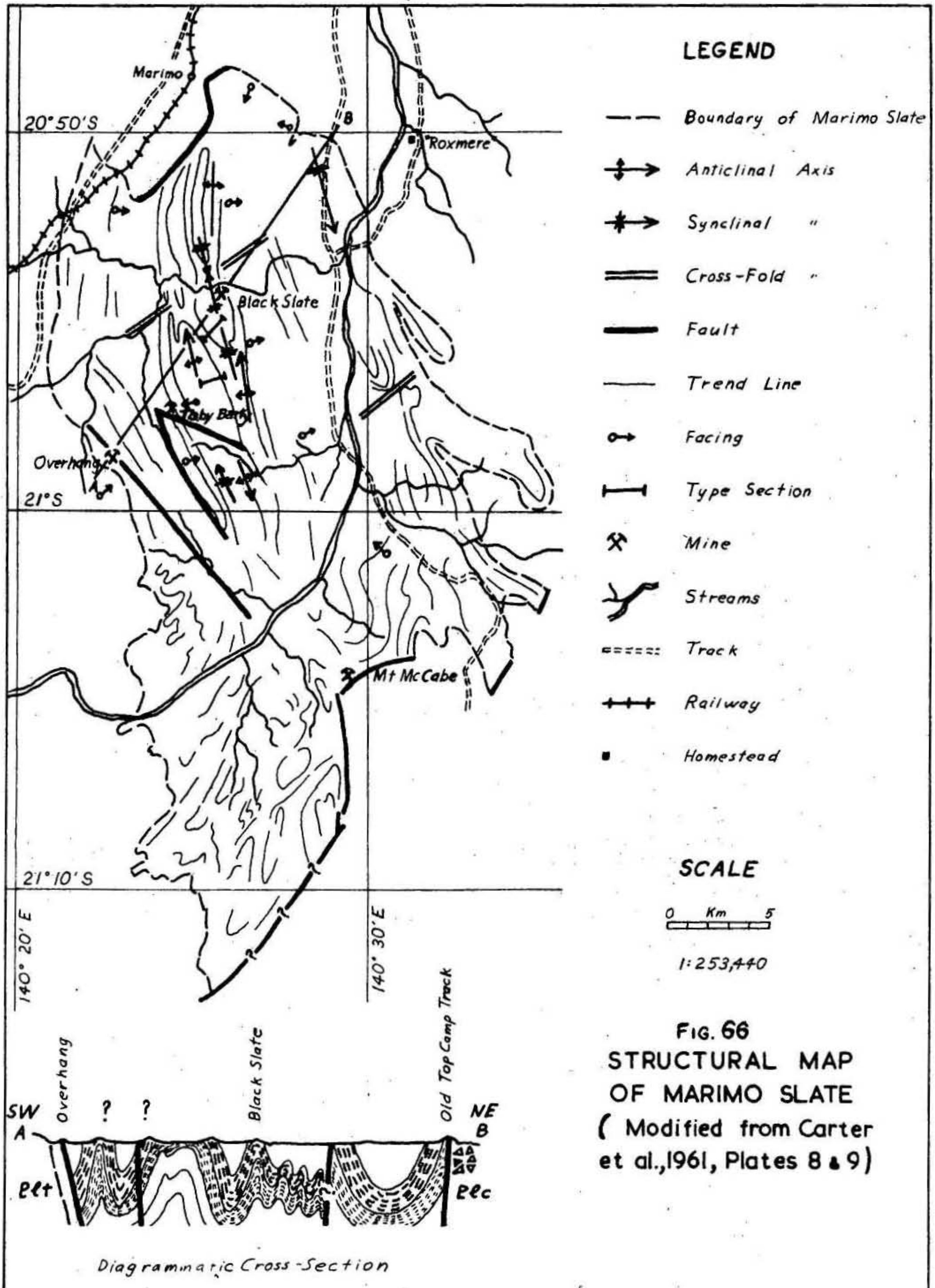
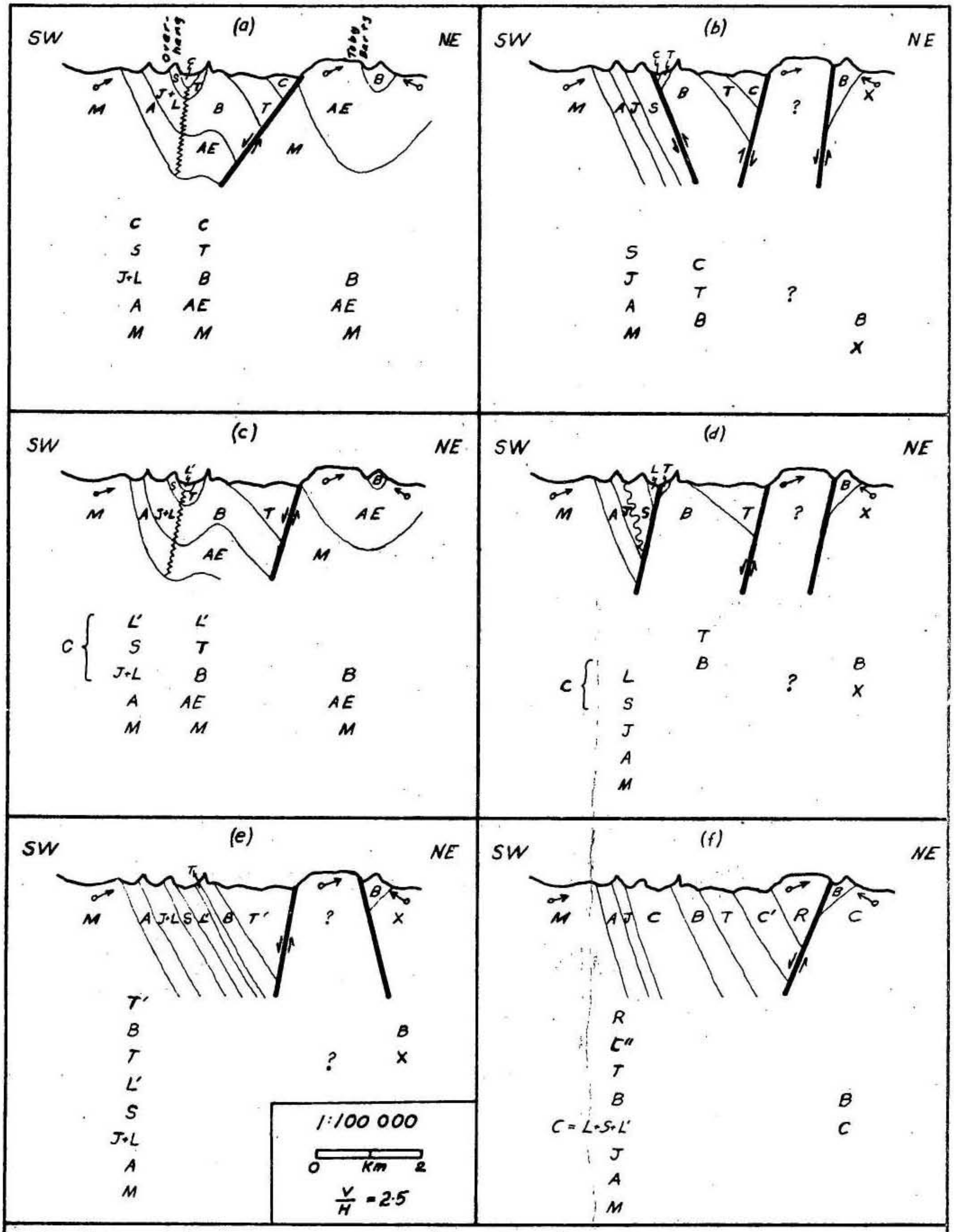



FIG. 66
STRUCTURAL MAP
OF MARIMO SLATE
( Modified from Carter
et al., 1961, Plates 8 & 9)

To accompany Record No 1971/56.

F54/A2/49




| | | | |
|---|---|---|---|
| A | Siltstone (Answer Slate or Upper M.) | M | Mitakoodi Quartzite and Equivalents |
| AE | Calcareous Siltstone Equivalent to A. | R | Roxmere " |
| B | Black Slate | S | Overhang Sandstone Unit |
| C | Corella Formation | T | Siltstone |
| J | Jaspilite | T′ | Upper T. |
| L | Limestone, Calc-silicate | X | Undefined Unit(s) below B. |
| L′ | Upper L. | ? | Unit with Unknown Relations |

Fig. 67. Possible detailed cross-sections through lower parts of Marimo Slate from Overhang to Toby Barty

Section (b) avoids any correlation between the Marimo Slate and other units.

Section (c) infers the same facies change as in (a) but here the Corella Formation is equated with the jaspilite and limestone unit, and hence with the Marimo Slate, which is overlain by a higher limestone unit of the Corella Formation.

Section (d) is similar to (b) but infers an unconformity above the jaspilite unit, and the relationship between the Corella Formation and the Marimo Slate is unspecified.

Section (e) infers that the Marimo Slate overlies most of the Corella Formation.

Section (f) infers that the Marimo Slate overlies the Corella Formation but has an upper calcareous unit and is overlain by a sandstone equivalent to the Roxmere Quartzite.

The relationships of the 'Toby Barty Sandstone Member' west of the Eight Mile Rock Hole with other units are little understood. In sections (a), (e), and (d), and on the geological map, the sandstone is considered to be older than the black slate. In sections (b) and (e) its relationships are not inferred. In section (f) it is considered to be younger. It should be noted that there is significant field evidence for faulting along the western margin of this unit, and this faulting may have restricted the outcrop of underlying units. The synclinal structure in the sandstone unit may be due to the upward movement of the eastern part of the Marimo Slate relative to the sandstone unit. It is hoped that further work, especially east of Malbon, will resolve the Marimo Slate problem.

## Roxmere Quartzite (Blr)

### Introduction

This unit was not shown by Carter et al (1961) in any part of the Marraba 1:100 000 Sheet area; however, large blocks of quartzite near Marimo Siding previously considered as part of the Corella Formation have now been included with the Roxmere Quartzite. In the adjoining Cloncurry 1:100 000 Sheet area two sandstone blocks in the Robur area, previously mapped as Roxmere Quartzite by Carter et al (op. cit) are now included in the Marimo Slate ('Mick Creek Sandstone Member') (Glikson & Derrick, 1970).

The name Roxmere Quartzite is taken from Roxmere landholding and homestead, 15 km south of Cloncurry, and the type section is in the Cloncurry 1:100 000 Sheet area, 5 km northeast of Roxmere homestead.

Field Occurrence and Lithology

New occurrences of Roxmere Quartzite have been recorded immediately south and west of Marimo Siding; they form upstanding, bevelled quartzite blocks with average relief of 90 to 100 m above the surrounding plains. The blocks are locally fault-bounded, and show a characteristic striated photo-pattern.

Feldspathic quartzite is the dominant rock type; it is pink to brown, thick-to thin-bedded, fine-to medium-grained, and characteristically contains 0.5 cm casts, probably after pyrite. Ripple marks and rare cross-bedding have been noted.

Siltstone, conglomerate, and calcareous siltstone and sandstone are less abundant; calcareous and micaceous beds are prominent towards the base of the sequence and could be transitional into the underlying Corella Formation.

Stratigraphic Relationships

The Roxmere Quartzite overlies the Corella Formation with probable conformity or disconformity; the boundary is locally brecciated. Relations with the Marimo Slate are uncertain because of faulted contacts, but in the area 2 km south of Marimo Siding the Roxmere Quartzite forms synclinal structures resting on a ferruginous siltstone unit tentatively assigned to the upper Marimo Slate, $Blm_2$. On this basis the Quartzite is probably younger than the Marimo Slate.

Petrography

The feldspathic sandstone contains up to 30 percent clouded feldspar. Muscovite forms small plates and poikiloblasts indicative of metamorphic growth; ironoxide is common, and tourmaline is a prominent accessory.

A mud-flake siltstone consists of fragments of fine-grained feld-spathic siltstone with plagioclase (40 to 50 percent), quartzite (30 percent) and minor chlorite, muscovite, and opaques, in a matrix (20 percent) of phyllitic slate containing abundant quartz, feldspar, and muscovite. Up to 30 percent calcite and up to 10 percent biotite occurs in siltstone near the base of the sequence near the Barronness mine.

Discussion and Correlations

The arenaceous rock type, and the presence of ripples and cross-bedding all suggest a shallow-water depositional environment, in which traction currents were initially relatively weak, allowing pelitic and calcareous material to be incorporated with fine-grained sandstone near the base of the sequence.

Carter et al (1961) considered that the Roxmere Quartzite is unlikely to be a correlative of the Deighton Quartzite in the Mary Kathleen Sheet area. Both units overlie the Corella Formation conformably or disconformably, they are similar lithologically (but differ slightly in sorting), both occupy local structural (and probably depositional) basins, and both are relatively undeformed. The only limitation on correlation of the two units is their distance apart which is about 75 km.

Within the Marraba Sheet area a correlation has been suggested (by Western Nuclear) between the Roxmere Quartzite block immediately southeast of Marimo Siding, and the 'Toby Barty Sandstone Member' of the Marimo Slate, about 15 km to the south. The proposed correlation is based on a broad lithological similarity, and the inferred presence of a major dextral strike-slip fault, now concealed for the most part, which has wrenched the two blocks apart. The presence of such a major fault cannot be proved in the poorly exposed country between the blocks, however, in the south the 'Toby Barty Sandstone Member' possibly overlies Marimo Slate. This apparent stratigraphic anomaly suggests that the proposed correlation is a tenuous one, and further work is required to test the proposal.

## UPPER PROTEROZOIC

### Quamby Conglomerate

#### Definition

| | | |
|---|---|---|
| Derivation of Name | : | Ball (1921, p.10) named the auriferous conglomeratic succession near Mount Quamby the Quamby Conglomerates. AGGSNA (1936a, p.50) grouped several conglomerates as the Mount Quamby Series. Carter et al (1961, p.123) defined the original conglomerates and several to the south as the Quamby Conglomerate. |
| Map Reference | : | Cloncurry 4-mile geological map (Marraba and Quamby 1:100 000 Sheets and Cameron River "a" 1:25 000 Field Compilation sheet). |
| Distribution | : | In the Marraba 1:100 000 Sheet area the Quamby Conglomerate occurs as a narrow downfaulted block which extends to the north-northeast from the old Mount Isa/Cloncurry Road, west of the Federal copper mine (lat. 20°35'40"S, long. 140°10'35"E) and to the north of the Sheet area near Mount Quamby. The area of outcrop in the Marraba Sheet area is about 12 $km^2$. |
| Lithology | : | Carter et al (1961) list conglomerate, pebble beds, greywacke (arkosic in part), quartzite and sandstone as the main rock types. The beds are locally strongly hematitic, apparently because of hydrothermally introduced iron. Strata are well compacted and lithified, but do not appear to be metamorphosed. The type section is an east-west section through Mount Quamby (Carter et al 1961). |

Thickness : About 300 m (Carter et al., 1961)

Age : Possibly Upper Proterozoic (see below)

Contacts : Underlain with strong angular unconformity by the Corella Formation. The angular discordance is not obvious on the Marraba Sheet.

Description and Comments

It is possible that there is a complete section of the conglomerate west and northwest of the Federal copper mine. The southern tip of the exposure is of fawn to brown pebble conglomerate with subangular slate and schist fragments and low-sphericity, rounded quartzite pebbles in the size range 10 to 50 mm with rare pebbles up to 20 cm. Beds are 0.3 to 8 m thick. Higher in the succession the clasts are of abrasion-resistant materials such as quartzite, feldspathic sandstone, and milky vein quartz, and some are up to 30 mm in diameter (Fig. 68). The matrix of the conglomerates contains predominantly angular grains to 0.2 mm, large muscovite plates and varying amounts of orthoclase, plagioclase, opaque minerals, chlorite, and limonite. In the upper part of the succession the number of pebbles decreases, they rarely exceed 50 mm, and usually occur in bands. The rock is a brown laminated micaceous sandstone with well defined bedding and some minor cross-bedding, with quartz dominant and chlorite common. Deformed muscovite plates and fine opaque minerals are uniformly distributed, with traces of zircon, limonite, chert (?jaspilite), and shale fragments. Carter et al (1961) reported localized boulder beds grading into greywacke, rare pebbles of rhyolite or meta-rhyolite, and the typical feldspar-rich groundmass.

The polymictic character of the basal conglomerates and the relatively high proportion of unweathered feldspar in the matrix suggest that the sediment was deposited rather rapidly. The angular metamorphic clasts are similar to schist and slate cropping out within 1 km of the conglomerate beds, whereas the more rounded quartzite pebbles have probably been transported some distance.

Hydrothermal alteration has been invoked (Carter et al, op. cit.) to explain the widespread chlorite and limonite. As much of the feldspar is fresh, except for limonite along cleavages, it is felt that hot solutions were not involved and that the alteration is related to subaerial processes. The highest parts of the Quamby Conglomerate in the type area form part of an old peneplain (Ball, 1921). The groundmass shows no evidence of metamorphism, and the conglomerate contains clasts of metamorphosed Lower Proterozoic to Carpentarian sediments. The conglomerate is thus post-metamorphism.

Structurally, the Quamby Conglomerate occurs as downfaulted blocks. In the Marraba Sheet area the fault block is elongated in a north-northeast direction, and the beds form a north-northeast-plunging syncline whose eastern limb has been largely truncated by faulting. Minor tight drag folds are present along the western limb, some cross-jointing is evident, and slickenslides have been observed on some strike-slip faults. Cleavage and schistosity are absent. Major quartz veining along the eastern boundary fault is quartz-filled, but there is only minor quartz veining in the conglomerate.

The conglomerate is younger than the Lower Proterozoic or Carpentarian metamorphism. The younger age limit cannot be readily fixed, but if the alteration is hydrothermal the conglomerate is probably older than the Naraku Granite. The graben structure in which the conglomerate is found is collinear with the post-Middle Cambrian Pilgrim Fault (Duchess 4-mile Sheet area) so that the conglomerate could be of Phanerozoic age.

Gold has been mined from the Quamby Conglomerate. Ball (1921) considers that it was derived from the neighbouring gold-rich copper ores, or else introduced in magmatic solutions following the faults. Later workers have favoured a hydrothermal origin. If the conglomerate ever contained uranium, it has probably been leached out by long periods of weathering and erosion that have led to peneplanation.

# IGNEOUS ROCKS

## LOWER PROTEROZOIC TO CARPENTARIAN(?)

## BASIC INTRUSIVE ROCKS

### Dolerites

Basic intrusive rocks are abundant in the Marraba Sheet area. They form a number of distinct groups, first recognised by Carter et al. (1961), which we have modified. The groups, with new symbols, are as follows:-

| | | |
|---|---|---|
| $do_2$ | : | metadolerite dykes (in places converted to amphibolite and chlorite and biotite schist) mainly in the Argylla Formation and Wonga Granite. Group $do_1$ does not occur in the Sheet area. |
| $do_3$ | : | metadolerite and amphibolite sills, irregular intrusives, and dykes in Corella Formation and lower units, emplaced before major regional metamorphism. |
| $do_4$ | : | dolerite and metadolerite dykes, stocks, and sills; some gabbroic lopoliths younger than or synchronous with major regional metamorphism, and intruded by granite. Alteration slight, ophitic texture preserved. |
| $do_6$ | : | dolerite dykes up to 30 km long, cutting late granites and Corella Formation; little or no alteration. |
| do | : | undivided metadolerite dykes and sills. |

Groups $do_5$ and $do_7$ are not represented in the Sheet area. In this Record some of the larger representatives of certain groups have been assigned formation names, e.g., 'Lunch Creek Gabbro' ($do_4$), and 'Lakeview Dolerite' dyke ($do_6$). Basalt flows in the Corella Formation are not specifically included in the above groups, although some metabasalt probably occurs as concordant amphibolites in Group $do_3$.

## Description of groups

Group 2, $do_2$: This group is confined to the Argylla Formation, particularly in the Bulonga Anticline, and to the Wonga Granite along the western Sheet boundary. In the Bulonga area they consist of chlorite and biotite schist and less commonly biotite amphibolite, with sporadic apatite crystals in some samples. Along the western Sheet margin garnetiferous amphibolite and highly foliated amphibolite reflect a higher grade of metamorphism than elsewhere.

Group 3, $do_3$: Most of the intrusions are concordant sills in the Corella Formation. They are amphibolitized, and show little or no subophitic texture. In the Duck Creek Anticline an extensive sill of

Fig. 68 Pebble conglomerate from the lower part of the Quamby Conglomerate, 4.5 km north of Federal copper mine. GA2951 IHW

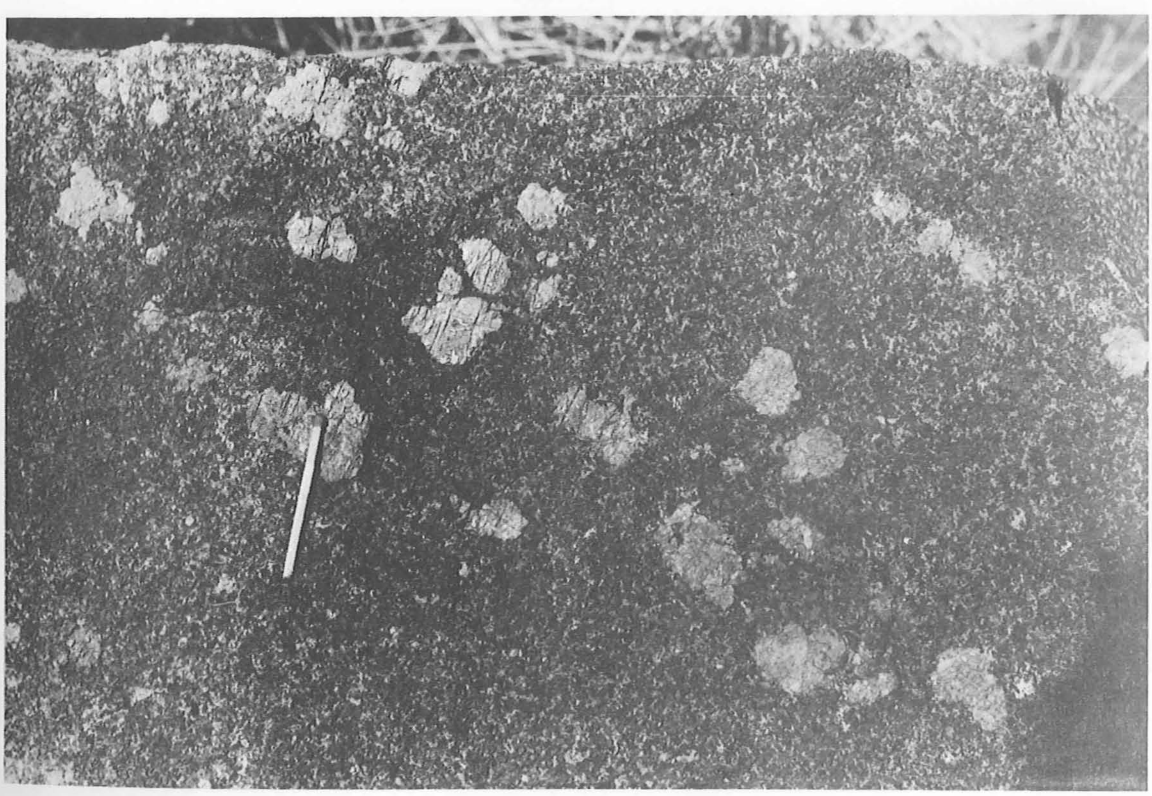
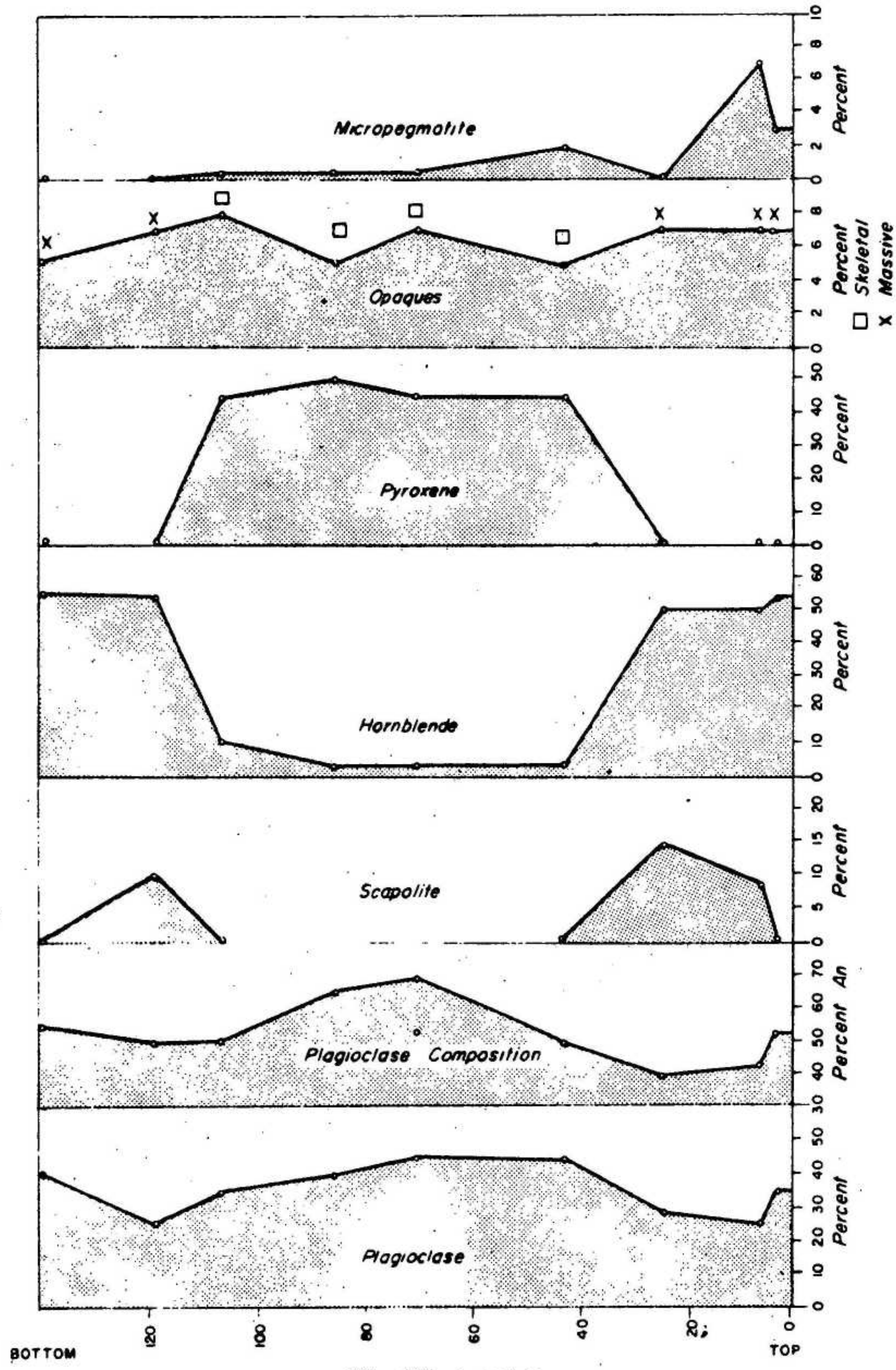


Fig. 69 Porphyritic dolerite ($do_3$) with plagioclase phenocrysts, in sill 2 km southwest of Duck Creek Bore M929/6a GMD

FIG. 70

## MODAL VARIATIONS-SILL OF DOLERITE DUCK CREEK ANTICLINE-ARGYLLA FORMATION

◦ *Sample localities*




*Sill width in metres*

Locality 8·5 km west of Mitakoodi siding, VB198844

*To accompany Record 1971/56*

F54/A2/28

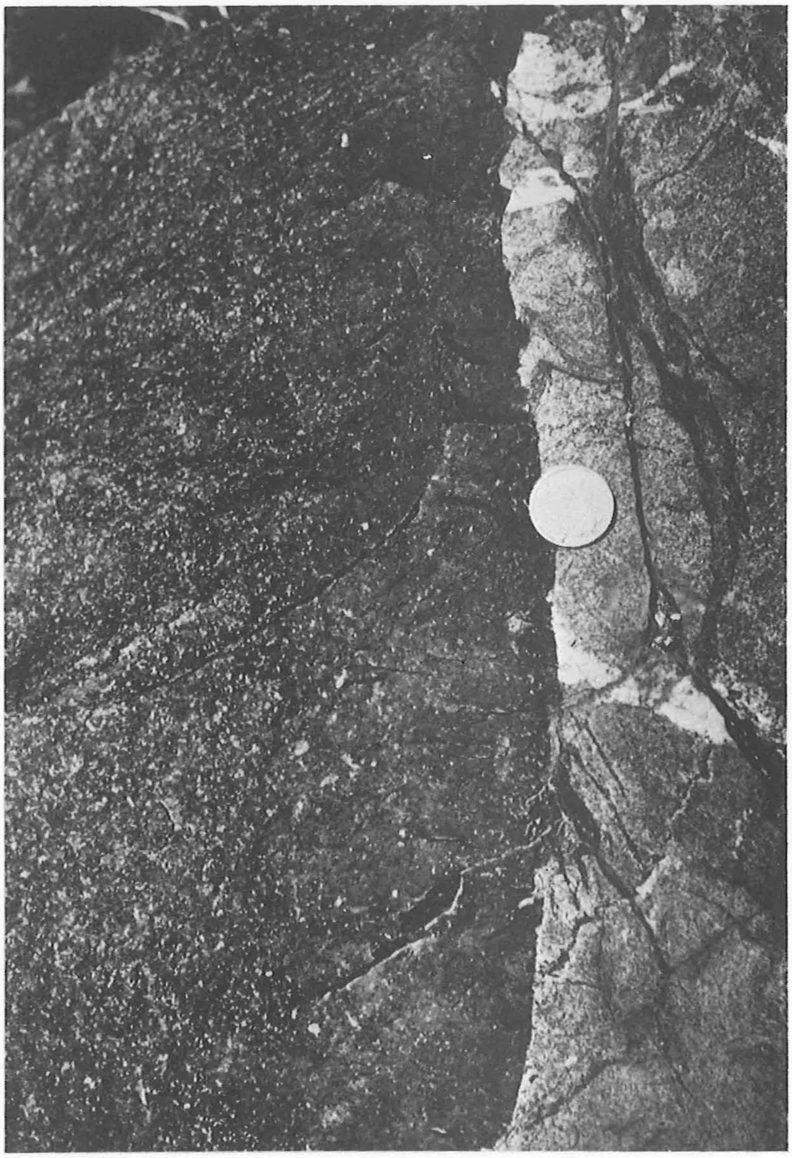


Fig. 71 Lakeview Dolerite Dyke ($do_6$), showing basaltic chilled margin against granite GA2724 GMD

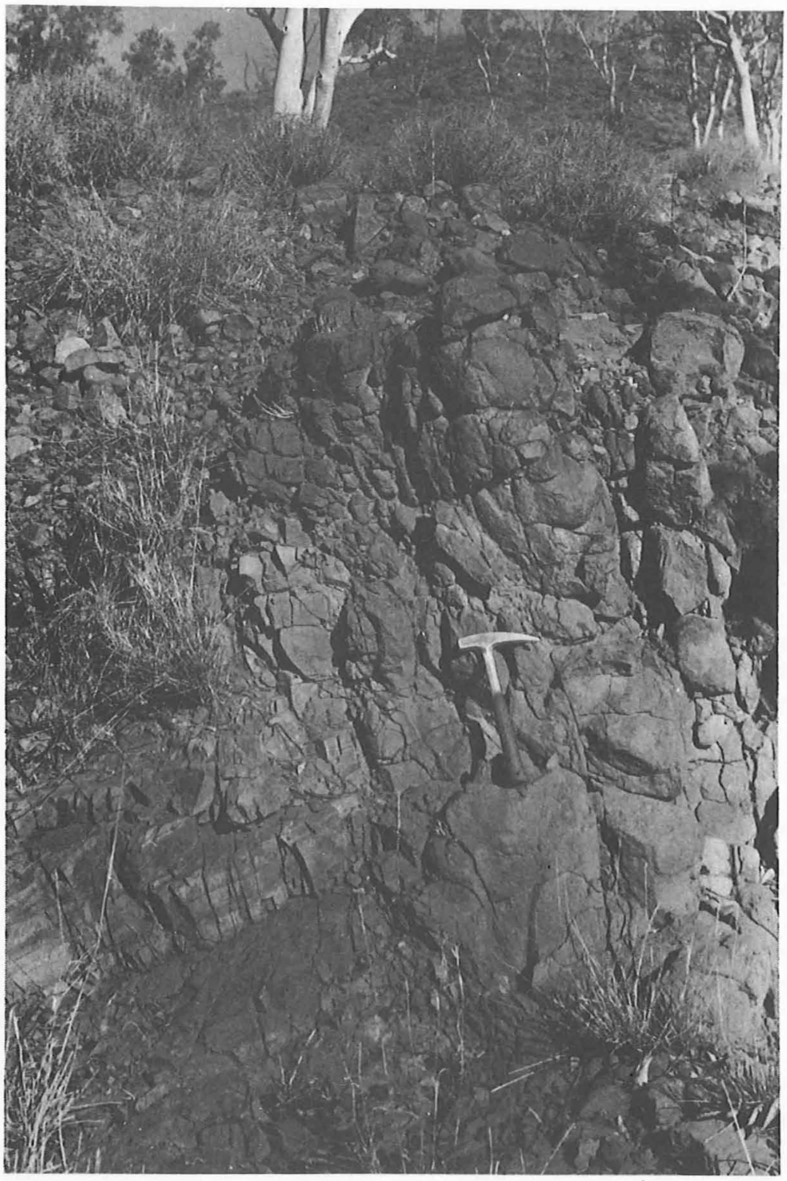


Fig. 72 Biotite lamprophyre dyke cutting Mitakoodi Quartzite,
3 km southeast of Butcher Bore M929/24a GMD

dolerite intrudes acid volcanics and sandstone of the Argylla Formation. This dolerite is massive and porphyritic (Fig. 69), and appears to be folded. The margins of the sill are slightly altered and amphibolitized, in contrast to the fresh central zone (Fig. 70), and this, together with its folded appearance, suggests that the sill is a pre- or syn-folding intrusive. It appears to be gradational into Group 4 ($do_4$) dykes which occur higher in the sequence. A similar problem was encountered by Carter et al (op. cit.) at Kuridala, where concordant sills of dolerite in folded strata were considered to be either Group 3 or Group 4 types.

It is possible that the sill was intruded during folding, and was followed by intrusion of dolerite dykes at higher stratigraphic level along radial cleavage planes, in the waning period of folding and fracturing. The slight alteration of the sill could be related to a greater depth of intrusion and more intense deformation in the axial parts of a major fold.

Group 4, $do_4$: As noted above, there is some difficulty in separating certain rock types in Groups 3 and 4. In general, the group 4 intrusives are massive, ophitic-textured, and moderately amphibolitized, and in the Marraba area they occur as dykes occupying a regional fracture pattern. They form irregular sills, plugs, and dykes in the Corella Formation (e.g., at Morris Creek and around Dolomite siding), and show little or no relation to regional folding. The 'Lunch Creek Gabbro' is a large example of this group, and is treated separately in a later section.

The dykes cutting the Marraba Volcanics and Mitakoodi Quartzite in the belt southwest of Cloncurry town terminate abruptly against the 'Overhang Jaspilite' and Marimo Slate. This could be the result of an unconformity, but it seems more likely to be due to differences in structural behaviour of the formations involved. Thus the jaspilite and Marimo Slate, in contrast to the Mitakoodi Quartzite, have not developed a strong radial or fan-like joint pattern which could facilitate dolerite intrusion; most dykes appear to peter out at the top of the quartzite, or form sills in the 'Wakeful Basalt Member' of the Mitakoodi Quartzite.

Group 6, $do_6$: The best example of this group is the 'Lakeview Dolerite' dyke, which extends for at least 30 km from the Lake Corella area northeastwards towards Corella Park homestead. It is fresh and massive, and up to 10 m wide, and has a basaltic chilled margin (Fig. 71). A suite of smaller dykes of this group cuts the 'Burstall Granite' northeast of the Mary Kathleen open cut, and another large example occurs in the Mount Godkin area.

Undivided dolerite (do): This includes representatives of all groups listed above. In general, dolerite bodies included in this group are confined to areas of limited sampling, areas of photo-interpretation, and areas of detailed mapping where two or three periods of dolerite intrusion are intimately associated, and have not been differentiated.

Lamprophyre

A distinctive biotite lamprophyre dyke extends for 7 km in the area 2 to 3 km southwest of Butcher Bore. It cuts Mitakoodi Quartzite (Fig. 72) and 'Overhang Jaspilite', and varies in width from 1 to 10 m. It is dull brown and highly weathered, and contains prominent biotite/phlogopite phenocrysts up to 4 mm across.

Petrography of the Basic Rock Groups

The petrography of rocks from some of these groups is summarised in Table 12. As noted above, the 'Lunch Creek Gabbro', an important representative of Group 4 basic rocks, is described separately.

Group 2, $do_2$: Only one sample of this group has been examined (359). Bands of amphibole and amphibole-plagioclase are abundant; the amphibole is subhedral, and shows Z= pale blue green, and X= pale fawn; sodic plagioclase is associated with fine-grained aphibolite and sphene. Crystals of clear, subhedral apatite, up to 3 mm long, are scattered through the rock. Textures suggest that the apatite is syn-or post-amphibole crystallization, and has possibly been derived from nearby small granite plugs.

Group 3, $do_3$: Most rocks of this group show little or no retention of subophitic texture, and are extensively amphibolitized. The amphibole is subhedral and lath-like, with preferred orientation; plagioclase is sodic and generally highly sericitized. Biotite and chlorite are common, and in the Mary Kathleen area scapolite replaces some or all of the plagioclase. Diopside replacing hornblende indicates amphibolite facies metamorphism.

Dolerite from a large sill in the Bulonga Anticline has been assigned to this group because of its apparent relation to folding. Petrographically it resembles some Group 4 intrusives (see Fig. 70). The margins of the sill are amphibolitized, but retain a blastophitic texture. Horenblende is xenoblastic, with Z = deep green, the most intense colour being adjacent to plagioclase. Relict pyroxene in the margins of the sill is partly replaced by hornblende. Scapolite replaces plagioclase in some samples, the latter mineral showing some clouding and a composition range from $An_{42}$ to $An_{52}$. Micropegmatite increases in abundance towards the top of the sill.

In the core of the sill ophitic texture is well preserved, and clinopyroxene is abundant. Plagioclase tends to be more calcic, $An_{52}$ to $An_{65}$, and unaltered. Biotite is a common accessory.

The textures of the opaque minerals in the hornblende-rich sill margins differs from that of the pyroxene-rich core. Opaques in the former are skeletal ilmenite, and in the latter irregular solid masses of ?magnetite or hematite.

The relation between skeletal opaques and hornblende development suggests that during cooling of the sill, exsolution of ilmenite lamellae in the (111) planes of magnetite took place (Edwards, 1954). At a later stage of crystallization, the magnetite was oxidised to hematite. During recrystallization of pyroxene to hornblende this hematite provided most of the iron needed to form the hornblende, thus leaving ilmenite as a skeletal relict in the altered sill margins.

## TABLE 12. MODAL COMPOSITIONS (ESTIMATED), BASIC ROCK GROUPS

| MINERAL | Cpx. | Opx. | Horn-blende | Trem. | Plag. | Plag. Comp. | Biotite, Chlorite | Opaques | Scap. | Access. |
|---|---|---|---|---|---|---|---|---|---|---|
| NUMBER | | | | | | | | | | |
| 359* $do_1$ | | | 80 | | 14 | $An_{12}$ | tr | | | 6 sp, ep, mu |
| 246 $do_3$ | 9 | | 70 | | | | | 1 | 20 | |
| 248 " | 10 | | 45 | | | | 4 | tr | 40 | |
| 259 " | 40 | | 15 | | | | tr | | 43 | 2 m, sp |
| 260 " | 30 | | 12 | | 45 | | 12 | | | 1 sp, q, m, |
| 269 " | | | 70 | | 25 | $An_5$-15 | | | | 5q, sp, ep |
| 367 | | | 65 | | 32 | | | 2 | | 1q, ep |
| 436 " | 40 | | 15 | | 41 | An55 | 1 | 3 | | |
| 446 " | | | 54 | | 36 | An52 | | 7 | tr | 3 q |
| 447 " | | | 52 | | 25 | An41 | | 7 | 9 | 7 q |
| 448 " | tr | | 51 | | 28 | An38 | | 7 | 14 | |
| 449 " | 46 | | 3 | | 44 | An48 | | 5 | tr | 2 q |
| 450 " | 43 | | 3 | | 47 | 70–50 | | 6 | | 1 q |
| 451 " | 49 | | 3 | | 42 | An62 | | 5 | | 1 q |
| 452 " | 44 | | 12 | | 36 | An50 | | 7 | tr | 1 q |
| 453 " | 2 | | 53 | | 28 | An50 | | 7 | 10 | |
| 454 " | | | 55 | | 40 | An52 | | 5 | tr | |
| 538 " | | | | 60 | | | 40 | tr | | |
| 539 " | | | 50 | | 48 | $An_{12}$ | | | | 2 sp, ep, c |
| 540 " | | | 75 | | 24 | | | tr | | 1 sp |
| 541 " | | | | 40 | | | | 5 | | 55 zo |
| 599 " | | | 89 | | | | 1 | tr | | 10 g |
| 625 " | | | 38 | | 43 | | | tr | | 15 q, 2 sp, ap |
| 630 " | 32 | | 33 | | | | | | 25 | 10 c |
| 196 $do_4$ | | | 45 | | 45 | An35 | tr | 5 | | 5 c, sp |
| 496 " | | | | 30 | 55 | An10 | tr | 5 | | 7 c, 3sp, 2p |
| 497 " | | | | 45 | 45 | | | 10 | | sp |
| 498 " | | | 45 | | 50 | | | 5 | | |
| 499 " | | | | 37 | 55 | An10 | | 8 | | sp |
| 553 " | 40 | | | 50 | | 30–60 | 5 | | | 5 q, sp |
| 242 $do_6$ | 43 | | 1 | | 40 | An68 | 9 | 5 | | 2 q, ap |
| 243 " | 43 | 2 | 2 | | 40 | An50 | 3 | 10 | | |
| 566 " | 63 | | | | 30 | An64 | 5 | 2 | | |

* BMR Registered Sample Number e.g. 69200359

Accessories q = quartz, c = calcite, sp = sphene, m = microcline, zo = zoisite, clinozoisite, ap = apatite, ep = epidote

Group 6, do$_6$: The 'Lakeview Dolerite' dyke is moderately fresh. Textures range from ophitic in the core to intersertal at the margins. Clinopyroxene occurs in both core and margin, but orthopyroxene is preserved only in the latter; it shows irregular alteration to serpentine or chlorite. Plagioclase occurs as fresh laths up to $An_{70}$ composition. The slight alteration in these dykes is probably automorphic in origin.

## 'Lunch Creek Gabbro' (New Name)

### Introduction

'The Lunch Creek Gabbro' is a large, layered, lopolithic or sill-like mass which is named after Lunch Creek. It exposes a good section of the gabbro 2 km north-northeast of Mount Burstall.

It forms a well exposed belt bordering the 'Burstall Granite', 3 to 10 km northwest of the Kuta limestone prospect, and a poorly exposed belt 4 to 8 km to the northeast. Most of the following information relates to the northwestern body.

### Stratigraphic Relationships

The 'Lunch Creek Gabbro' intrudes the Corella Formation, which it has metamorphosed to cordierite-anthophyllite schist at a contact 2 km west of the Lady Vera mine. It is intruded by the 'Burstall Granite' (Fig. 78) and related aplogranite dykes, and by the 'Lakeview Dolerite' dyke.

### Field Occurrence

The Gabbro forms moderate hills with smooth grey air-photo tones; it is heavily grassed, and is moderately well exposed (see Fig. 7), especially in creeks 2 to 4 km northwest of the Lady Vera mine, where most specimens have been collected. It is coarse to medium-grained (average grain dimension 1-2 mm), and in places contains very coarse-grained pegmatoidal patches with average grain dimension 1-2 cm. Large poikilitic grains of biotite characterize most of the gabbro, which becomes more tonalitic in the vicinity of granite stocks. In these contaminated contact zones the granite also becomes tonalitic, and zones of resorbed basic xenoliths are widespread (Fig. 73).

Layering is a common small-scale feature in both gabbro masses (Fig. 74), particularly near the middle, but no major differentiation has yet been noted; e.g., there is no development of granophyre, and some of the most mafic rock types (olivine gabbro) occur near the top of the sequence. Leucogabbro occurs at the top of the easternmost mass of the gabbro. Facing in the gabbro shows top of the east and west, and attitudes of 80° to the west have been measured from the layered zones.

Fine-grained dolerite veins cut the gabbro near the western margin; these contain rare pyrite and chalcopyrite, and abundant epidote. Quartz-feldspar-tourmaline veins related to the 'Burstall Granite' also cut the gabbro. Massive magnetite veins occur in the eastern mass.

Thickness of the 'Lunch Creek Gabbro' ranges from a maximum of 1 500 m in the western mass, to 450 m in the eastern mass.

Petrography

The petrography of the gabbro is summarised in Table 13, and plotted diagrammatically in Fugures 75 and 76. Most of the samples studied retain a subophitic texture, and contain clino and orthopyroxene. Fresh olivine occurs in two samples, and in one forms up to 30 percent of the rock. The orthopyroxene is hypersthene, faintly pleochroic and invariably clouded, and with few or no exsolution lamellae. The clinopyroxene is augite, which is generally partly altered to normal green hornblende. Other alteration phenomena include chloritization of biotite, sericitization of plagioclase, and replacement of plagioclase by scapolite. Scapolite forms a euhedral primary phase in olivine gabbro (sample 217). Biotite shows foxy-red pleochroism and a slight poikilitic habit, and appears to be a primary phase.

Accessory minerals are mainly apatite and sphene; in sample 224 apatite forms laths up to 1 mm long, and forms up to 1 percent of the altered quartz gabbro. Iron ore is not particularly abundant, and is generally associated with biotite.

Discussion

The widespread preservation of igneous textures and olivine-clinopyroxene-hypersthene assemblages suggests that the 'Lunch Creek Gabbro' is younger than the regional metamorphism which affected the Corella Formation. Deuteric alteration of the gabbro is probably related to the 'Burstall Granite' and its associated porphyry and aplite dykes.

Whittle (1960) considered that the 'Lunch Creek Gabbro' ("hypersthene diorite") to be the first phase in the differentiation and crystallization of the 'Burstall Granite' (granodiorite - Whittle's terminology). We suggest that the 'Burstall Granite' and 'Lunch Creek Gabbro' are not products of a single period of intrusion, as the intrusion of gabbro by stocks of coarse-grained granite indicates an age difference between the masses. The large volume of granite compared with gabbro, together with the absence of granophyritic textures, precludes the possibility of the granite being a normal differentiate of the gabbro.

Correlatives of the 'Lunch Creek Gabbro' have been noted in the Duchess area; these are the Group 4 basic intrusives containing hypersthene, olivine, and rare scapolite (Carter et al., 1961, pp. 139).

ACID INTRUSIVE ROCKS

Previous Literature

Jack's Geological Map of Queensland (Jack, 1892) showed a granite body approximately in the position of Wonga Granite to the north of Mary Kathleen. A later geological map (Cameron, 1960) showed one excessively large mass of granite extending northwards from a line joining Cloncurry to

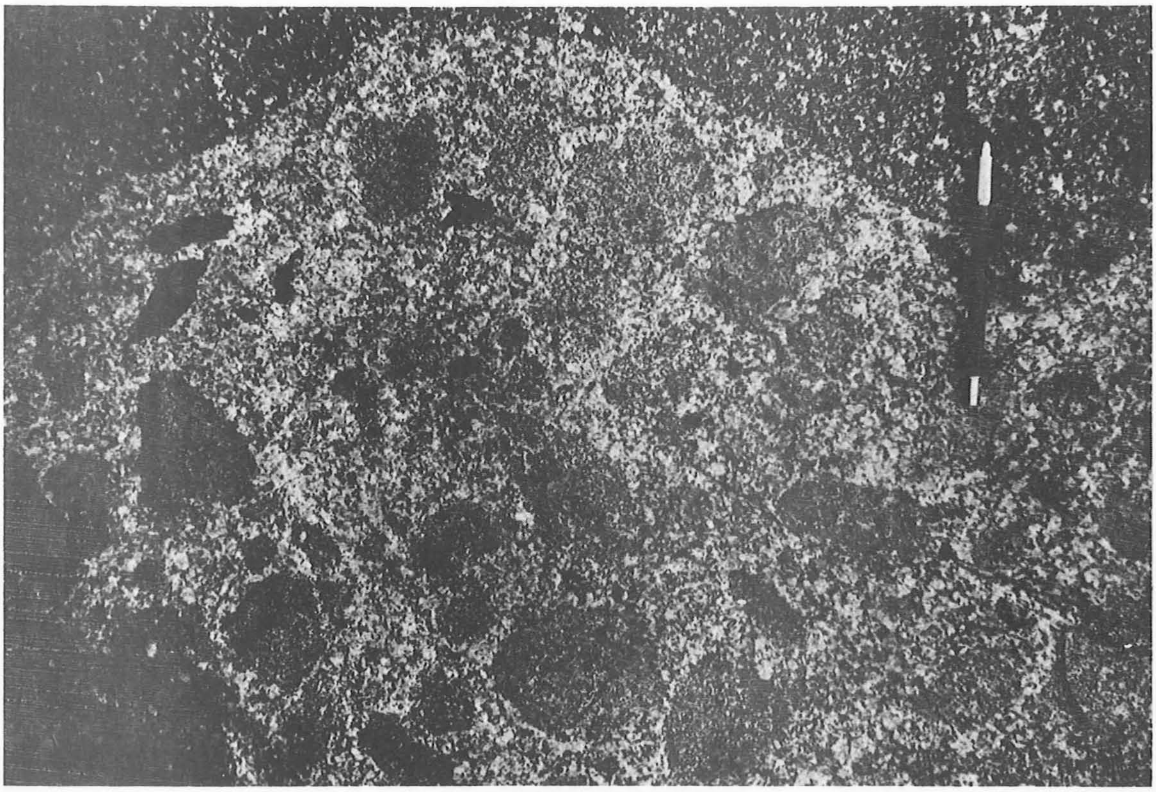


Fig. 73 Resorbed basic xenoliths in gabbro-granite contact zone,
5 km east of Mary Kathleen open cut GA2725 GMD

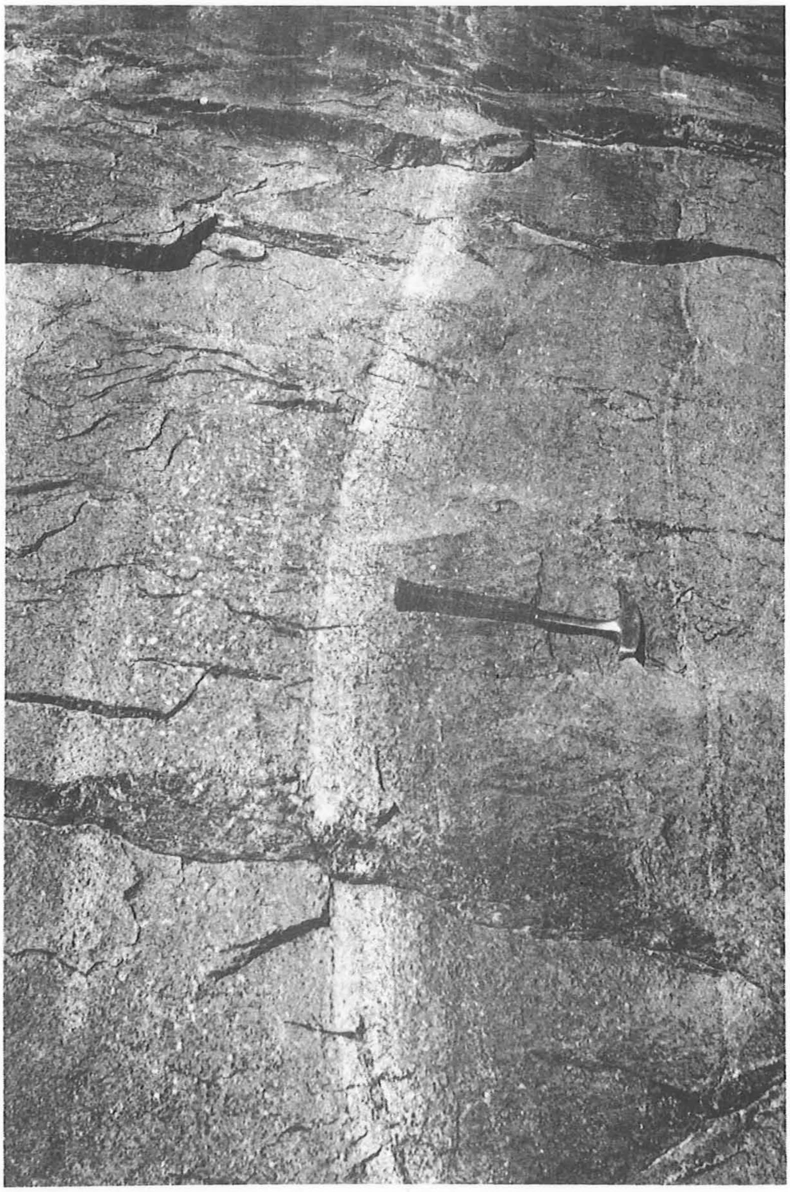


Fig. 74 Mineral layering in 'Lunch Creek Gabbro', 6.5 km east of Mary Kathleen open cut GA2798 GMD

Fig. 75

ESTIMATED MODAL VARIATIONS IN LUNCH CREEK, GABBRO

NORTHERN SECTION

(SECTION FROM VC017077 TO VC028082)

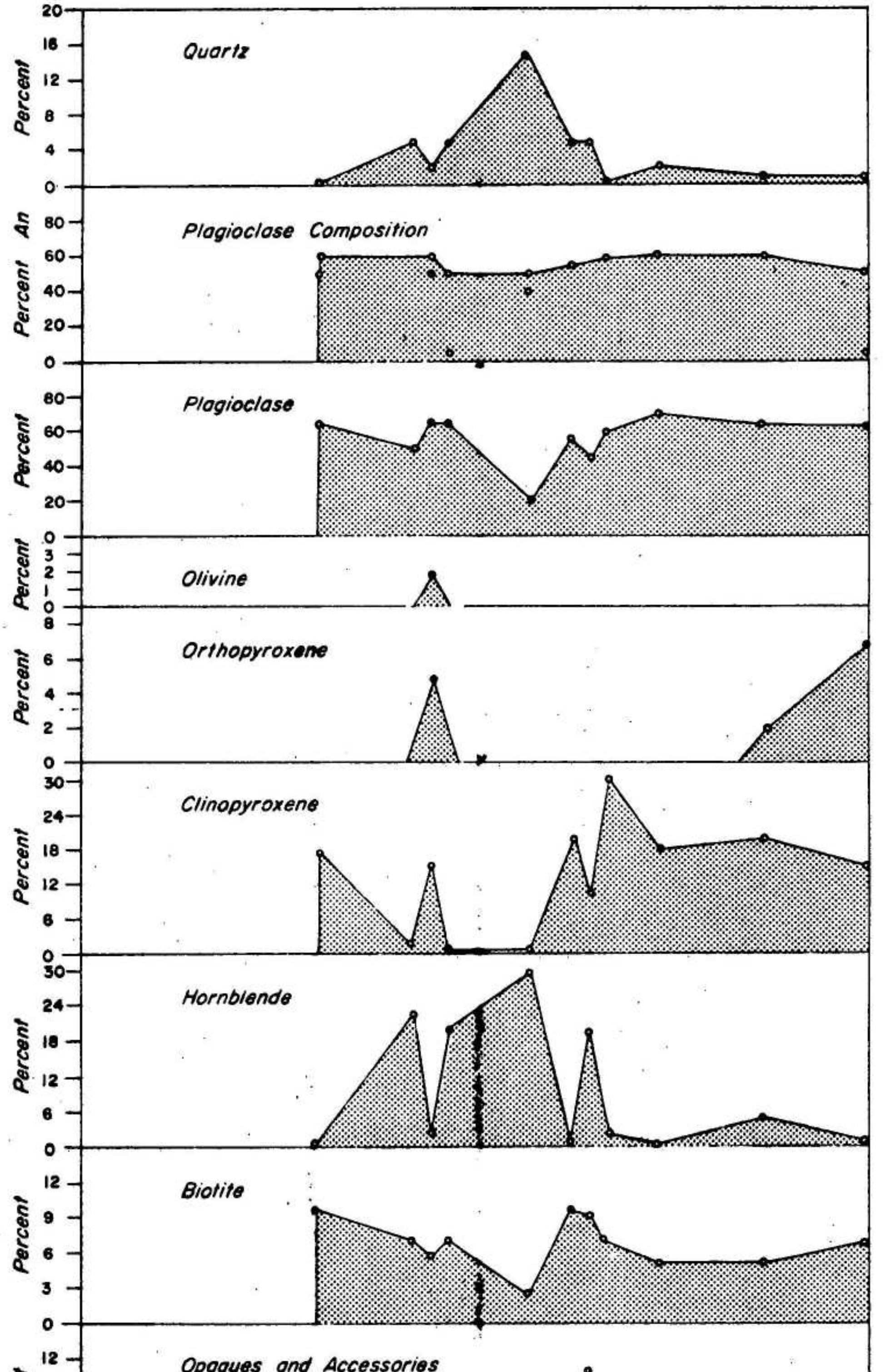
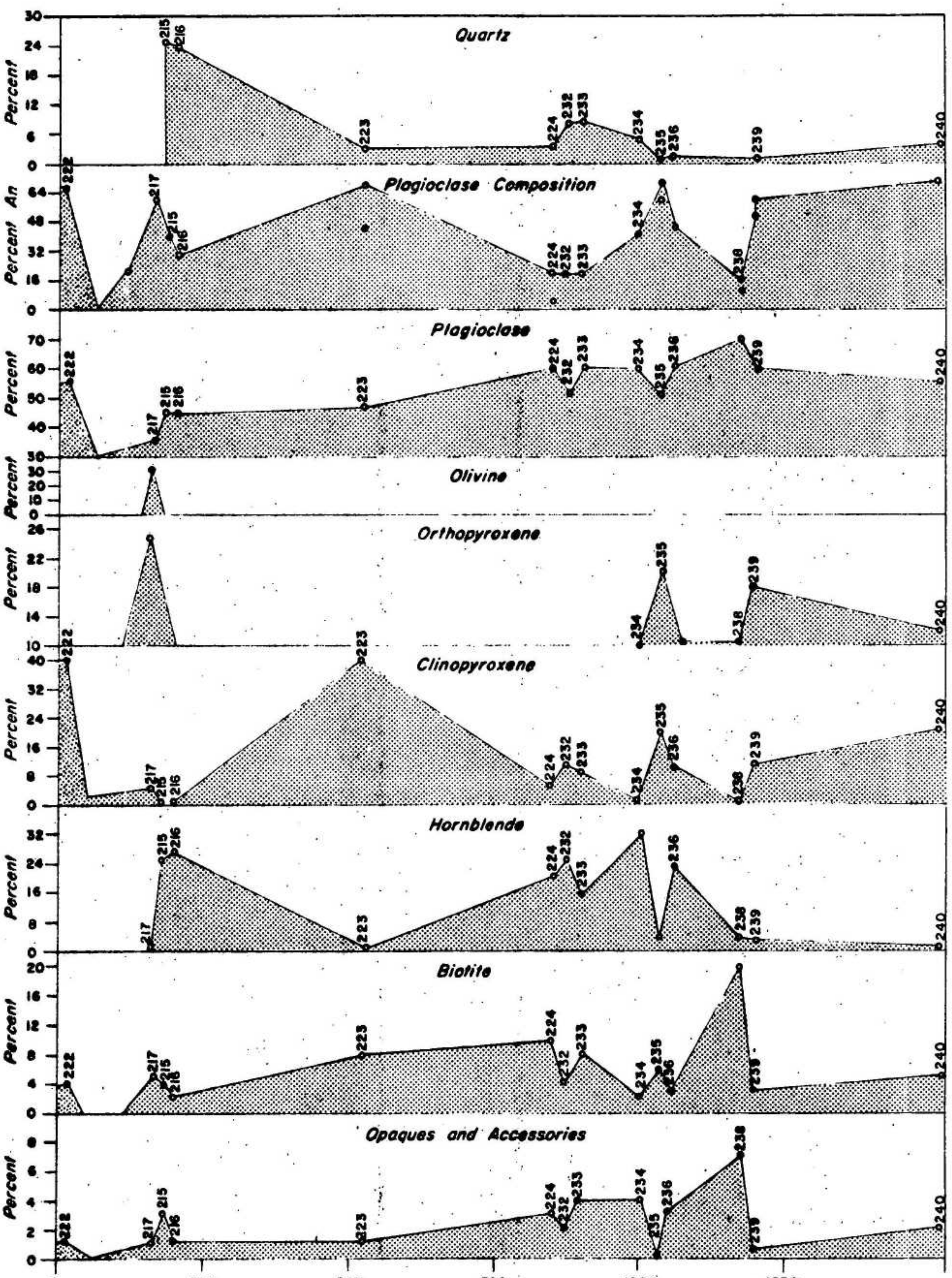


Fig. 76

ESTIMATED MODAL VARIATIONS IN LUNCH CREEK GABBRO

SOUTHERN SECTION
( SECTION FROM VC018048 TO VC034044)




To accompany Record 1971/56

F54/A2/35

TABLE 13. ESTIMATED MODAL COMPOSITIONS, LUNCH CREEK GABBRO

| Mineral Number | Qtz. | Kf | Plag. | Plag. Comp. | Olivine | Opx | Cpx | Horn-blende | Biotite | Epidote | Opaques | Access. | Rock Name. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CR-7-30-14o+ | 2 | | 65 | 50–60 | 2 | 5 | 15 | 2 | 5 | | 3 | 1 | Olivine gabbro |
| M 97 * | 1 | | 65 | 60 | | 2 | 20 | 5 | 5 | | 2 | | " " |
| M 104 | | | 68 | 65–70 | | | 19 | | 10 | | 2 | 1 | Gabbro |
| M 102 | | | 60 | 60 | | | 30 | 2 | 5 | | 3 | | " |
| M 105 | 1 | | 65 | 60–55 | | 7 | 15 | | 7 | | 2 | 1 | " |
| M 101 | 5 | | 45 | | | | 10 | 20 | 9 | | 11 | | Altered Gabbro |
| M 98 | 5 | | 64 | 50–55 | | | | 20 | 7 | | 1 | 4 | " " |
| M 103 | 2 | 3 | 70 | 60 | | | 18 | | 5 | | 2 | | Leucogabbro |
| M 96 | 5 | 5 | 50 | | | | 1 | 23 | 7 | 5 | 2 | 3 | Hybridized gabbro |
| M 100 | 5 | 5 | 55 | 50–55 | | | 20 | | 10 | | 3 | | " " |
| M 99 | 15 | 30 | 20 | 40–50 | | | 1 | 30 | 2 | | 1 | 2 | Monzodiorite |
| 6920 0222** | | | 55 | 60–45 | | | 40 | | 4 | | 1 | | Fine grained gabbro |
| 0219 | | | 60 | 10–20 | | | 5 | 35 | | | | 1 | Diorite (altered) |
| 0217 | | | 35 | 64 | 30 | 25 | 4 | | 5 | | 1 | | Olivine gabbro |
| 0215 | 25 | | 45 | 37–40 | | | | 25 | 4 | | 2 | 1 | Tonalite |
| 0216 | 24 | | 45 | 31 | | | | 27 | 2 | | | 1 | Tonalite |
| 0223 | 3 | | 47 | 67–45 | | | 40 | | 8 | | 1 | | Quartz gabbro |
| 0224 | 4 | | 60 | 20–25 | | | 5 | 20 | 10 | | 2 | 1 | Altered quartz gabbro |
| 0232 | 8 | | 30 | 10 | | | 11 | 25 | 4 | | 1 | 1 | Diorite |
| 0233 | 8 | | 60 | 20– | | | 9 | 15 | 8 | | 2 | 2 | " |
| 0234 | 5 | | 60 | 40 | | | | 33 | 2 | | 2 | 2 | " |
| 0235 | 0.5 | | 50 | 70–60 | | 20 | 20 | 3 | 6 | | | | Gabbro |
| 0236 | 1 | | 60 | 45 | | | 10 | 23 | 3 | | 1 | 2 | Altered gabbro |
| 0228 | | | 70 | 10–15 | | | | 3 | 20 | 7 | | | C.g altered gabbro |
| 0239 | 1 | | 60 | 60–50 | | 18 | 15 | 3 | 3 | | | 0.5 | Gabbro |
| 0240 | 4 | | 55 | 70 | | 12 | 21 | 1 | 5 | | 2 | 2 | Gabbro |

+ Field number    * G.S.Q. Polished Slide Nos    ** BMR Registered Numbers; e.g., R69200222

Mary Kathleen, and others to the south. Of the five granite bodies described by Ball (1908), only one corresponding to the Naraku Granite is shown cropping out in the area covered by the Marraba 1:100 000 Sheet. He described this as one of the peaks of a batholith underlying Cloncurry, and intruding the schists. Ball also noted gneisses about 50 km south of Mary Kathleen which may be sheared granites.

Shepherd (1928) divided the granites into three groups: the gneisses of the Kalkadoon Series which intruded the Leichhardt Series, the Wonga Series which intruded the Argylla Series, and the granite near Cloncurry which intruded the Mount Isa Series and the Corella Series, and was held responsible for the mineralization in the area (see Table 1). Nye & Rayner (1940) recognized two types of granite: a gneissic granite which intruded the Mount Isa Series and a non-gneissic granite, to which they related the porphyry, microgranite, and aplites in the district.

Joplin (1955) carried out the first petrographic work on the granites of the Cloncurry Mineral Field. Her map showed a mass of even-grained microgranite north of Cloncurry (corresponding to the Naraku Granite), and showed other coarse porphyritic granitic bodies to the west (corresponding to the Wonga, Kalkadoon, and Sybella Granites). She also noted a microgranite phase which invades the coarser porphyritic type, and described albitites and soda granites, coarse porphyritic granites, microgranites, and pegmatites as well as xenoliths and hybrids associated with each type, and listed 12 chemical analyses of the granites. The granite now known as Wonga Granite was called a synchronous intrusion while the older Kalkadoon Granite was called a subsequent intrusion (Browne, 1931). The Sybella Granite was called a quasi-synchronous intrusion. She concluded that the different types of batholiths were related to their position in the geosyncline and the degree of competence of the country rock. Granitization was held to be important in some areas.

The explanatory Notes for the Cloncurry 4-mile Geological Map (Carter, 1959) contain an account of the field characteristics of the granites within the Marraba 1:100 000 Sheet area, and point out that the names refer to areas of granite outcrop rather than rock type. It was also noted that all the bodies are probably composite. Brief petrographic descriptions are included, and the ages of intrusion are equated with each of the two Precambrian orogenies; a fine-grained granitic phase was considered to have followed each orogeny.

In conjunction with the regional mapping by BMR and GSQ, a systematic study of the granites of northwestern Queensland was carried out by Joplin & Walker (1961) who named nine masses of granites on a geographical basis. Some are composite bodies, but were not sub-divided in the reconnaissance mapping. Joplin & Walker described the major phases, and used a large number of micrometric (modal)analyses. Field characteristics were used (but not systematically described) to sort the granites into the crustal levels of intrusion of Buddington (1959). The Kalkadoon, Ewan, and Cliffdale Granites are considered to be epizonal, intruding some possibly co-magmatic lavas. The Wonga Granite shows features of catazonal emplacement, but field evidence indicated shallow burial, and it was suggested that the gneissic migmatitic and metasomatic features were a result of incompetence of the calcareous country rocks. The other granites were considered to be mesozonal. In a discussion of their origin, assimilation in situ was considered of little importance. Granitization and/or potash metasomatism were considered to be widespread, but only as localized processes. Differentiation was discussed in relation to the pressure-temperature conditions indicated by alkali feldspar compositions, but the discussion was complicated by continual reference to soda and potash metasomatism. It was suggested that the Williams, Wimberu, and Naraku Granites are of similar age, and that the Wonga Granite is younger. The Wonga Granite received special attention because of its magmatic and metasomatic features.

Carter et al (1961) defined each of the nine granites and described their field relations and petrography. Five ages of granitic rocks were recognized, and all were thought to be of Lower Proterozoic age with the possible exception of the oldest part of the Sybella Granite which was regarded as possible Archaean. The field relationships of the granites were then discussed, and the information was summarized in Carter et al. (1961, Table VI, p. 137). Local assimilation of country rocks was reported. Soda, silica, and potash enrichment leading to hydrothermal solutions which caused potash metasomatism and granitization were thought to occur in at least two granite series (Read, 1955). The older series begins with the intrusion of the Wimberu adamellite which differentiated along three trends, the end product of the siliceous trend being the Naraku microadamellite. Soda enrichment produced the Williams adamellite and later soda aplite and albitite. Potash enrichment produced the Wonga Granite.

A program to determine the absolute ages of the granites was begun in 1956 (White, 1962). More recent dating was recorded in Harding (1969). The significance of this work was summarized by Richards (1966), who dated the two episodes of granite emplacement at 1 760 m.y. and 1 540 m.y. The older episode includes the Kalkadoon, Ewen, and part of the Sybella Granites. An initial Sr ratio of 0.7043 suggested that the Wimberu Granite, belonging to the later episode, represented the introduction of new material of deep-seated origin. Richards also explained the age, which is younger than the second igneous event, by the loss, during metamorphism, of radiogenic Sr and Ar from biotite used in the determinations.

The problem that still exists despite all the preceding work is that composite granites with phases of different ages are given one name, and the phases have not been delineated. Smith (1967) examined the particular case of the two phases in the Kalkadoon Granite.

Current Work

Detailed regional mapping of the Marraba 1:100 000 Sheet area has enabled more accurate boundaries to be placed around the various granite bodies, and several new outcrops have been located. Further petrographic studies have been undertaken to complement the existing body of data. In addition, the 'Burstall Granite' (new name), originally a part of the Wonga Granite, and the 'Tommy Creek Microgranite' (new name) are described.

## Wimberu Granite(?)

(Carter et al., 1961, p. 147-148)

Several small outcrops of monzo-diorite were found within the Argylla Formation in the Bulonga Anticline. They are fine-to medium-grained and porphyritic, and at one locality contain 0.5 cm pyrite cubes. On the map they are labelled dr (diorite) and appear undivided but could be part of the Wimberu Granite.

## Naraku Granite

(Carter et al., 1961, p.148)

### Field Occurrence

The southwestern part of the extensive Naraku Granite forms masses of tors and sandy boulder-strewn rises along the northeastern limit of the outcrop of Precambrian rocks to the north of Cloncurry. The contact with the Corella Formation is rarely exposed but at latitude 20° 48'55"S, longitude 140° 21'5"E, basic schists and impure quartzites of the Corella Formation are intruded by a fine-grained slightly porphyritic foliated granite cut by narrow veins of aplite. This granite is thought to be part of the Naraku Granite. Elsewhere sediments are intruded by coarse-grained quartz-feldspar pegmatites and quartz-tourmaline veins. Minor muscovite-rich granite is present.

Further north, to the east of the Corella River at Carsland homestead, the granite is porphyritic and its grain size increases with the distance from the inferred contact (Fig. 77). It is moderately foliated, especially near the contact, and xenoliths of grey biotite schist are commonly aligned parallel to the foliation. A moderately well defined system of joints is visible on the air-photographs.

East of the Normanton-Cloncurry Road, outcrop is sparse except for a few tors near the Cloncurry River, which are mostly medium-grained to coarse-grained porphyritic granite, although some areas are slightly finer-grained. The air-photographs show a strong east-northeasterly trend which can be observed in the field in some cases as a poorly defined shallow south-dipping igneous foliation.

Quartz veins are abundant and some aplite dykes occur within the Naraku Granite. No evidence for more than one phase was found within that part of the batholith covered by the Marraba 1:100 000 Sheet area.

### Petrography

The main Naraku Granite mass is a holocrystalline fine-grained to coarse-grained slightly porphyritic granite. The phenocrysts (2-10 percent) are microline euhedra up to 10 mm in length. In thin-section the groundmass is hypidiomorphic granular with 30 to 45 percent of subhedral to euhedral albite-andesine crystals whose size ranges from 0.2 to 0.5 mm in the fine-grained rocks, and is rarely more than 5 mm in the coarse-grained rocks.

The crystals are slightly corroded, and have altered cores. Microcline (15 to 35 percent) occurs as anhedral grains measuring 0.2-0.5 mm in the fine-grained and greater than 2.00 mm in the coarse-grained granite. Quartz forms 30 to 40 percent of the rock, biotite 2 to 6 percent, and muscovite up to 1 percent in some specimens. One thin section contains amphibole. The most common accessories are zircon and apatite; sphene was noted in one rock, and opaque minerals are rare. The mass is an adamellite according to Joplin (1968), but a monzogranite in Streckeisen's (1967) classification. A pink fine-grained muscovite-rich granite is present in places, and contains 20 percent quartz, 50 percent microcline, and 20 percent albite in the size range 0.5-1.5 mm with the albite tending to be finer-grained. The rock contains about 10 percent of muscovite flakes up to 0.5 mm long and traces of zircon.

Minor masses of Naraku Granite

At least 15 bodies of intrusive granite ranging from 200 m to 3 km across have been mapped within the Corella Formation. These granites are typically fine-grained, porphyritic, and contain xenoliths of the intruded rocks. Two are leucocratic granites (the albitites of Joplin, 1955), located at latitude 20° 52'56"S, longitude 140° 24'48"E, and at latitude 20° 35'5"S, longitude 140° 3'40"E. The latter shows a variation in grainsize from a fine-grained leucocratic margin into a pink medium-grained core. Several of these granitic bodies have less quartz than the granites of Streckeisen, and are classified as fine-grained monzonites. The grainsize is in the range 0.3-1.0 mm, and the minerals present are quartz (10 to 15 percent), orthoclase (20 to 30 percent), albite-andesine (35 to 45 percent), muscovite (10 percent), rare opaque minerals, and traces of zircon. The texture is hypidiomorphic granular and slightly porphyritic.

A small intrusion within the Marimo Slate is geographically related to the other small pods in the surrounding Corella Formation; it is more basic than other Naraku Granite pods, and may represent a distinct type of granite or a heavily contaminated variety of Naraku Granite. It is located at latitude 20° 54'27"S, longitude 140° 26'35"E, and has metamorphosed the surrounding siltstone. The intrusive rock is pinkish-grey, slightly porphyritic, fine-grained to medium-grained, and contains phenocrysts of microcline (5 percent) up to 10 mm long and altered in patches, with inclusions of orthoclase, biotite, and opaque minerals. The groundmass consists of quartz (2 percent), microcline (5 percent), (?)orthoclase (16 percent), andesine (50 percent), biotite (15 percent), calcite (2 percent), pyrite (2 percent), chlorite (2 percent), scapolite (2 percent), and apatite (1 percent). The rock is severely altered, has no foliation, and may have been metasomatized. The biotite is randomly oriented, and it is suggested that the intrusion is post-metamorphism. The rock is an orthoclase diorite according to Joplin's (1968) classification, or a monzodiorite according to Streckeisen (1967).

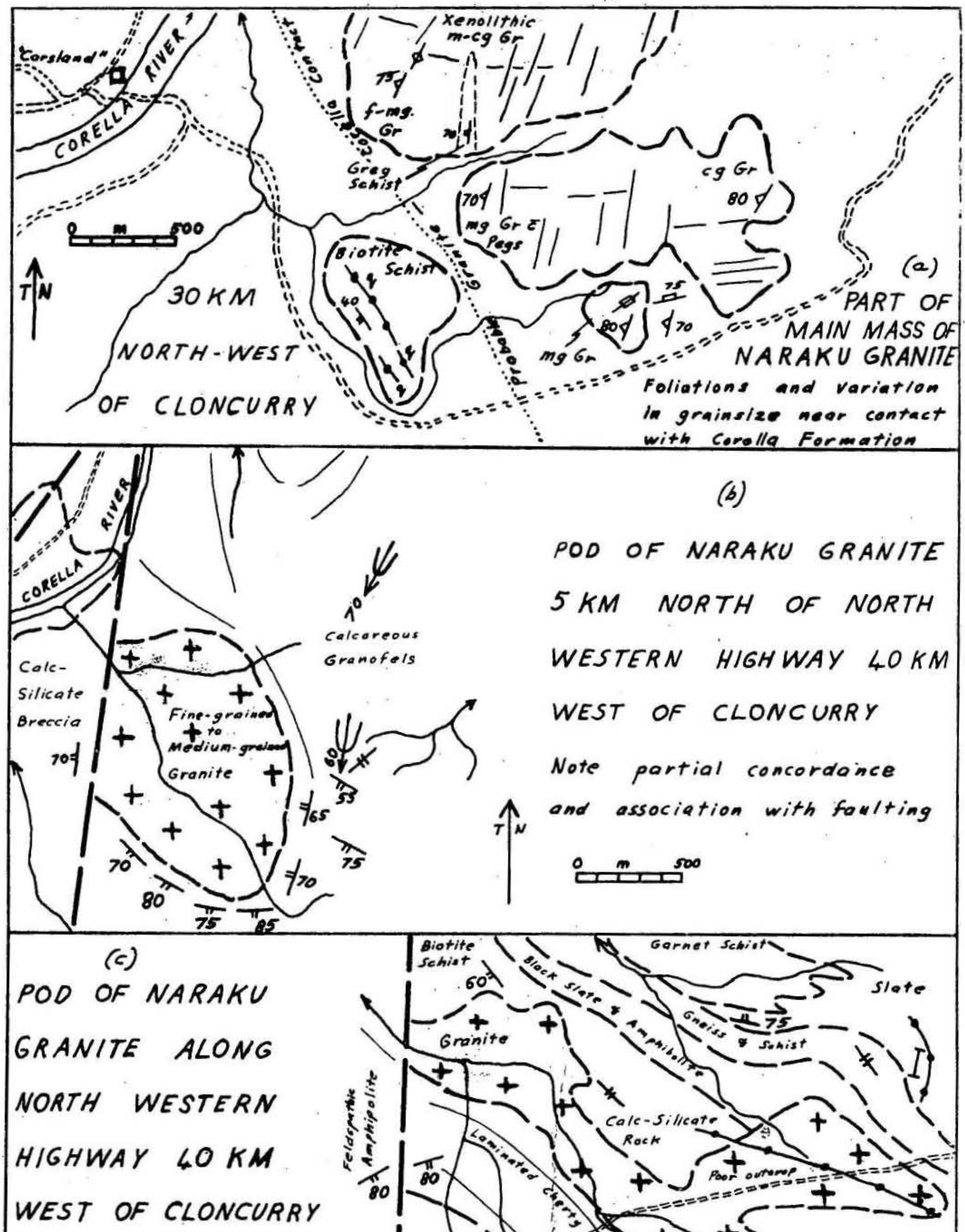



FIG. 77. Contact Relations and Grain Size Variation in Naraku Granite.

To accompany Record No 1971/56. F54/A2/51

TABLE 14. ESTIMATED MODAL COMPOSITIONS, "TOMMY CREEK MICROGRANITE"

| Mineral Number | Quartz | Orthoclase (+ Microcline) | Plag. | Chlorite | Biotite | Hornblende | Muscovite | Opaques | Accessories |
|---|---|---|---|---|---|---|---|---|---|
| 126* P | 60 | 21 | 12 $An_7$ | 4 | 2 | - | - | 1 | tr zr |
| 127 P | 60 | 24 | 10 $An_7$ | 4 | | - | tr | 2 | |
| 128 P | 55 | 28 | 9 $An_7$ | 4 | 2 | | 1 | | 1 zr |
| 130 P | 75 | 15 | - | 2 | | | 3 | 5 | |
| 134 P | 50 | 10 | 40 $An_{33}$ | | | | | | |
| 135 P | 45 | 20 | 26 | 5 | | | 2 | 2 | |
| 136 P | 45 | 16 | 30 | | | | | | 1 zr |
| 151 | 50 | 18 | 30 | tr | | | | 2 | tr sp, tr zr |
| 502 | 25 | 10 | 50 $An_{12}$ | - | 2 | 5 | 0.5 | 3 | 2 sp, 2 c, 0.5 ap |
| 504 | 20 | 25 | 45 $An_{12}$ | 0.2 | 4 | | 2 | 2.4 | 0.3c, 0.1 sp, 0.1 ap, 0.1 zr 0.5 fl |
| 505 | 15 | 40 | 25 $An_{10}$ | 3 | 1 | | 6 | 5 | 4 c, 0.5 sp, 0.2 ap, 0.2 zr, 0.1 fl |
| 507 | 20 | 25 | 45 $An_8$ | 5 | | 2 | | 0.2 | 2 c, 0.5 sp, 0.2 op, 0.1 zr, tr fl |
| 520 | 15 | 40 | 30 $An_{12}$ | | | 5 | 0.1 | 2 | 5 di, 0.5 c, 2 sp, 0.3 ap 0.2 ep |
| 603 | 40 | 30 | 28 $An_5$ | 1 | | | 0.5 | tr | tr op, tr zr, 0.3 fl |
| 609 | 34 | 35 | 30 | | | | | | 1 c |
| 611 | 30 | 50 | 20 | tr | | | | | tr c, tr zr |

ep = epidote; di = diopside; tr = trace amounts; sp = sphene; ap = apatite; zr = zircon; fl = fluorite; c = calcite

* BMR Registered Sample Number, i.e., 69200126 P = porphyritic texture

## 'Tommy Creek Microgranite' (New Name) $Bgu_h$.

### Introduction

This unit occurs as a series of concordant bodies cropping out between the Fox Mountain area to the east and the Corella River to the west, and between the old Mount Isa Cloncurry road and the Barkly or North Western Highway. These sills form prominent, well exposed ridges and rounded bouldery hills. Smaller pods and lenses occur to the south and southwest of the main outcrop which totals about 40 $km^2$. It is tentatively correlated with the Naraku Granite, and has been symbolized $Bgu_h$ ('h=hypabyssal') on the accompanying 1:50 000 maps.

### Stratigraphic Relationships

This unit everywhere intrudes the middle part ($Blc_2$) of the Corella Formation. Many of the sills are lenticular, and are grossly concordant with the metasediments. Some contacts are locally discordant.

### Field Occurrence

At least three separate lenses occur in the northern part of the outcrop area, and their apparent thickness ranges from 400 m to 1 km. The regional basin-and-dome structure and the lenticular nature of the sills has caused the apparent thickness variations. The pink micro-granite crops out as small tors and flattened, exfoliated boulders, up to 2 m across, and in hand specimen is pink to white, holocrystalline, and mostly even and fine-grained (average grain dimension 0.3 mm), although microporphyritic phases are common. Phenocrysts of quartz and feldspar (up to 5 mm) are set in a pink aphanitic quartzo-feldspathic groundmass (average grain dimension 0.2 mm) containing minor mafic minerals. In places the microgranite resembles a feldspathic quartzite, but sedimentary structures are lacking.

A very common feature is the poorly developed foliation which is mainly defined by the orientation of mafic minerals, and by lenticular streaking of fine-grained polygonal quartz grains on weathered surfaces. There is no obvious variation in grainsize, texture or composition in the intrusion except in the northern part of the area where there is a progressive increase in grainsize and proportion of phenocrysts in the higher sills. There, the lowest three sills are even grained, fine-grained microgranite, and the two granite porphyry lenses at higher levels are medium to coarse-grained.

### Contact Metamorphism

Calcsilicate granofelses adjacent to sills show minor contact metamorphic effects including patchy development of mafic minerals, especially actinolite, diopside, epidote, and biotite, which form small irregular aggregates and spots superimposed on the prominent foliation. Epidote especially is located along joints and fractures. At one contact near the Corella River (VC 201 189) long prismatic actinolite crystals (up to 5 cm long) form veins in the metasediments.

Quartzo-feldspathic pegmatite dykes and narrow pegmatoidal masses, produced by local anatexis, occur adjacent to some microgranite contacts. Elsewhere, minor mineral spotting in slate near contacts is due to andalusite (partly converted to kyanite).

Regional Metamorphism

The intrusive contains up to 10 percent of hornblende-chlorite-biotite assemblages, with rare diopside. These indicate low amphibolite-high greenschist facies regional metamorphism, similar to that affecting the calc-silicate granofels. Chlorite, calcite, and fluorite in the intrusive could indicate either retrograde metamorphism or late stage deuteric alteration. The foliation and mineral streaking suggest that regional metamorphism of the granite post-dated contact metamorphism in the intruded metasediments.

Petrography

Modal compositions are summarized in Table 14. The bulk of the intrusion consists of orthoclase, plagioclase, and quartz in nearly equal quantities (each 30 percent), although there is some variation. The texture is hypidiomorphic granular, and the rocks are even-grained to porphyritic. In the latter subhedral phenocrysts of feldspar and quartz up to 4 mm across are set in a fine-grained granular groundmass (average grain dimension 0.3 mm).

The primary mafic minerals are hornblende (Z = dark green) and brown biotite; chlorite showing anomalous interference colours replaces biotite as well as forming discrete subhedral flakes. Sphene (up to 2 percent), subhedral apatite, interstitial calcite, purple fluorite, and euhedral zircon are accessory minerals. Tourmaline and epidote are rarely present.

Orthoclase forms subhedral, equant phenocrysts (up to 4 mm) which are commonly rounded and show incipient alteration (clouding, faint hematite spotting, and very minor sericite development). Microcline is usually restricted to anhedral interstitial grains with little or no alteration. Plagioclase forms fresh anhedral grains (average grain dimension 0.3 mm) showing albite twinning; larger phenocrysts (average grain dimension 2 mm) show some alteration to sericite, and are mostly untwinned. Compositions range from $An_6$ to $An_{30}$, but most are albite.

Quartz phenocrysts (average grain dimension 1 mm) are composed of a granoblastic mosaic of finer grains; fine-grained lenticular aggregates of quartz also define a foliation. Muscovite forms primary subhedral inter-granular laths. Opaques (magnetite?) occur as minute black square and triangular grains, generally associated with mafic minerals and sphene aggregates, and some hematite occurs as fine dusty spots in altered feldspars. One section (69200620) contains 5 percent green pyroxene, probably diopside, which could be either primary or metamorphic in origin.

According to Streckeisen (1967) the rock is a micro-monzogranite, with about equal amounts of alkali feldspar and plagioclase, and abundant quartz.

Discussion

The complex, steeply dipping basin-and-dome geometry outlined by the microgranite sills suggests that intrusion of the microgranite occurred before cross-folding. It has probably been intruded as shallow-dipping tabular sheets originating from some deep seated source.

The high albite-microcline content and the leucocratic nature of the microgranite suggest it is a hypabyssal equivalent of the slightly less potassic Naraku Granite to the east. As the sills are affected by cross-folding, probably caused by the intrusion of the Naraku Granite, the hypabyssal 'Tommy Creek Microgranite' was possibly emplaced before the batholithic Naraku Granite.

## 'Burstall Granite' (Lgb)

### Introduction

The 'Burstall Granite' (new name) is named after Mount Burstall, one of the highest points in the Marraba Sheet area. This granite was originally part of the Wonga Granite of Carter et al., but has been separated from it because:

a) it intrudes the Corella Formation

b) it shows distinctive topographic expression, and

c) it is geographically well removed from the Wonga Granite.

It is similar compositionally to parts of the gneissose Wonga Granite, which intrudes only acid volcanics of the Argylla Formation.

### Stratigraphic Relationships

The 'Burstall Granite' intrudes the Corella Formation, older doleritic masses ($do_3$), and the 'Lunch Creek Gabbro' (Fig. 78) and is intruded only by young dolerite ($do_6$ - the 'Lakeview Dolerite' dyke) and aplite. Along the eastern contacts of the granite with the Lunch Creek Gabbro agmatite or xenolith-rich zones are well exposed (Fig. 79); about 2 km northwest of the Lady Vera mine xenoliths of laminated calc-silicate granofels are common (Fig. 80).

### Field Occurrences

The main masses of 'Burstall Granite' occur in a belt which extends northwards from Mount Burstall, immediately east of the Mary Kathleen syncline; and near Mount Godkin, in the northwest corner of the Marraba Sheet area.

#### a) 'Burstall Granite, Mary Kathleen area

This mass is an elongate pluton intrusive into laminated feldspathic granofels. The western margin of the granite forms a rugged bouldery plateau; towards the east the outcrop is less rugged because of abundant aplite and microgranite dykes and shear zones. The granite is fairly homogeneous, leucocratic, coarse, even-grained to porphyritic, and massive to only slightly foliated. It is pale pink to grey, with alkali feldspar and quartz prominent. Hornblende, chlorite and biotite are the only mafic minerals evident macroscopically, and purple fluorite is visible in many hand specimens. Rare xenoliths of fine-grained granite occur near Mount Linsay.

Near the contact with the 'Lunch Creek Gabbro', 5 km east of the Mary Kathleen open cut, local contamination of granite by gabbro has produced zones of inhomogeneous tonalite and diorite.

?Subeconomic masses of fluorite have been located in three places 1 to 2 km northeast of Mount Colin. They form veins and pods up to 10 m thick associated with aplite-quartz bodies in a broad shear zone, and are described in detail in the Economic Geology section.

Contacts with country rock are knife-sharp; the granite shows a narrow aplitic margin up to 10 m wide in some areas, but remains coarse-grained to the contact in many places. Tourmaline, garnet and fluorite occur sporadically in the contact zone. About 4 km northeast of the Mary Kathleen open cut, the granite shows jointing subparallel to bedding of the adjacent sediments; 3 km east of the open cut, metasediments are slightly upturned and locally brecciated for 2 m from the contact. Transposition of bedding is evident near the granite contact about 1 km northeast of Mount Linsay mine, and also 0.5 km east of Mount Colin mine, producing vermicular textures in the metasediment (Fig. 81).

b) 'Burstall Granite', Mount Godkin area

The granite body occupies a high dissected plateau, and is well exposed. Contacts are sharp, and some granite veins occur within the para-amphibolitic country rocks. Microgranite is common as a marginal phase and also as small satellite intrusions which are slightly more basic (e.g., microgranodiorite). The main mass is a massive fine-grained to medium-grained granite containing a number of pods of fine-grained leucocratic granite. On the eastern flank of the intrusion there is a sheared feldspar-porphyritic rhyolite. It is most probably intrusive, as its outcrop is discordant, and xenoliths occur in some exposures. Figure 82 shows the detailed geology of the Mount Godkin area.

Petrography

a) Mary Kathleen area

Estimated modal compositions of granites and dyke rocks are listed in Table 15. The granitic rocks include granite, alkali granite, and quartz-bearing syenite (Streckeisen, 1967). Textures are hypidiomorphic granular; alkali feldspar is perthitic microcline, and occurs as 1 cm phenocrysts, and granular aggregates with quartz and plagioclase in the groundmass. Plagioclase is highly sericitized in most cases, and only the sodic rims remain unaltered. Plagioclase lamellae in perthite in specimen 257 are $An_{3-5}$.

Amphibole, actinolite and chlorite are the chief mafic minerals; the amphibole shows Z = very deep blue-green, and is possibly a ferro-hastingsite. Biotite is partly altered to chlorite, and contains lenticles of fluorite along cleavage planes in specimen 258. Sphene is a very abundant accessory (up to 2 percent), and zircon (up to 1.5 mm long) and apatite are widespread.

TABLE 15. Estimated Modal Compositions, "Burstall Granite", Mary Kathleen area

| Mineral | GRANITES | | | | | | | | DYKE ROCKS | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BMR Rock No. | 214 | 244 | 256 | 257 | 258 | 266 | 268 | | 218 | 220 | 229 | 255 | 5675* |
| Quartz | 45 | 30 | 40 | 27 | 15 | 24 | 24 | 20 | 30 | 25 | 10p<br>25m | 30p<br>30m | 5 |
| Plagioclase | 40 | 10 | 8 | 1 | 15 | | 1 | 16 | 30 | 25 | 5p<br>10m | | 90 |
| Plagioclase comp'n | $An_{26}$ | | | | | | | $An_{35}$ | | $An_{10}$ | $An_5$ | | $An_{35}$ |
| K-feldspar | | 30p<br>25m | 50 | 70 | 65 | 73 | 70 | 53 | 30 | 50 | 10p<br>25m | 10p<br>40m | |
| Hornblende | 3 | 2 | 2 | 1 | 1 | | 1 | 5 | 1 | | 8 | | |
| Biotite | 10 | | | | 4 | | 3 | 3 | | | | | |
| Sphene | | | | | | | | | | | | | |
| Epidote | | 0.5 | | | | 1.5 | | | | | 5 | | |
| Iron Ore | | | | | | | | 1 | tr | | | | |
| Diopside | | 0.5 | | | | | | | | | | | |
| Chlorite | | 1 | | tr | | .5 | | | 8 | | | | |
| Sphene | 1 | 1 | | 1 | | 1 | 1 | 2 | | - | 2 | | |
| Accessories | 0.5zr<br>ap<br>to,ep | ap<br>op<br>zr<br>al | ep<br>zr<br>sp | ep<br>sp<br>zr | f<br>sp<br>zr<br>ap | f<br>zr | zr<br>op | ap | 1<br>sp<br>zr<br>ap<br>ep | sp<br>zr<br>ep | zr<br>al<br>ap | g | r<br>5zr<br>to |

sp = sphene    to = tourmaline    p = phenocrysts

zr = zircon    op = opaques    m = matrix

ap = apatite    f = fluorite

ep = epidote    g = garnet

al = allanite    r = rutile

214 Quartz diorite or tonalite
244 Granite
256 Quartz-rich porphyritic granite
257 Alkali granite
258 Quartz-bearing syenite
266 Alkali microgranite
268 Alkali granite

218 Granite
220 Granite
229 Porphyritic microgranite
255 " "

( after Streckeisen, 1967)

* G.S.Q. Slide No.

Fig. 78 'Burstall Granite' intruding 'Lunch Creek Gabbro', 5km east-northeast of Mary Kathleen open cut GA2979 IHW

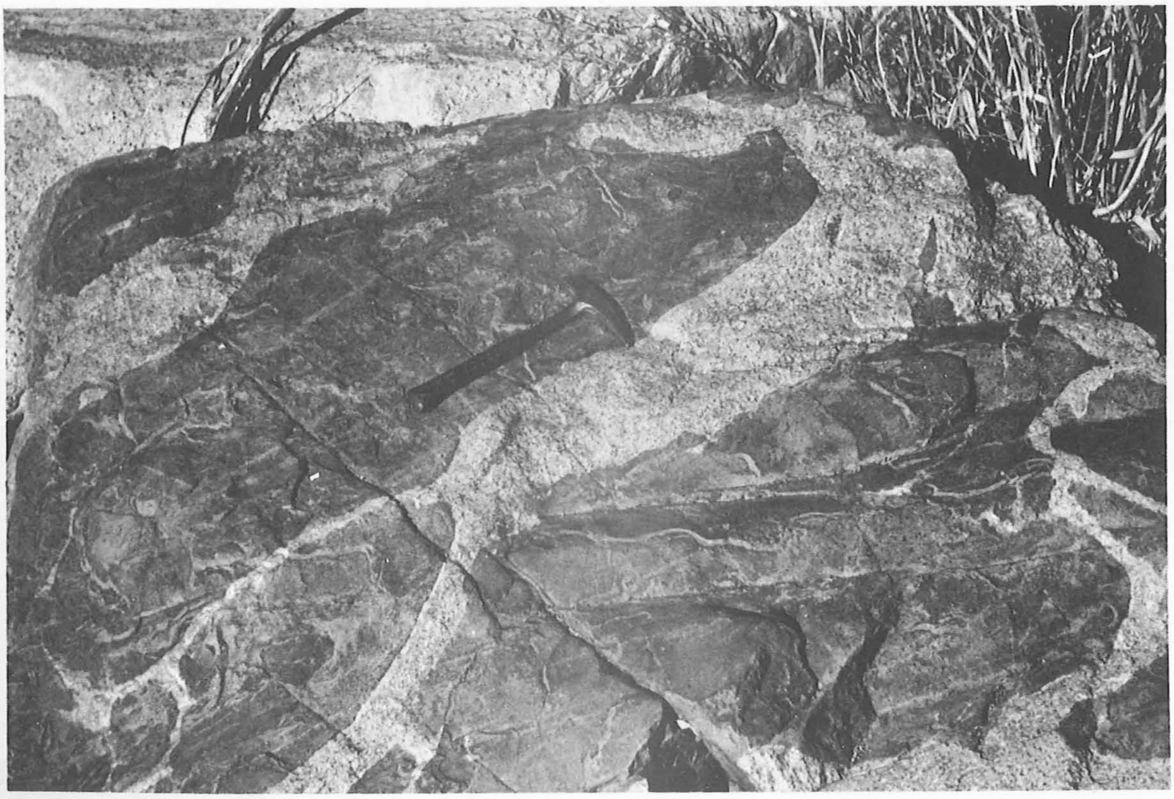


Fig. 79 Agmatitic net-veining of 'Lunch Creek Gabbro' by 'Burstall Granite', 5 km east of Mary Kathleen open cut

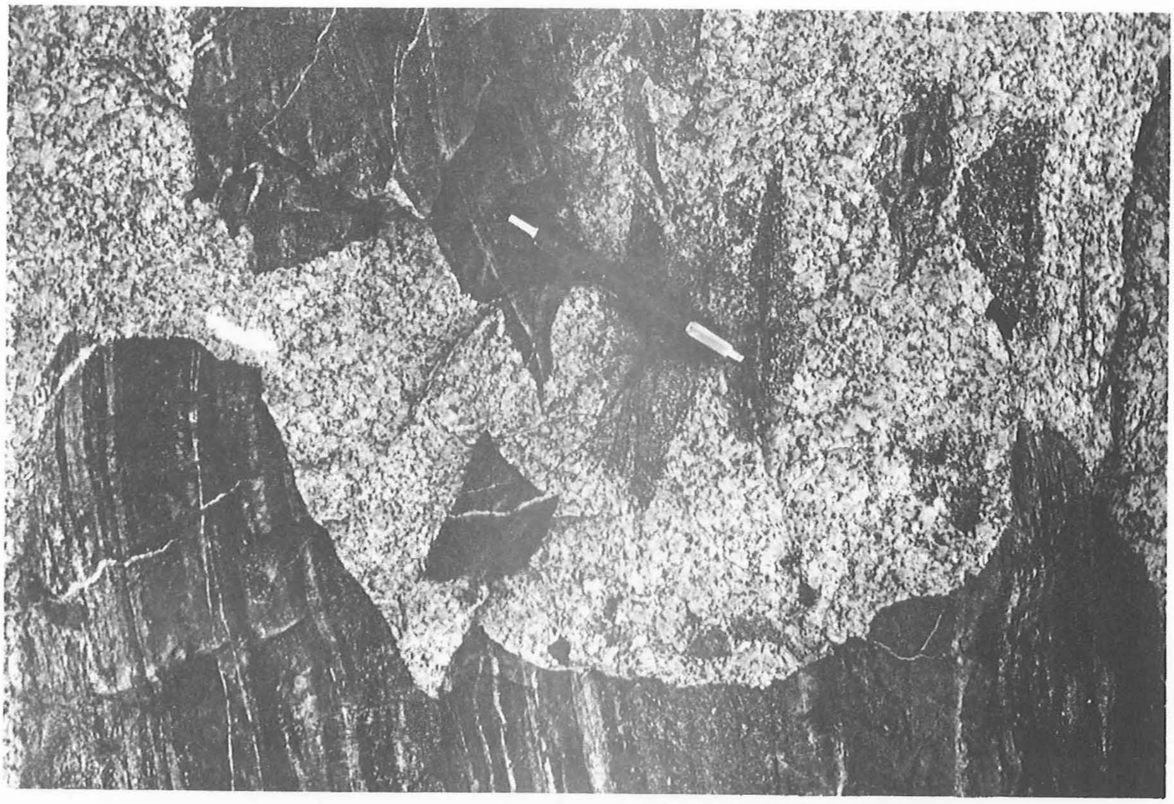
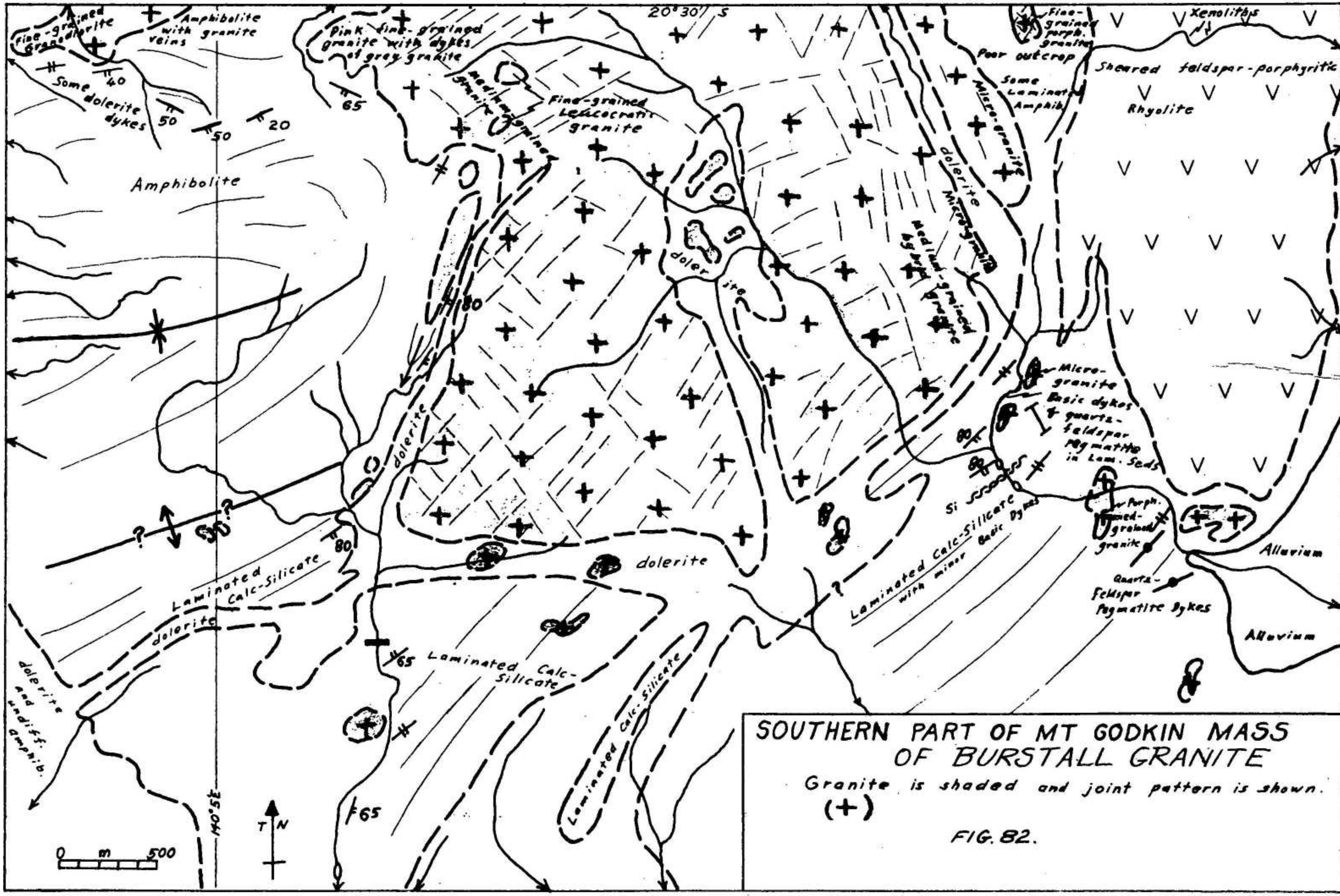


Fig. 80 'Burstall Granite' cutting laminated calc-silicate granofels, 2 km northwest of Lady Vera mine GA2775 GMD

Fig. 81 Vermiform texture in calc-silicate granofels of Corella Formation, resulting from recrystallization of transposed bedding. Actual bedding trends at right angles to hammer handle. The texture is developed at contacts between the Corella Formation and the 'Burstall Granite', 0.5 km east of Mount Colin Mine. M1250/3 GMD




## SOUTHERN PART OF MT GODKIN MASS OF BURSTALL GRANITE

Granite is shaded and joint pattern is shown. (+)

FIG. 82.

To accompany Record No 1971/56.

F54/A2/52

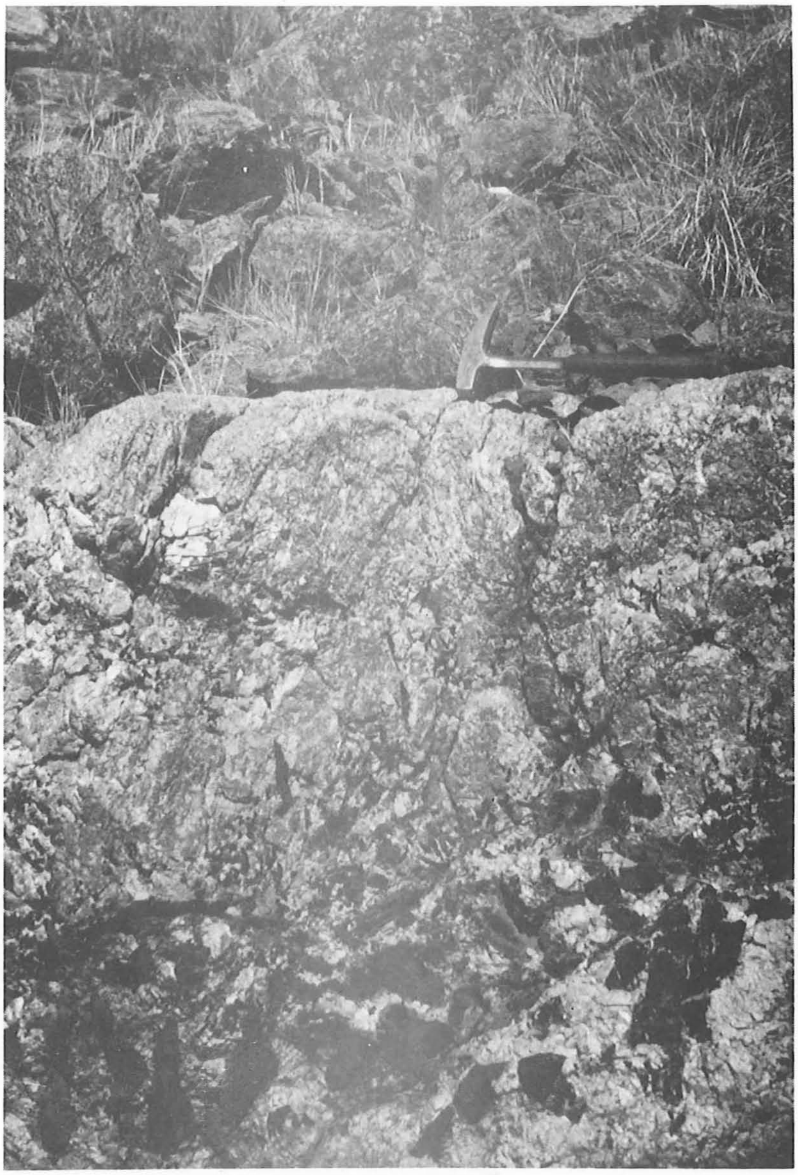


Fig. 83 Shallow dipping sill of tourmaline pegmatite cutting calc-silicate granofels of Corella Formation, 1 km southeast of Lime Creek mine GA2701 GMD

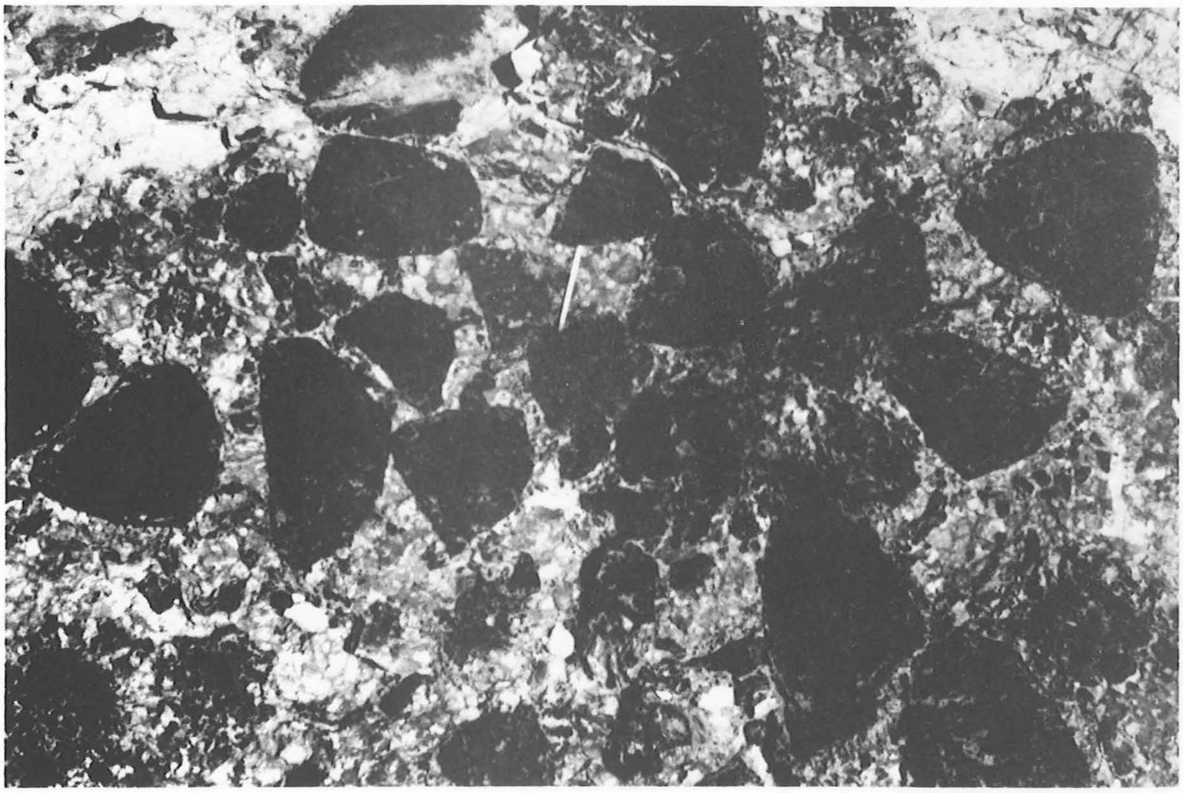


Fig. 84 Detail of tourmaline crystals in pegmatite GA2705 GMD

b) Mount Godkin area

The main intrusion consists of a pink, even-grained to slightly porphyritic, fine-grained granite containing up to 10 percent perthitic microcline phenocrysts 1.0-5.0 mm in length. The groundmass contains 20 to 30 percent quartz, 20 to 30 percent microcline, 40 to 50 percent albite, and traces of biotite, zircon, and opaques. The texture is allotriomorphic granular; irregular grain boundaries are suggestive of some recrystallization.

The microgranites are more variable in composition, ranging from microgranodiorite to microsyenite. Some are extremely porphyritic, with microcline perthite phenocrysts up to 10 mm long. Quartz makes up 15 to 20 percent of the rock, resulting in some specimens being classified as syenites according to Streckeisen (1967) whereas they are granites according to Joplin (1968). The microgranodiorite contains up to 75 percent subhedral poikilitic andesine crystals from 0.2 to 2 mm long. The rock contains about 5 percent calcite, 2 percent hornblende, and 1 percent angular opaques. The accessories include zircon, sphene, and monazite. The texture is subeven-grained, fine-grained allotriomorphic granular, and there is evidence of slight recrystallization.

One specimen of porphyritic microgranite from the western edge of the intrusion contains 5 percent subhedral microcline-perthite phenocrysts 1 to 8 mm long, 5 percent coarser quartz crystals 1 to 5 mm across, and about 1 percent chloritized amphibole set in a groundmass of fine granular cystals of quartz (15 percent), microcline (55 percent), albite (15 percent), and about 1 percent each of biotite, opaques, and sphene. Trace amounts of zircon about 0.03 to 0.1 mm were noted.

The syenite found on the northwestern edge of the intrusion is a dark pink, even-grained (0.3 to 0.6 mm) allotrimorphic granular rock with rare microcline perthite phenocrysts up to 4 mm. The rock is composed of 15 percent quartz, 70 to 80 percent microcline, 5 percent albite, 2 percent opaque minerals, about 1 percent biotite, and traces of very fine-grained zircon. Much of the feldspar has been kaolinized. Micrographic texture is irregularly developed. Irregular grain boundaries and fracturing of some grains indicate some recrystallization and shearing.

The pink to pale brown fine-grained porphyritic sheared rock that crops out along the eastern flank of the intrusion contains 10 to 20 percent quartz with slightly sutured boundaries, 30 to 40 percent microcline, 50 to 60 percent labradorite, about 3 percent chloritized amphibole, 1 percent opaques, and almost 1 percent zircon. The texture is allotriomorphic granular, though some microcline crystals are subhedral. A few crystals have been fractured by shearing, and there is a poorly defined foliation. Slight recrystallization has occurred. Dark elongate bodies up to 20 mm long in the central western part of the exposure may represent either xenoliths or pumice fragments. Contacts were not observed, and the origin of the rock type and its relation to the Mount Godkin Granite is in doubt.

Minor and Late Stage Variants of the 'Burstall Granite'

a) Pegmatite veins and sheets

Pegmatite dyke swarms occur in psammitic schist ($Blc_2$) in the Wonder Valley mine area. They are labelled "qf" (quartz-feldspar) and peg. (pegmatite) on the accompanying maps. Most are 1 to 10 m wide, and show a coarse graphic texture. One specimen (5675) consists of andesine (90 percent), quartz (5 percent), abundant rutile (2 percent), zircon (1 percent), and tourmaline (2 percent).

Sheets of coarse-grained graphic tourmaline pegmatite ($Bgb_p$) crop out about 1 km southeast of the Lime Creek mine (Fig. 83). Tourmaline crystals up to 18 cm in diameter, and rare, small biotite-pyrite veins with malachite are present. The largest sheet is about 80 m thick, dips shallowly to the west, and intrudes steep-dipping calc-silicate granofels.

b) Aplite and porphyritic microgranite

Dykes of very fine-grained microgranite ($Bgb_h$) extend from the 'Burstall Granite' westwards to the open cut at Mary Kathleen. These dykes are white to pale pink, aphanitic, and locally garnetiferous. Phenocrysts of quartz and alkali feldspar are common (average grain dimension 1 mm) in a quartzofeldspathic matrix. Some parts of the dykes show replacement by albitite masses.

Dykes of fine to medium-grained porphyritic aplite are common near the Mount Linsay and Mount Colin mines; phenocrysts of alkali feldspar to 1.5 cm across are abundant. Similar dykes also intrude the 'Lunch Creek Gabbro'.

Origin of the 'Burstall Granite'

The 'Burstall Granite' appears to be an epizonal or mesozonal magmatic granite; it is intrusive, but has been emplaced in the Corella Formation by pushing aside, doming, and accommodation of the latter rather than by large-scale stoping and assimilation. The relation of the granite intrusion to other tectonic events is treated elsewhere; however, in the Mary Kathleen area the narrow contact aureole of the 'Burstall Granite' is superimposed on regionally metamorphosed rocks. It also intrudes the 'Lunch Creek Gabbro', a mass which itself probably post-dates the major regional metamorphism. Thus the intrusion of the 'Burstall Granite' and its associated dykes and veins appears to be a relatively "young" event; These rocks probably belong to the Group 4 granites of Carter et al. (1961).

The volatile content of the granite appears to have been high, as evidenced by, for example, late stage dykes with albitite patches, the presence of fluorite masses, tourmaline pegmatite, and probably the rare earth-uranium mineralization at Mary Kathleen.

Wonga Granite (Bgw)

Field Occurrence

This granite crops out as an elongated north-trending belt along the western border of the Sheet area; it is intimately associated with a unit of severely sheared acid volcanics. It consists of two phases; a

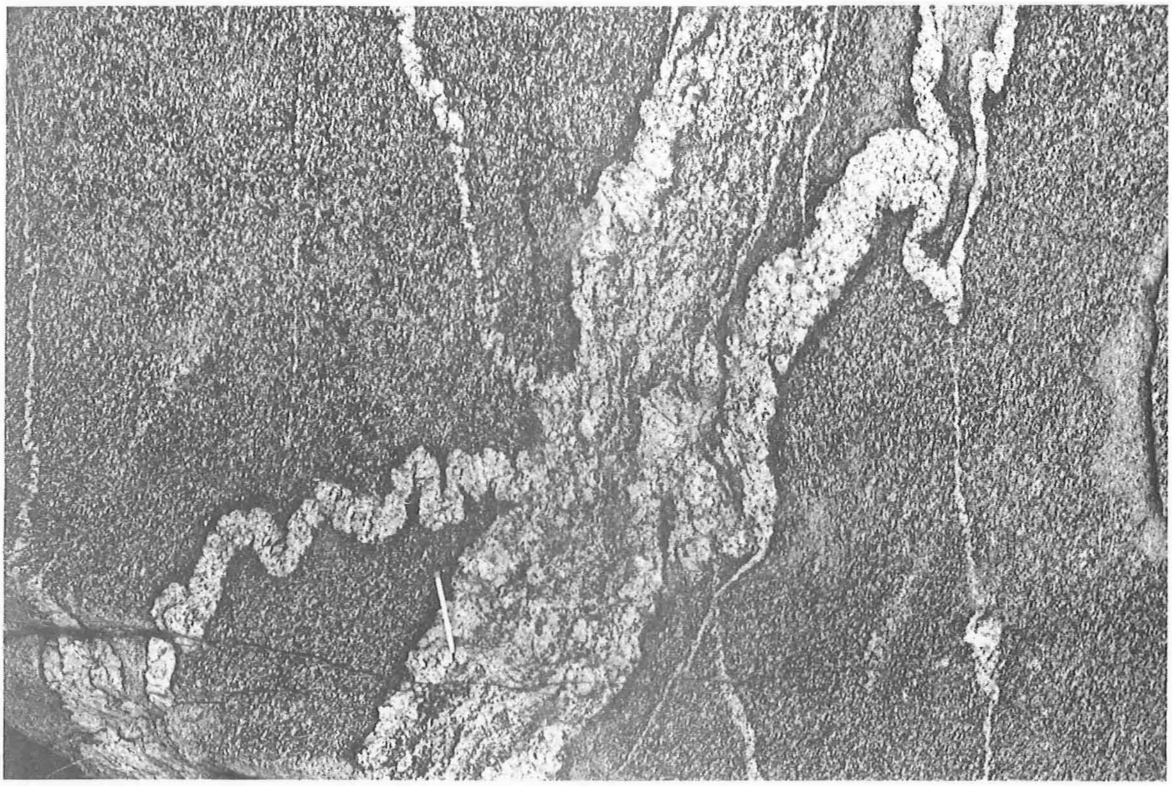


Fig. 85 Ptygmatic veins of leucogranite cutting fine to medium grained gneissose granite, 3 km south-southwest of Lime Creek mine M1166/2f GMD

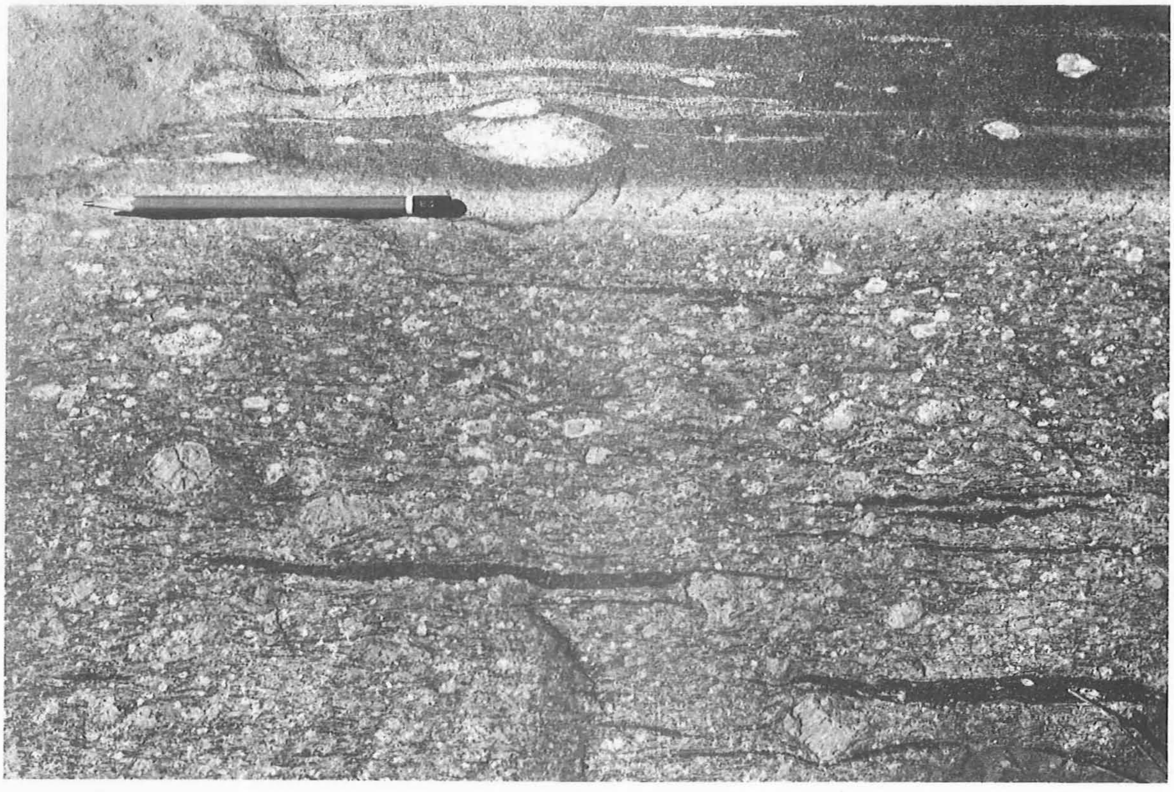


Fig. 86 Foliated coarse-grained porphyritic granite (Wonga Granite) and flattened basic xenoliths, in contact with meta-acid volcanics of Argylla Formation; 3 km south-southwest of Lime Creek mine M1166/2c GMD

porphyritic (or porphyroblastic) medium to very coarse-grained granite and a fine-grained to aplitic granite which intrudes the porphyritic phase. Lenses of sheared amphibolite occur within the granite, and reaction rims are present locally. Several large scale north-northeast-trending faults cut the granite, and they are occupied in places by large aplite dykes. Carter et al. (1961) note that these faults have brecciated the coarser grained granite, and therefore post-date the solidification of the older phase.

The medium-grained porphyritic granite forms low, poortly outcropping tors within a broad belt of sandy alluvium, north of the Mary Kathleen mine. It is strongly foliated, and is cut by coarse-grained pegmatite and leucocratic granite veins (Fig. 85). It intrudes garnetiferous amphibolite, biotite schist, and augen gneiss, and probably meta-acid volcanics. The foliated granite shows a fine aplitic selvedge, and numerous flattened basic xenoliths (Fig. 86).

The fine-grained phase is a pale pinkish grey, foliated even-grained allotriomorphic granular granite. The grains are from 0.2 to 1.00 mm in diameter. Quartz comprises about 55 percent of the rock, sericitized potassium feldspar about 40 percent, biotite, muscovite, hornblende, and chlorite, 1 or 2 percent each and sphene and zircon trace amounts. The mafic minerals are well aligned, and are concentrated along thin bands. Quartz veinlets up to 2 mm wide are common.

### Origin of the Wonga Granite

The origin of the Wonga Granite has been the subject of much debate. Although only a small part of it occurs in the Marraba Sheet area, Carter et al. (1961) thought it could have originated by potassium metasomatism of Corella Formation, but this is considered unlikely since the relict "bedding" that previous workers (Carter et al., 1961) have noted probably represents stratification in the acid volcanics which have sharp or sheared contacts with the granite. Melting or partial melting of the acid volcanics and at least some movement of magma is suggested as the mode of origin of the Wonga Granite. The acid volcanics may in fact be part of the Argylla Formation.

## METAMORPHISM

### Metamorphic Facies

Three facies have been delineated in the Sheet area. They are greenschist, amphibolite, and hornblende-hornfels facies, and their distribution is shown in Figure 87.

#### (A) Greenschist Facies

Greenschist facies rocks are widely distributed, and cover all but a quarter of the western part of the Sheet area. Isolated pods of higher grade rocks occur in the Slaty Creek area, east of the Corella River in the centre of the Sheet area, and in the core of the Duck Creek anticline. A tentative subdivision of the greenschist facies has been made, into a lower and upper part.

In the lower greenschist facies typical assemblages are as follows:

| | |
|---|---|
| in pelitic rocks: | quartz-biotite-muscovite-chlorite<br>quartz-muscovite-biotite |
| in calcareous pelites: | quartz-chlorite-calcite<br>albite-chlorite-biotite-calcite<br>quartz-biotite-muscovite-calcite<br>quartz-muscovite-biotite-chlorite-calcite<br>quartz-scapolite-biotite<br>quartz-oligoclase-calcite-biotite-scapolite<br>chlorite-muscovite-sphene-calcite |
| in basic rocks: | oligoclase-biotite-chlorite-calcite<br>oligoclase-actinolite-biotite-chlorite<br>albite-chlorite-biotite<br>chlorite-biotite-sphene<br>albite-biotite-calcite-epidote |

The upper greenschist facies is characterized by the appearance of garnet in basic igneous rocks (metadolerites, basic tuffs, etc.), together with tremolite/actinolite; biotite remains an abundant constituent.

Deep green amphibole could be hornblende, indicating a transition to the amphibolite facies, although tremolite and hornblende are stable in the low pressure (Abukuma) greenschist facies. Typical assemblages are as follows:

| | |
|---|---|
| in basic rocks: | hornblende-biotite-oligoclase-garnet<br>garnet-oligoclase-biotite<br>garnet-hornblende-calcite<br>albite-tremolite-calcite<br>hornblende-biotite-epidote<br>oligoclase-biotite-hornblende-sphene<br>albite-hornblende-biotite |
| in pelites: | garnet-muscovite-quartz |
| in calcareous pelites and calcareous psammites: | garnet-muscovite-quartz<br>garnet-tremolite-biotite-calcite<br>oligoclase-garnet-scapolite-biotite<br>hornblende-scapolite-calcite<br>hornblende-biotite-sphene-actinolite<br>tremolite-epidote-garnet-calcite |

(B) Amphibolite Facies

Amphibolite facies rocks occur in the western part of the Sheet area, and in a small area near the centre of the Duck Creek Anticline. There appears to be a reasonable correlation of the higher grade rocks with intrusive igneous bodies. The term 'amphibolite facies' is used in the sense of Turner (1968) and others in preference to the term 'almandine amphibolite facies'.

On the accompanying facies map (Fig. 87), the greenschist-amphibolite facies boundary is defined by the presence or absence of diopside in calc-silicate granofels, according to the reaction

$$3 \text{ calcite} + 1 \text{ tremolite} + 2 \text{ quartz} \rightarrow 5 \text{ diopside} + 3CO_2 + 1H_2O$$

In rocks of suitable composition, staurolite, kyanite, sillimanite, cordierite, and anthophyllite have also been used to delineate the facies boundary. In general the amphibolite facies assemblages are typical of relatively low to moderate pressure regional metamorphism (Abukuma-type), and in the vicinity of Mary Kathleen appear transitional into hornblende hornfels assemblages. Some typical assemblages are as follows:

| | |
|---|---|
| in calcareous rocks: | scapolite-actinolite-diopside-sphene<br>diopside-tremolite-calcite<br>actinolite-diopside-scapolite-biotite<br>diopside-calcite-scapolite-hornblende<br>scapolite-hornblende-epidote-calcite |
| in calcareous psammites: | diopside-scapolite-garnet-calcite<br>scapolite-diopside-tremolite-epidote |
| in impure limestones: | tremolite-biotite-diopside-andesine-calcite<br>vesuvianite-garnet-diopside |

The last assemblage occurs 1 km east of the Jubilee mine; it is one assemblage which marks the base of the amphibolite facies according to Winkler (1967). Diopside and grossular may have formed according to the following equations which describe possible reactions at the greenschist-amphibolite facies boundary:

$$5 \text{ vesuvianite} + 4 \text{ epidote} + 11 \text{ quartz} \rightarrow 16 \text{ grossular} + 10 \text{ diopside} + 12\ H_2O$$

and

$$3 \text{ vesuvianite} + 2 \text{ tremolite} + \text{quartz} \rightarrow 16 \text{ diopside} + 6 \text{ grossular} + 8\ H_2O$$

Winkler notes that any vesuvianite remaining in excess after these reactions will co-exist with minerals on the right-hand side of the equations.

Staurolite occurs in siliceous agglomerate with pelitic bands, near Butcher Bore. The assemblage is staurolite-garnet-biotite-chlorite, and could have resulted from the following reaction (Winkler, 1967, p. 107):

$$\text{Iron-rich chlorite} + \text{muscovite} \rightarrow \text{staurolite} + \text{biotite} + \text{almandine} + H_2O$$

Kyanite occurs in slate just north of the staurolite locality, and could indicate a change from the staurolite-almandine subfacies to the kyanite-almandine-muscovite subfacies.

In basic rocks, typical assemblages are:

hornblende-diopside-scapolite-sphene
hornblende-diopside-andesine-sphene

The assemblages clinopyroxene-labradorite-ilmenite and clinopyroxene-orthopyroxene-hornblende-labradorite are typical of metastable amphibolite facies and post-metamorphic assemblages, respectively. The former occurs in the Duck Creek Anticline, the latter in dykes cutting the 'Burstall Granite'.

Sillimanite occurs in biotite schist south of Mary Kathleen. The most common assemblage is sillimanite-muscovite-biotite-quartz-iron ore, in which sillimanite has formed within muscovite aggregates. This could represent the highest grade facies in the Barrovian amphibolite facies (sillimanite-almandine-orthoclase sub-facies), or alternatively, the hornblende hornfels facies of low-pressure metamorphism, in which sillimanite forms in place of andalusite because of local temperature rises.

(C) <u>Hornblende/hornfels facies</u>

Apart from the example of sillimanite noted above, only two other assemblages can be positively assigned to this facies. The first is cordierite-anthophyllite-biotite-iron ore-quartz in schist adjacent to the 'Lunch Creek Gabbro', east of Mary Kathleen. It could reflect metamorphism of suitably magnesian pelites by either the 'Lunch Creek Gabbro' or 'Burstall Granite', probably the latter.

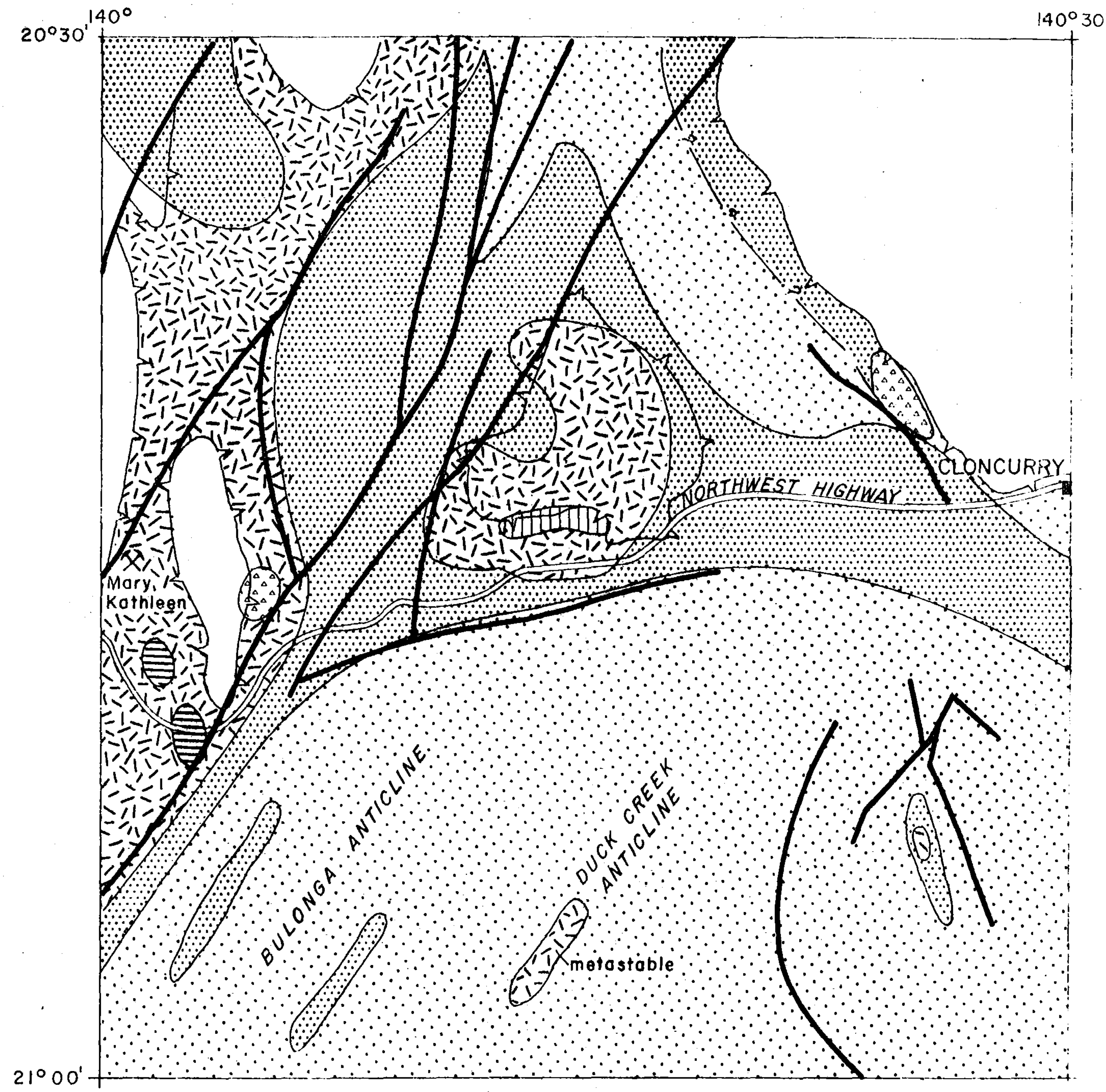
The second occurrence is a garnet-diopside skarn 3 km east and northeast of Chumvale homestead, which indicates contact metamorphism of calcsilicate granofels by the nearby Naraku Granite.

## Evidence for Polymetamorphism

In the Mary Kathleen area regionally metamorphosed rocks have been subjected to at least two periods of contact metamorphism, due to intrusion of the 'Lunch Creek Gabbro' and 'Burstall Granite', respectively. The occurrence of cordierite-anthophyllite rocks is an example of at least one of these phases of contact metamorphism.

A dolerite sill immediately north of the open cut at Mary Kathleen shows the following sequence of crystallization: primary diopside-hornblende-secondary granoblastic diopside. The development of hornblende rims around primary diopside possibly results from an initially hydrous regional metamorphism in the amphibolite facies, or from late-magmatic deuteric activity. The secondary diopside is more strongly coloured than the primary, and generally is mutually exclusive of hornblende. This suggests that the secondary diopside is a product of recrystallization of both the primary

FIG 87 METAMORPHIC FACIES MAP, MARRABA 1:100 000 SHEET AREA




Scale 1:312 000 approx.

*Lower greenschist:*
*biotite, chlorite, muscovite*

*Upper greenschist:*
*actinolite, tremolite, biotite, garnet*

*Hornblende-hornfels:*
*cordierite, anthophyllite, biotite, garnet, diopside, skarn*

*Amphibolite.*
*sillimanite, muscovite, biotite*

*Amphibolite:*
*kyanite*

*Amphibolite: diopside, tremolite, hornblende, calcite, staurolite, vesuvianit*

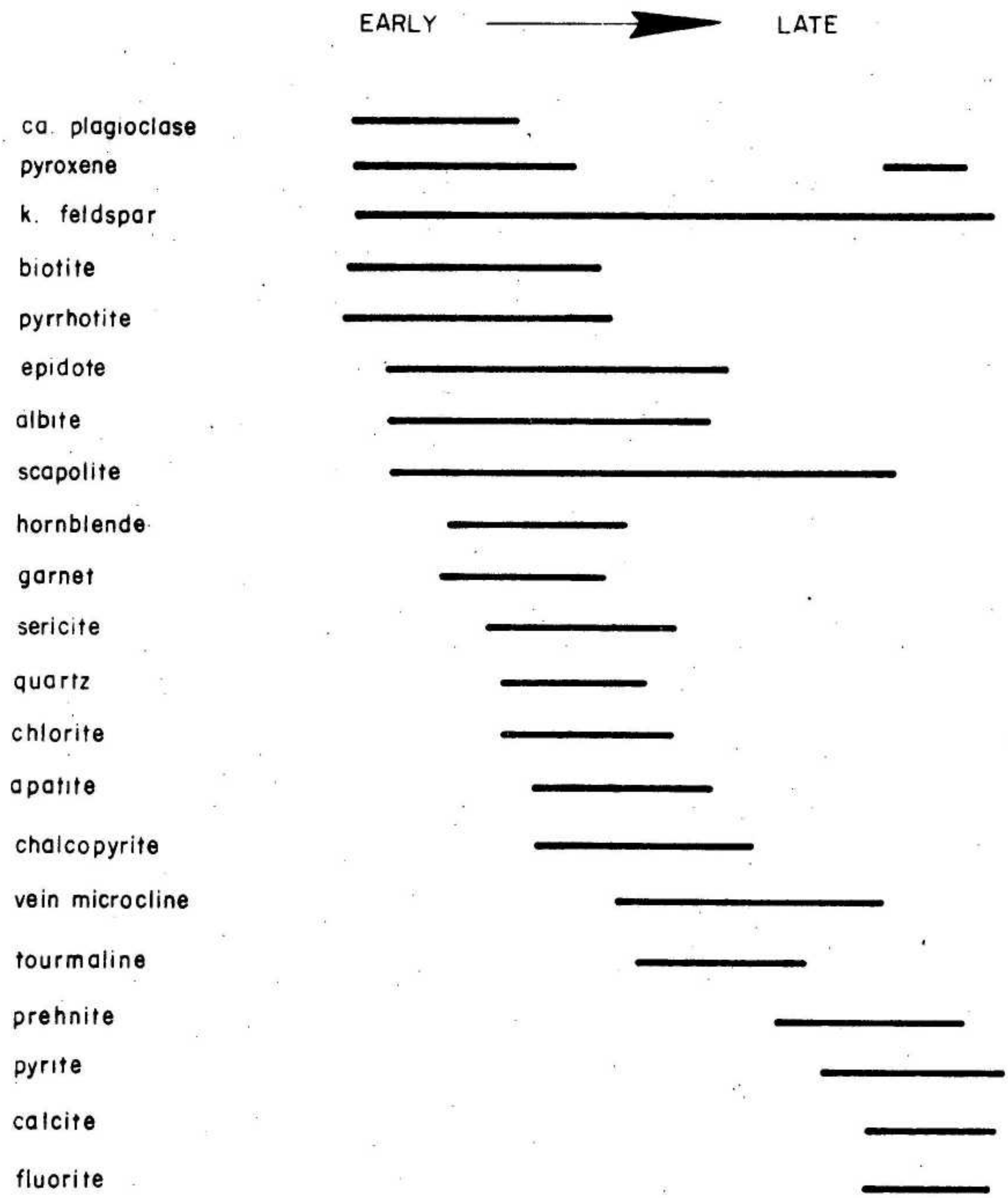
*Intrusive, igneous rocks*

*Metamorphic facies boundary*

*Major fault*

FIG. 88

Paragenetic sequence of crystallisation of rock-forming and pegmatite minerals at Mary Kathleen



diopside and secondary hornblende, due to a second phase of moderately high-grade metamorphism most probably produced by intrusion of the 'Burstall Granite'.

In the basic tuffs and pelites, two to three kilometres west and northwest of Butcher Bore, textural relationships between matrix foliation and porphyroblasts indicate polymetamorphism. Here, primary plagioclase phenocrysts, moderately altered and subhedral to anhedral, composition $An_{20}$, deform the matrix foliation, i.e., they have undergone rotation and deformation during metamorphism, and are consequently pre-tectonic, (Spry, 1963).

Large garnet porphyroblasts occur in the basic tuff. A minority of garnets are wrapped around by the matrix foliation, and, like plagioclase, are probably pre-tectonic, produced by the first phase regional metamorphism.

A majority of garnets, however, show internal foliation continuous with matrix foliation, and thus are probably syn or post-tectonic; as both pre and post-tectonic garnets occur in close proximity, it is likely that they represent two periods of metamorphism, the second being a predominantly thermal, non-stress event. In the Butcher Bore area, this event is probably related to the intrusion of sills of 'Tommy Creek Microgranite'.

In the same area the pseudomorphous replacement of andalusite by kyanite in black slate is also indicative of polymetamorphism. A pelitic garnet schist from just south of the kyanite locality shows garnet porphyroblasts with helical internal structure, typical of pre to syn-tectonic growth. Muscovite flakes define an old schistosity nearly parallel to bedding, and a second crenulation cleavage probably related to the second, predominantly thermal metamorphic event noted above.

A paragenetic sequence of crystallization has been established for rock-forming minerals in the vicinity of Mary Kathleen, using replacement criteria established from thin sections (Fig. 88).

## Conditions of Metamorphism

In areas containing abundant carbonate sequences the values of $P_{CO_2}$ relative to $P_{H_2O}$ assume some importance in various metamorphic reactions. In the reaction

$$1 \text{ tremolite} + 3 \text{ calcite} + 2 \text{ quartz} \longrightarrow 5 \text{ diopside} + 3\,CO_2 + H_2O,$$

a high value of $P_{CO_2}$ will inhibit diopside development. However, as diopside is widespread in the area, and as $P_{CO_2}$ is probably initially high because of the calcareous nature of the original sediments, it can be assumed that $P_{CO_2}$ was lowered during regional metamorphism by extensive outwards diffusion of $CO_2$. Similarly, extensive migration of $CO_2$ could be expected in the development of diopside-scapolite assemblages, which involve decarbonatization (White, 1959). This postulated regional diffusion of $CO_2$ could be a major factor in the development of secondary calcite veins, dykes, and lenses throughout the area.

Adjacent to large intrusions such as the 'Burstall Granite', diopside-forming reactions have probably proceeded because of depression of $P_{CO_2}$ relative to $P_{H_2O}$, which could be expected to be high in contact aureoles. Large-scale outward diffusion of $CO_2$ need not be postulated.

Equilibrium curves for the tremolite-diopside reaction are shown in Figure 89. Temperature and pressure data from these curves have been used in conjunction with other reactions to plot the approximate temperature and pressure fields of metamorphism in the Marraba Sheet area (Fig. 90).

Some values of temperature and pressure are as follows:

1. Lower limit of hornblende hornfels facies (after Winkler, 1967, p. 72): for tremolite-diopside, 520°C at $P_f$ 500 bars (f=fluid)
535°C " " 1000 "
540°C " " 2000 "

For the same boundary Turner (1968) lists:

550°C at $P_f$ 1000 bars, $X_{co_2} = X_{H_2O}$

For cordierite, a stability field of 450°C to 700°C +, at 1000 bars, is noted by Turner (1968).

2. Low pressure to Barrovian Amphibolite facies: Using many reactions Winkler (1967) plots the base of the amphibolite facies from the following:

540°C at 2000 bars $P_{H_2O}$
550°C " 4000 " "
560°C " 7000 " "

From the reaction

muscovite + quartz = K feldspar + sillimanite,

the following figures have been obtained:

550°C at $P_f$ = 1000 bars
and 650°C at $P_f$ = 3000 bars

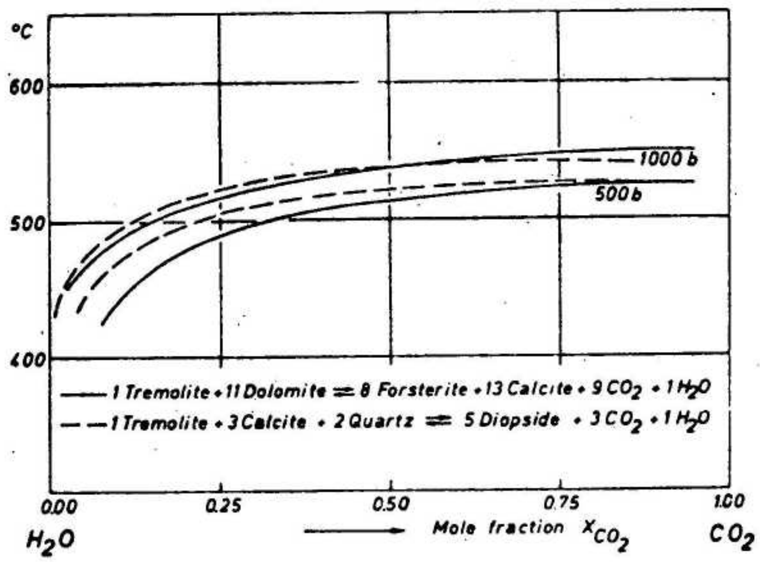
For the reaction andalusite - kyanite, approximate temperature and pressure conditions are 450°C at 5500 bars.

For staurolite, a lower stability limit of

530°C at from 3000 to 7000 bars has been determined by Hoschek (1967).

The temperature of deposition of pyrrhotite-pyrite assemblages in the Mary Kathleen open cut has been determined by Derrick (1963), using the method of Arnold (1962). Using d spacing results, a temperature of 625°C was obtained.

Fig. 89. Equilibrium curves defining an approximate base to the amphibolite facies, in calcareous assemblages. Figure taken from Winkler (1967, p. 31).



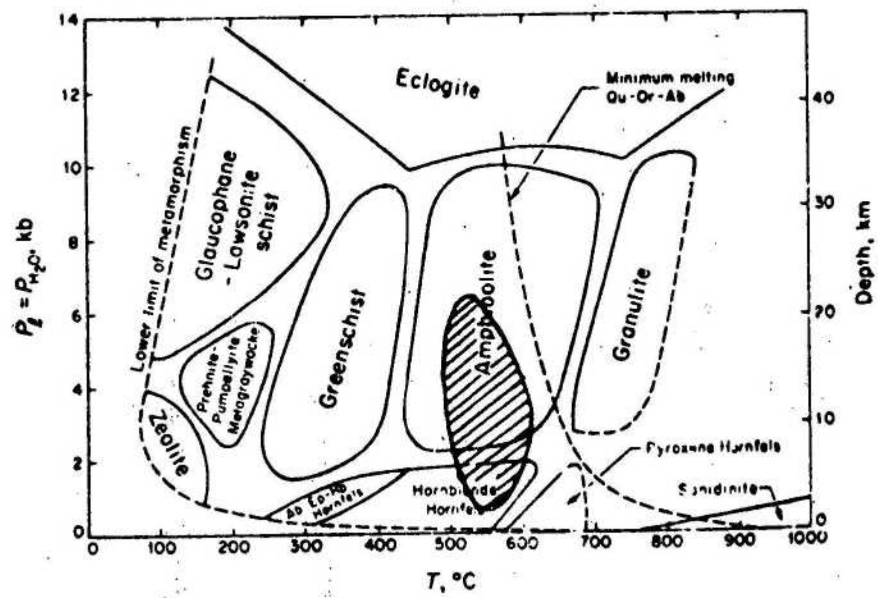

Equilibrium curves for the stated reactions at 500 and 1000 bars fluid pressure. At $P_f$ = const., the equilibrium temperature depends on the composition of the $CO_2$-$H_2O$ fluid phase, at $X_{CO_2} > 0.3$ this dependency is only very small.

To accompany Record 1971/56.

F54/A2/53

Fig. 90 Approximate limits of amphibolite facies metamorphism, Marraba Sheet area. Figure taken from Turner (1968, p. 366).

Limits shown thus




Tentative scheme of metamorphic facies in relation to $P_l$ ($= P_{H_2O}$) and $T$. All boundaries gradational.

To accompany Record 1971/56. F54/A2/54

## Retrogressive Metamorphism

Retrogression of metasediments and acid and basic igneous rocks is fairly widespread, but is particularly evident along some of the major fault-zones. The most obvious changes are the development of chlorite from biotite in amphibolite to high greenschist facies rocks, and sericite and epidote from feldspars.

## Metamorphism in Relation to Orogeny, Plutonism, and Time

We conclude from the foregoing that at least two distinct periods of prograde metamorphism have affected the area - an older regional metamorphism affecting all rocks in the Sheet area, and a younger metamorphism, predominantly thermal, which affected mainly the Corella Formation. The latter metamorphism is attributed to the intrusion of the relatively young Burstall and Naraku Granites and 'Tommy Creek Microgranite'. The place of the earlier metamorphism in time is not definitely known, (see below).

The regional association of high-grade rocks with the Wonga Granite is notable (Carter et al., 1961, p. 169), and suggests that the earliest regional metamorphism is either a product of Wonga Granite intrusion, or vice-versa. However, the table of Tectonic History (Table 18) indicates that intrusion of Wonga Granite antedates regional metamorphism, based on the association of Wonga Granite with Argylla Formation volcanics, and its regional metamorphic foliation and shearing. Thus the association of higher-grade metamorphic rocks with the Wonga Granite is only an apparent one, and is possibly a result of reactivation of the Wonga Granite zones at depth, in post-Corella Formation time. This reactivation has preceded the intrusion of the younger granites (Burstall, Naraku) into the Corella Formation.

It is tentatively concluded that the initial period of regional deformation over most of the Sheet area took place following deposition and lithification of the Corella Formation. This produced the relatively broad folding in the Bulonga and Duck Creek Anticlines and the Corella Formation and tighter isoclinal folding in the Marimo Slate, which was deposited in what was probably a narrow elongate north-south trough. Faulting accompanied folding, and regional metamorphism accompanied or followed faulting. The regional metamorphism, as noted above, appears to be related to reactivation about intrusions of Wonga Granite.

The second period of metamorphism accompanied the intrusion of a younger suite of granites, the 'Burstall Granite', 'Tommy Creek Microgranite' and Naraku Granite. The intrusions probably caused cross-folding of the Corella Formation and, to a lesser extent, older formations, and in the Soldiers Cap area developed breccia in the Corella Formation. The greatest extent of cross-folding appears to be related to the Naraku Granite, and the least to the 'Burstall Granite'.

The initial period of deformation and metamorphism outlined above is thought to have post-dated deposition of the Corella Formation. In the adjoining Soldiers Cap area to the east the initial period of deformation is thought to ante-date the deposition of the Corella Formation (Glikson & Derrick, 1970). This means that the Soldiers Cap Formation has been affected by an orogeny much older than the initial period of deformation affecting the Marraba Sheet area, and is tenuous evidence for a migration westwards with time of a major orogenic focus.

## STRUCTURE

The Precambrian rocks have been affected by several periods of deformation; there is a dominant north to northeast structural trend. The main structural features are as follows:

(i) Minor penecontemperaneous faulting and warping

(ii) broad open northeast-trending folds and tight to isoclinal north-trending folds (accompanied by regional metamorphism)

(iii) a system of normal strike faults also with a northerly trend

(iv) at least two periods of granite intrusion

(v) an intricate pattern of open cross-folds with approximately easterly axial trends

(vi) a northeast-trending system of strike-slip faults

(vii) large areas of brecciation, especially within the Corella Formation, and

(viii) dolerite dyke swarms with a general north-northeasterly trend and younger dolerite dykes with a northeasterly trend.

Because of wide variation in the structural style it is convenient to divide the sheet area into three (Fig. 91): the major Ballara-Corella River Fault Zone divides the Mary Kathleen area in the northwest from the eastern areas which are differentiated on the basis of style of folding into the Mitakoodi area and the Marimo area. Map 5 shows the major stratigraphic units and structural elements of the Marraba Sheet area.

### Mary Kathleen Area

#### Folding and cleavage

The western part of this area forms the eastern limb of a major anticline with its axis to the west of the Sheet area. A series of smaller folds is developed in the east of the area adjacent to the Ballara-Corella River Fault Zone. These moderately tight folds are cross-folded, and include the Lakeview Anticline and the truncated Mary Kathleen Syncline in the south, and to the northeast a block of tightly folded Corella Formation with shallow northeast-plunging fold axes. These structures are basins and domes rather than elongate folds.

The bedding dominantly strikes north and dips are steep (70-90$^\circ$) to the east. Tight to isoclinal folds have been recognized, ranging from small-scale structures in the laminated calc-silicate rocks of the Corella Formation to large folds such as the Mary Kathleen Syncline. Cleavage with a strong northerly trend is developed in the major folds, especially in the northwest of this area where acid and basic volcanic rocks are involved. Small outcrops of gneiss and Wonga Granite show a similar orientation, as do the contacts of the granite. Cleavage is also developed in the pelitic schists of the middle Corella Formation.

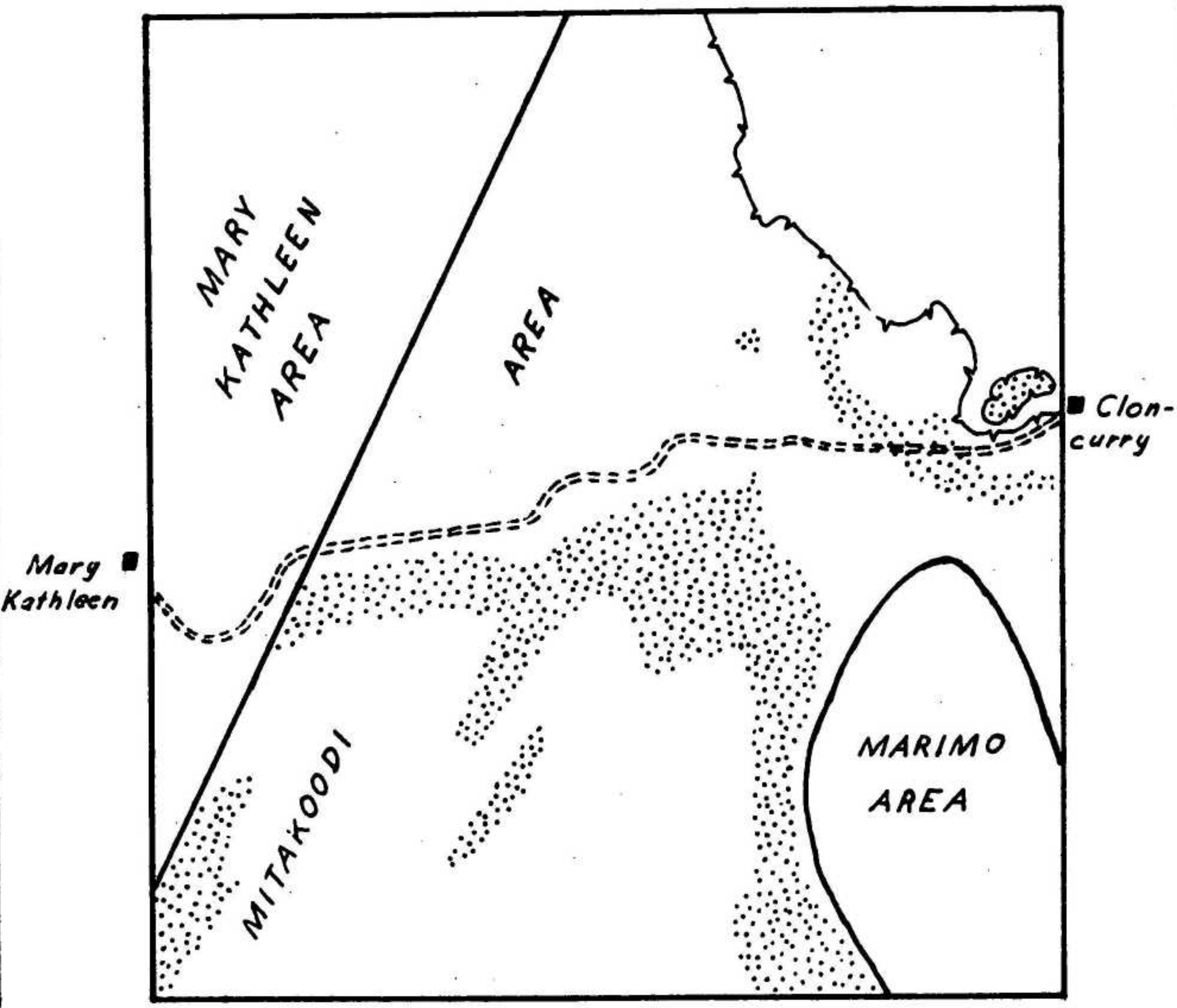



Figure 91

Areas of Differing Structural Style
Marraba 1:100 000 Sheet

Scale
1:400 000

0 8 Miles
0 8 Km.

Boundary of Structural Areas
Outcrop of Mitakoodi Quartzite
Boundary of Naraku Granite
Barkly Highway

I.H.W.

To accompany Record No 1971/56

F54/A2/55

## Faulting

Faulting in the Mary Kathleen structural unit is of two main types. The older type is represented by normal strike faults with northerly trends which repeat some units and truncate some of the fold structures. These normal faults are commonly curvilinear; an example is the Mary Kathleen Shear which shows about 300 m of relative vertical displacement (west block up). A younger system of major dextral strike-slip faults trending northeast divides the area into a number of blocks about 10 km wide. Apparent displacements on these faults are 3 km for the Wonga Fault and 2 km for the Cameron Fault. Within the Ballara-Corella River Fault Zone a graben exposes Upper Proterozoic Quamby Conglomerate. This north-northeast trending block measures about 20 km by 1 km, and is folded into a tight syncline.

## Igneous Intrusion

Two phases of granite intrusion are recognized within the Mary Kathleen area. The earlier is the gneissose Wonga Granite which intrudes the Argylla Formation and displays contacts and internal foliations parallel to the regional structural trend. Foliated aplite dykes are common. The Wonga Granite is considered to be early tectonic, and has characteristics of the catazonal plutons of Buddington (1959). The later phase of intrusion is represented by several discordant granite plutons in the vicinity of Mount Burstall and Mount Godkin; these are massive, and have a well developed joint system trending northeast and northwest. They have the characteristics of epizonal plutons, and are thought to be late or post-tectonic intrusions.

A large basic intrusion (the 'Lunch Creek Gabbro') has been mapped to the east and northeast of Mount Burstall. It is essentially concordant, forming a sill about 10 km long and has been intruded by the 'Burstall Granite'. Smaller discordant bodies of basic rock were mapped, especially near the Cameron Fault, widespread north-trending swarms of basic dykes and sills range in width from about 1 m to 1 km. Two younger basic dyke systems which trend northeast, and cut across all folds, faults, and other igneous bodies in the area have been mapped. Their most conspicuous features are their persistence along strike, and lateral grain size variation from very fine-grained contact zones to a medium to coarse-grained (3-5 mm) interior (e.g. the "Lakeview Dolerite" dyke). The average thickness of these dykes is 10 to 50 m.

## Brecciation

A major zone of brecciation closely associated with dolerite intrusions extends for 15 km along the Cameron Fault, to the northeast of Wollondonga. A narrow zone of intensely deformed calcsilicate rocks of the Corella Formation has been formed within the Ballara-Corella River Fault Zone.

## Mitakoodi Area

### Folding

The southern half of this area is a broad, shallow, north-plunging anticlinorium consisting of the Duck Creek and Bulonga Anticlines, which plunge about 10° and 50°, respectively, to the northeast, and are separated by the narrow, northeast-plunging Wakeful Syncline (see Map 5 and Fig. 92). Acid volcanics and quartzite of the Argylla Formation are exposed in the core of the anticlinorium, and these are overlain by the basic Marraba Volcanics and Mitakoodi Quartzite. The latter unit forms prominent ranges, and clearly defines the major structures (Figs. 92 & 93).

Bedding on the east-limb of the anticlinorium is nearly vertical, and towards the south it is tightly folded about near-vertical axes (Fig. 93). The western limb is truncated and deformed by the Ballara-Corella River Fault Zone.

Folding about the northwest-trending Butcher Bore syncline has resulted in the re-appearance of Mitakoodi Quartzite and older rocks in the northwest of the area, (Fox Mountain Dome, Chum Anticline). These structures are truncated by the post-tectonic Naraku Granite.

Slaty cleavage is well developed in the area, and is invariably near-vertical, and trends northeast. In competent units such as the Mitakoodi Quartzite, folding has produced a series of joints which trend northeasterly in the north, but are rotated to an easterly trend in the east. This pattern of weakness has been followed by later dolerite dykes.

The 'Overhang Jaspilite' overlies the Mitakoodi Quartzite, and is of interest because of the prevalence of incongrous minor folding within it. At least two fold axes are well developed within the more iron-rich beds, and folding is commonly disharmonic with relation to the less intensely deformed limestone beds (see Figs. 28 and 94). Orange-brown silts and slates below the jaspilite show excellent fan cleavage, possibly as a result of refolding (Fig. 95).

The northwest and southeast parts of the Mitakoodi Area contain complex synclinal structures. The south-eastern or Butcher Bore syncline is a narrow trough about 2 km wide and 10 km long containing brecciated rocks of the Corella Formation. The structure in the northwest is a complex cross-folded belt with three main components. The first is a simple basin elongated in a northwesterly direction, and exposing middle Corella Formation pelitic schists north of the old Cloncurry - Mount Isa road and east of the Corella River. The second is the Fox Mountain dome immediately south of this basin, and the third is a cross-folded belt of Corella Formation and 'Tommy Creek Microgranite' immediately west of the dome. The cross-folding is outlined by narrow synclines of cleaved graphitic slate, and steeply plunging lineations on cleavage suggest that the east-trending cross-folds are younger than the north trending folds.

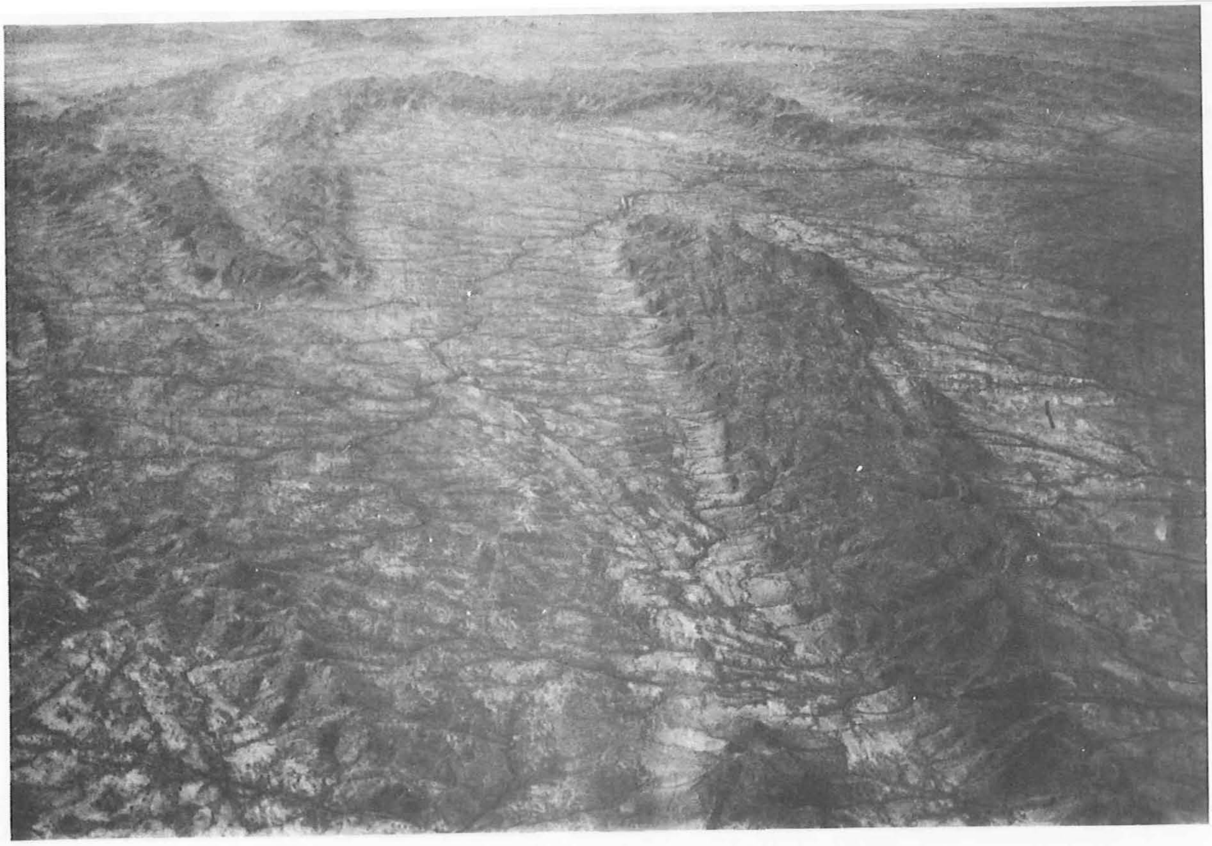


Fig. 92 From left to right, part of Bulonga Anticline, Wakeful Syncline and Duck Creek Anticline, outlined by basal Mitakoodi Quartzite. Faulted outlier of Mitakoodi Quartzite (right foreground) is Boomerang Waterhole Block. Oblique aerial photograph looking northeast. GA3714 AYG

Fig. 93 Oblique aerial photograph of folded Mitakoodi Quartzite (foreground), with near vertical axes, contrasting with structural trends in Marimo Slate (middle distance), almost at right angles to Mitakoodi Quartzite trends. View looking east to Cloncurry River GA3720 AYG

## Faulting

Faulting within the Mitakoodi Area is less systematic than in the Mary Kathleen Area. The two most common trends are northeast to east-northeast and northwest to north. Fault planes are typically steep, and slickenslides are rarely preserved, but when they are a steep northerly plunge is commonly observed. Apparent movements indicate the predominance of normal faulting with an east block up sense of movement. To the south of Boomerang Waterhole near the headwaters of Slaty Creek a tightly folded block of Mitakoodi Quartzite has been faulted from the axial zone of the Duck Creek Anticline by a northeast-trending fault, with an east block down sense of movement. A sinistral strike-slip displacement is observed on the east-northeast trending fault extending from the Corella River to Butcher Creek just south of the highway, and this has been called the Butcher Bore Fault, along which extensive silicification has taken place.

Minor faulting in the Upper Marraba Volcanics could have been initiated at the time of deposition, as this occurred in a time of continued volcanic activity. As these faults do not continue into the Mitakoodi Quartzite it is inferred that conditions had stabilized by that time. Minor faulting and quartz veining are common in the older rocks, and are of particular economic interest in the Marraba Volcanics, where the association of minor fractures with dolerite dykes has localized copper mineralization.

## Igneous Intrusion

The Naraku Granite and 'Tommy Creek Microgranite' are the only major acid plutonic rocks in the area. The former has sharp contacts with greisenized sandstones and skarns in the northwest of the area, and has caused some deformation of the country rock. Faulting is common adjacent to (but seldom at) the contact. Igneous laminations parallel the contacts of the pluton, and the grain-size ranges from fine-grained (1 mm) near the contacts to medium to coarse-grained (5 mm) in porphyritic granite about 1 km from the contact. The intrusion is thought to have been late tectonic, and to have occurred in the epizone or mesozone (Buddington, 1959). The 'Tommy Creek Microgranite' crops out as irregular discordant stocks less than 2 km long, or as concordant bodies continuous for up to 10 km along strike. These intrusions are thought to be comagmatic with the Naraku Granite.

Dolerite dykes and sills are abundant in the Argylla Formation and Marraba Volcanics, and elongate bodies of dolerite up to 500 m thick account for almost half the outcrop area of these formations. In the Mitakoodi Quartzite the main evidence of hypabyssal activity is the swarm of dykes following the radiating joint system discussed previously. The Overhang Jaspilite and Corella Formation in this area are intruded by several large subconcordant dolerite bodies, but the intensity of basic intrusion is far less than in the older rocks.

## Marimo Area

### Folding

The Marimo Area (Fig. 91 and Map 5) is characterized by a very consistent pattern of moderately tight north-northwest trending folds and silicified strike ridges. This trend is approximately perpendicular to the trends in the Mitakoodi Quartzite immediately to the west (Fig. 93), and is divergent from the main northeasterly structural trend of the Mitakoodi Area. The Marimo Area is bounded to the north by a one to two kilometre thick belt of tight to isoclinally folded fine-grained sandstone (Roxmere Quartzite) which is refolded to form a south-plunging synform.

Bedding is not easily recognized in the finer-grained and more carbonaceous slates, but is discernible in silty slate, siltstone, and calcilicate rock. Facing structures such as micro-lamination have been preserved within the siltstone. A well developed slaty cleavage in the slate strikes north-northwest, and is approximately vertical. This is parallel to the axes of the major folds and congruous drag folds (Hills, 1940) that were observed in the field, especially in the axial zone of the larger folds. Where folding was more intense, the siltstone is brecciated, and brecciation of calcsilicate rock may also be in part related to folding (Glikson & Derrick, 1970). Some fracture cleavage and kink folding have been observed (Fig. 96).

The folds are essentially cylindrical plane folds with wave-lengths of 0.5 to 1.5 km and amplitudes of similar magnitude. The axial planes are approximately vertical, and the plunges of the major folds are less than 30°. The area is cross-folded by an open east-trending synform with its axis near Slaty Creek, but in the northeast and east of the area this fold pattern dies out in the broad south-plunging syncline. Major oblique faults near Fort Roger Mount have also disrupted the fold trends.

### Faulting

The majority of faults in the area are strike faults with little observable displacement. They are expressed as upstanding silicified ridges in the grey slate, and in some places disruption of adjacent bedding is observed (Fig. 97). Belts of silicified fault breccia 100 to 200 m wide in the southwest of the area are associated with a major northwest-trending dextral strike-slip fault system which truncates a folded fine-grained sandstone unit. Northeast and north-northwest trending faults, accompanied by drag folds, phyllonite, and breccia, are seen in the sandstone block to the north of the area. The northeast edge of the area is a complex faulted zone between the Marimo Slate and the Corella Formation, along which drag folding, brecciation, and manganese nodules are common. There are few large transverse faults but numerous minor northwest-trending faults within the Marimo area; these are of special interest as localizers of copper mineralization in the slate. It is possible that much of the major faulting in the Marimo area has not been elucidated by the present mapping because of poor outcrop.

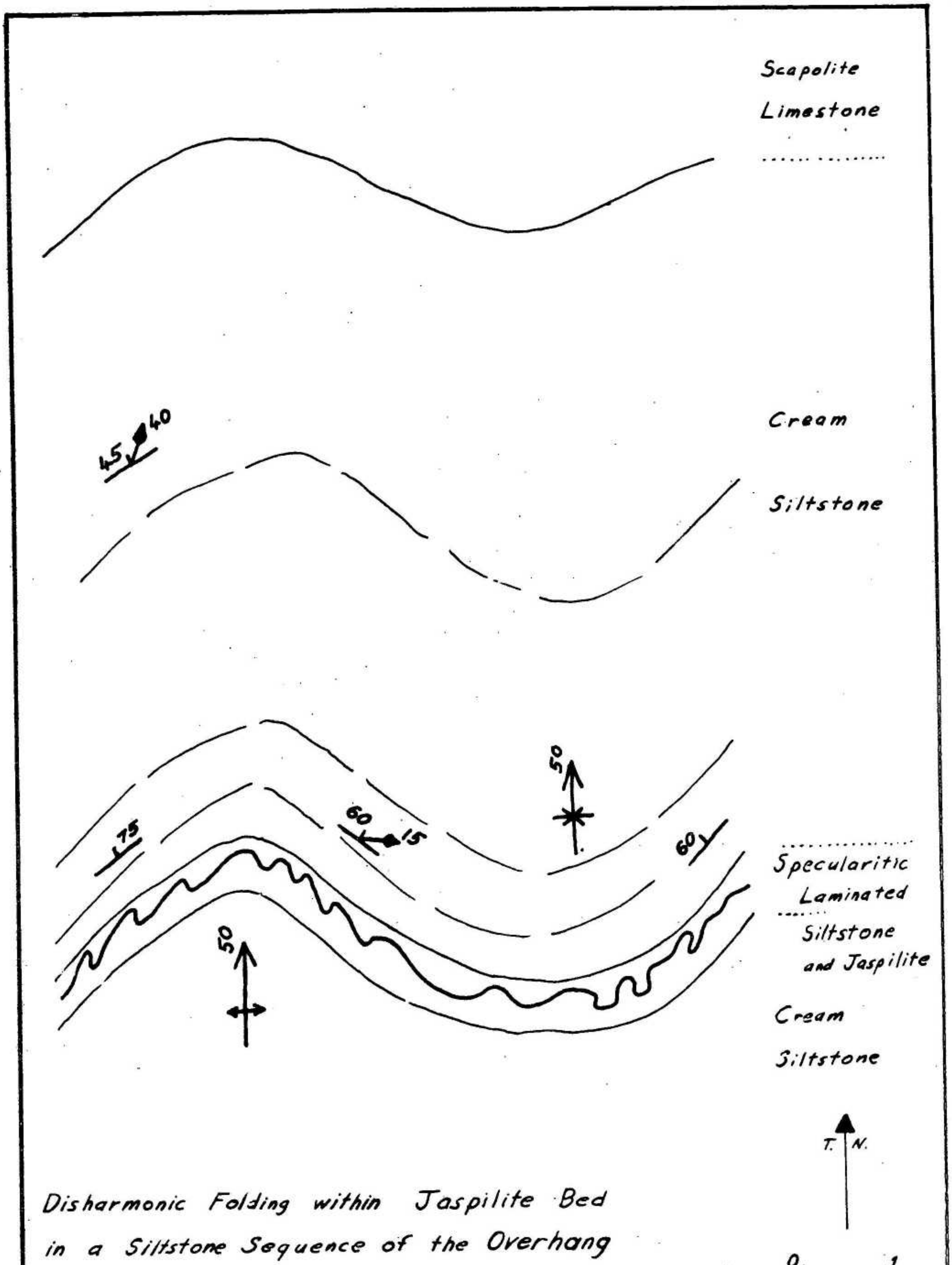



Figure 94.

To accompany Record No 1971/56.

F54/A2/56

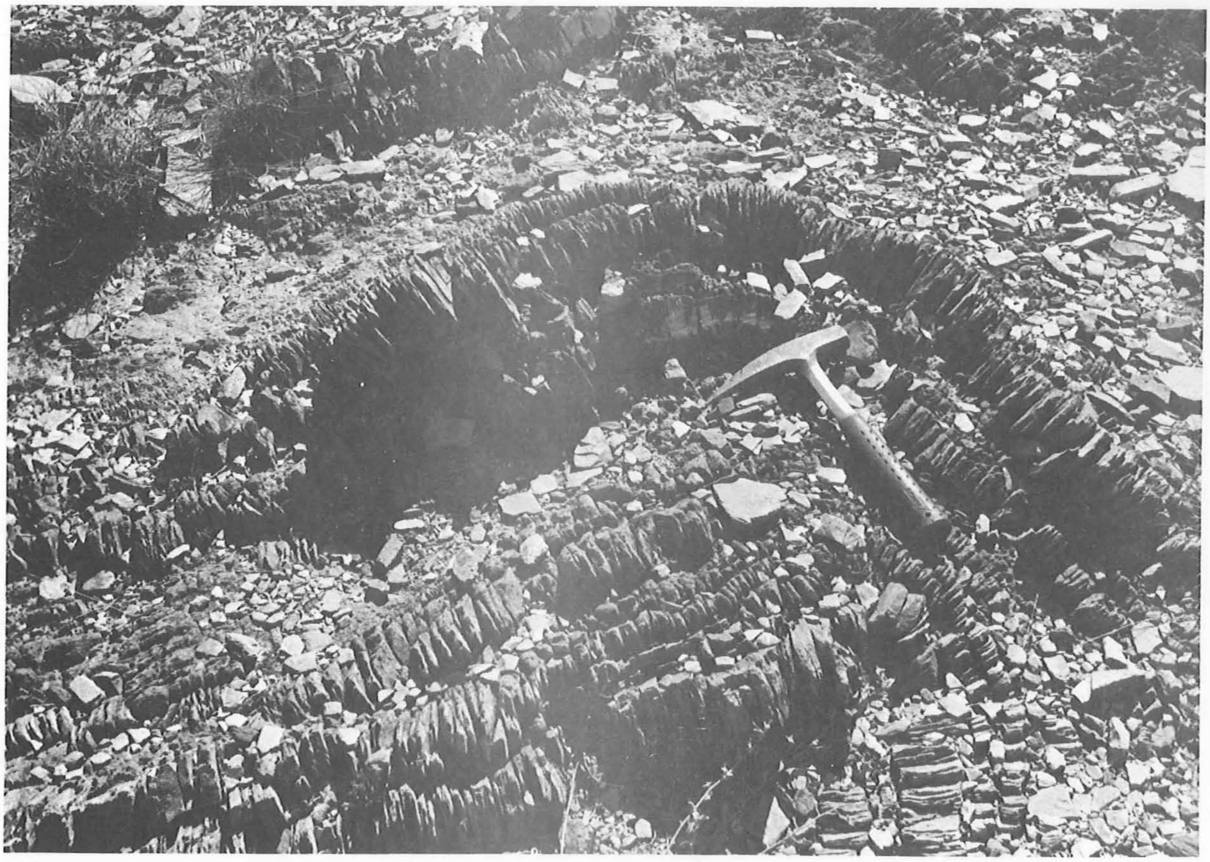


Fig. 95 Fan cleavage in orange brown silt and slate near base of 'Overhang Jaspilite', 1.5 km south of the Overhang mine
M909/5A GMD

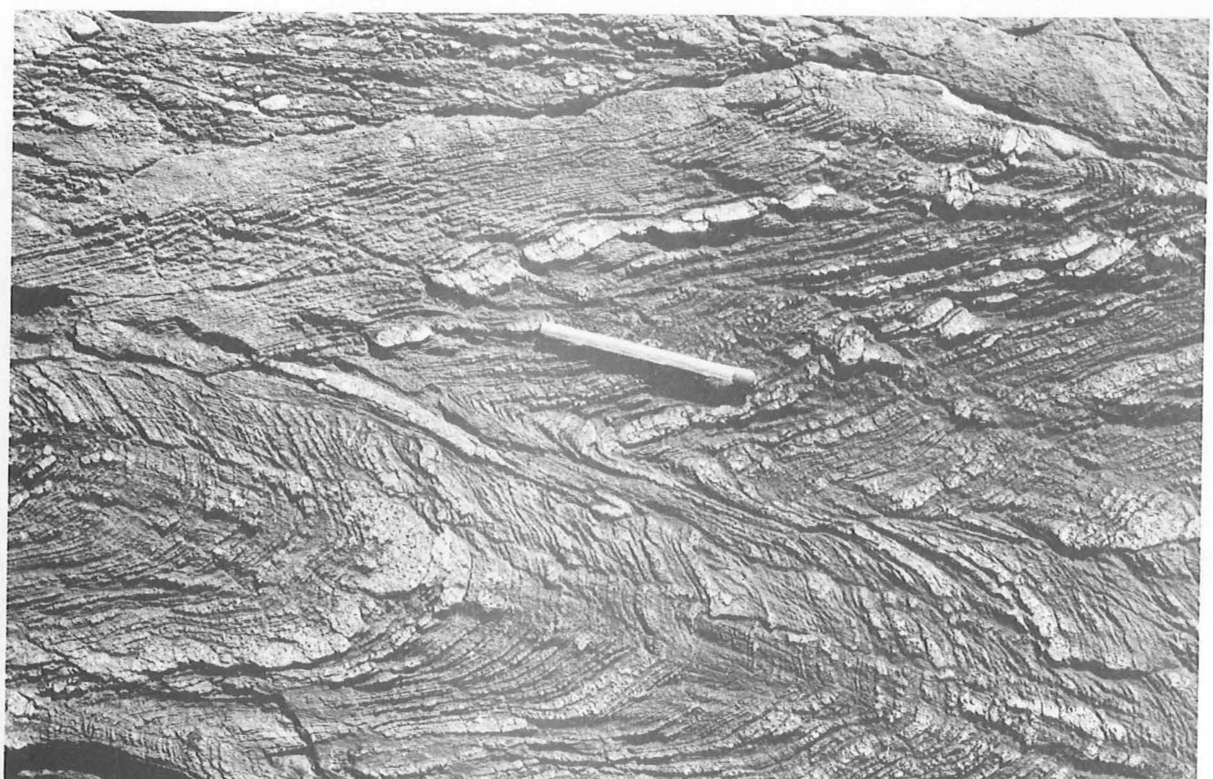


Fig. 96 Fracture cleavage (parallel to match) in laminated silt in Marimo Slate, unit $Blm_{1s}$, 2.5 km west of Black Slate mine
M909/1 GMD

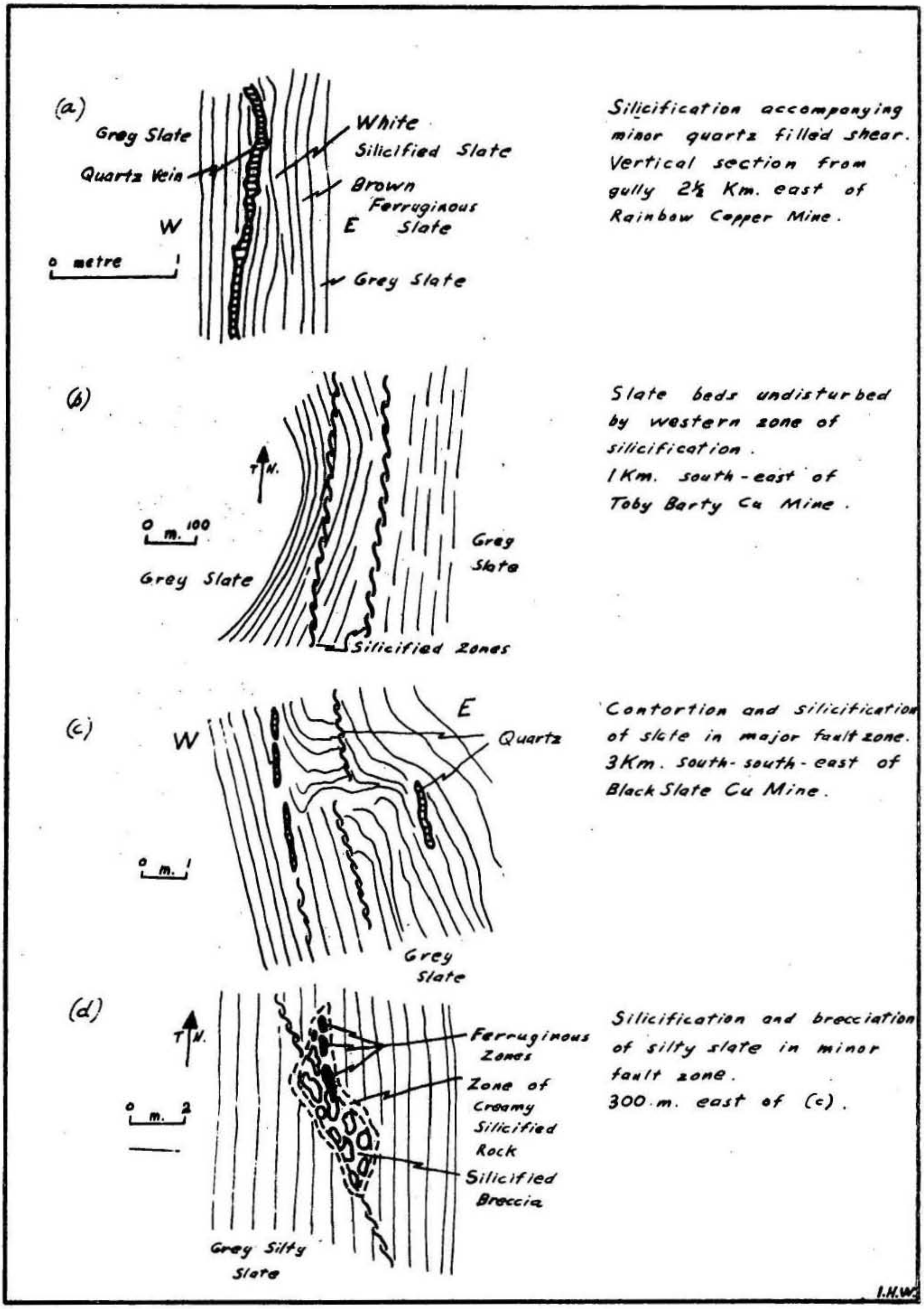



Fig. 97. Effects of Faulting in the Marimo Slate.

To accompany Record No 1971/56.

F54/A2/57

TABLE 16

Summary of Deformation in various Formations.

(3,2,1 = Upper, middle and lower parts of formation)

| Formation | | Preservation of Bedding | Cleavage Development & Orientation | Fold Style | Fold Axes | Cross - folds & Axes | Expression |
|---|---|---|---|---|---|---|---|
| Quamby Conglomerate | | Good | Nil | Simple, tight | 015 | Nil | Some jointing |
| Marimo Slate | (3) | Good | Nil | Repeated, simple, moderately tight, minor crenulations | 180-175 | 085 (open) | Brecciation |
| | (2) | Good | Rare 000 | " | " | " | Brecciation Qtz-hem veins |
| | (1) | Poor | Ubiq. 000 | " | " | " | Silicification |
| Corella Fmn | (3) | V. good | Nil | Intraformational, tight isoclinal, drag-folds common | 180-165 | 0.85 (tight) | Qtz, qtz-hem, mobil lst, calcite veins, breccia, valleys. |
| | (2) | Fair | Common 000 and 085 | Simple, tight | " | " | Qtz, displacement |
| | (1) | V. good | Rare 000-030 | as (3) | " | " | as (3) |
| 'Overhang Jaspilite' | | V. good | Rare | Complex folding, at least two axes | ? Random | complex | Qtz-hem.-Mn, brecciation, silicificat ion |
| Mitakoodi Quartzite | (3) | V. good | Rare | Simple, open, with minor crenulations | 030 | 030 (open) 045 (tight) | Displacement, brecc iation, silicification |
| | (2) | Poor | Common 000-045 | " | " | " | " |
| | (1) | V. good | Rare | " | " | " | " |
| Marraba Volcanics | (3) | Fair | Common 000-030 | Simple, open with minor crenulations | 030 | 045 (tight) | Displacement, Brecciation, Qtz. |
| | (2) | Good | Rare | Intraformational, complex | " | " | Displacement |
| | (1) | Poor | Ubiq. 030-045 | as (3) | " | " | Alteration, calcite brecciation, qtz. |
| Argylla Formation | (2) | Fair | Common 030-040 | Simple, open | 030 & 000 | not observed | Displacement, |
| | (1) | Poor | Ubiq. 030-040 | " | " | " | Shearing, qtz. |

## Style of Deformation in the Marraba Sheet Area

Table 16 presents a summary of the variation in style of deformation in the different formations of the Marraba Sheet area. The main control on style of folding is the competence of the lithologies within the formation, and this information is summarized in Table 17. The development of slaty cleavage has been controlled by the ability of micaceous minerals to form in the various chemical environments under the influence of low-grade regional metamorphism.

TABLE 17: COMPETENCE OF LITHOLOGIES WITHIN THE MAJOR FORMATIONS

| Formation | Rock Types | Competence |
|---|---|---|
| Argylla Formation | Acid volcanics, Quartzite | Competent |
| Marraba Volcanics | Basic volcanics, slate, and calcareous siltstone | Plastic |
| $Pla_2$ ('Mt Start Member') | Chert and fine-grained quartzite | Very plastic |
| Mitakoodi Quartzite | Quartzite and minor basic volcanics | Competent |
| 'Overhang Jaspilite' | Ferruginous chert and laminated limestone | Very plastic |
| Corella Formation | Laminated calcsilicate rock, limestone, and pelite | Plastic to very plastic |
| Marimo Slate | Carbonaceous slate, siltstone, and calc-silicate rock | Competent to plastic |

One feature associated with faulting which has not previously been noted is the dependence of the fault-filling material on the country rock. Large upstanding silicified fault ridges dominate the landscape in many places, but they are most likely to occur where a fault cuts siliceous units such as quartzite, and to a lesser extent grey slate and acid volcanics. Faulting in the acid volcanic and siltstone units is more likely to be expressed as a deeply eroded lineament, as the phyllonite produced by the faulting is not cemented, and weathers rapidly. Essentially calcareous rocks, e.g., parts of the Corella Formation, behave plastically and are folded where adjacent older rocks are faulted. When there is a rupture in the limestone it is usually filled by grey coarse-grained calcite veins up to 20 m wide, and calcite-actinolite-quartz breccia.

Rocks of the Corella Formation are mostly characterized by alternating laminae of calcareous and siliceous material. When these rocks are deformed the calcareous material behaves plastically whereas the more competent beds fracture. One exposure may exhibit the whole range of this effect, from isolated fracture of the siliceous beds, through "pull-apart structures" - e.g., 'platelet' limestones, intraformational breccia, to complete brecciation (see Figs 52, 55 and 56).

The 'Overhang Jaspilite' deforms in a similar way to the Corella Formation. Decalcification of the calcsilicate and limy rocks and silicification of the resulting porous breccia is common. These silicified masses have been called the 'Chumvale Breccia' by Carter et al. (1961), and have been redefined in this report.

## Discussion of Structural Development

Before attempting to unify all the observed structures in the area, several aspects of a more theoretical nature should be discussed. They are:

(i) the importance of penecontemperaneous deformation

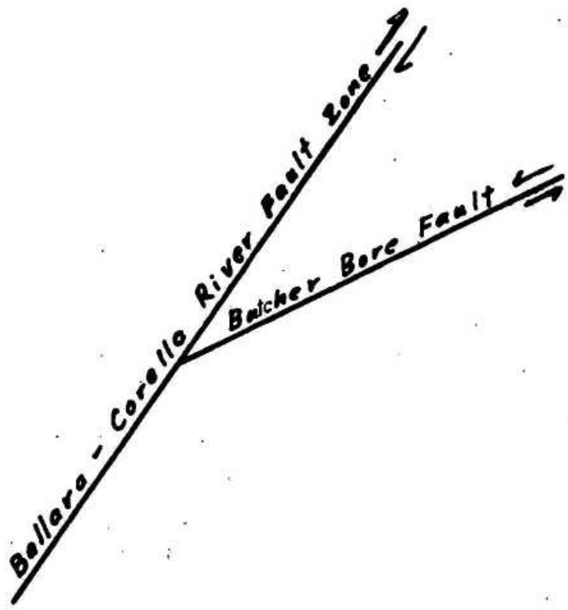
(ii) the relevance of strike-slip fault tectonics, and

(iii) the relationship of this area to a possible rift valley system to the west.

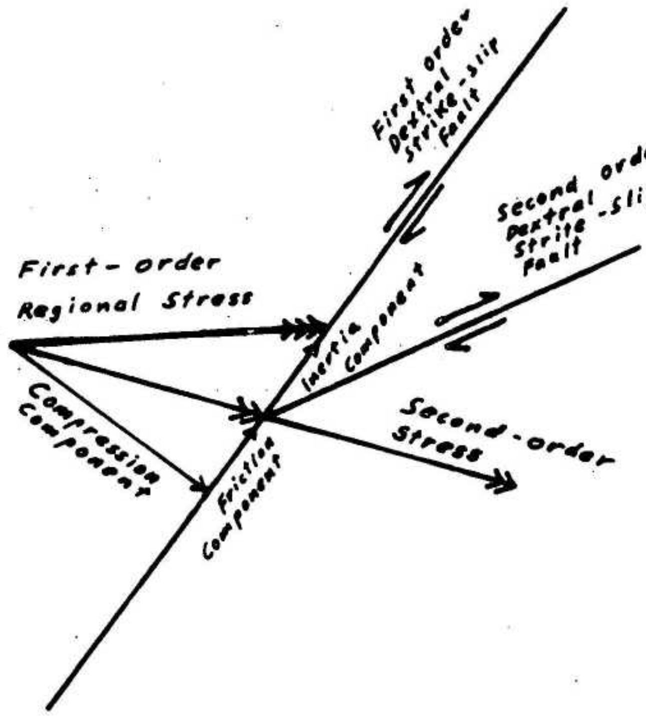
(i) Penecontemporaneous faulting and warping during Marraba time appears to have had little effect on overall structural development. The origin of certain sedimentary structures by slumping has been suggested at various times. Specific examples include the complex folding within the 'Overhang Jaspilite', the brecciation of the Corella Formation, and "attenuated siltstones" within the Marimo Slate. In this report we contend that only the structures within the Marimo Slate can definitely be attributed to slumping, and that none of these possible examples would have had a significant effect on the structural development of the area as a whole. A more significant problem is the possible existence of an unconformity between the Mitakoodi Quartzite and the 'Overhang Jaspilite'. Although no definite stratigraphic evidence for an unconformity could be found in this structurally complex area southwest of Cloncurry, a consistent tectonic explanation of the disharmonic folding has been devised.

(ii) The theory of strike-slip fault tectonics depends on the assumption that once a stress field has caused a strike-slip fault, the stress is not completely dissipated; this remnant stress will be reoriented in the fault block adjoining the applied stress, and may cause further strike-slip faulting (Moody & Hill, 1956; Badgley, 1965). An area where this theory could possibly apply is in the Mitakoodi structural area. Here the dextral Ballara Corella River Fault Zone would be the initial major shear, corresponding to an east-west primary-stress direction. This primary-stress direction is consistent with the north-trending fold system which predominates in the whole Precambrian belt, with the possible thrusting south of Cloncurry. Fig. 98 shows how the primary-stress is resolved, and how a second-order stress is redirected in the adjoining block (McKinstry, 1953). The resulting theoretical second-order shears have the opposite sense of movement to that observed in this area. This indicates that the sinistral strike-slip fault south of the Barkly Highway to the east of the Corella River is not genetically related to the Ballara Corella River Fault Zone.

Actual Faulting




Theoretical Faulting if Stress Reorientation applied.




I.H.W

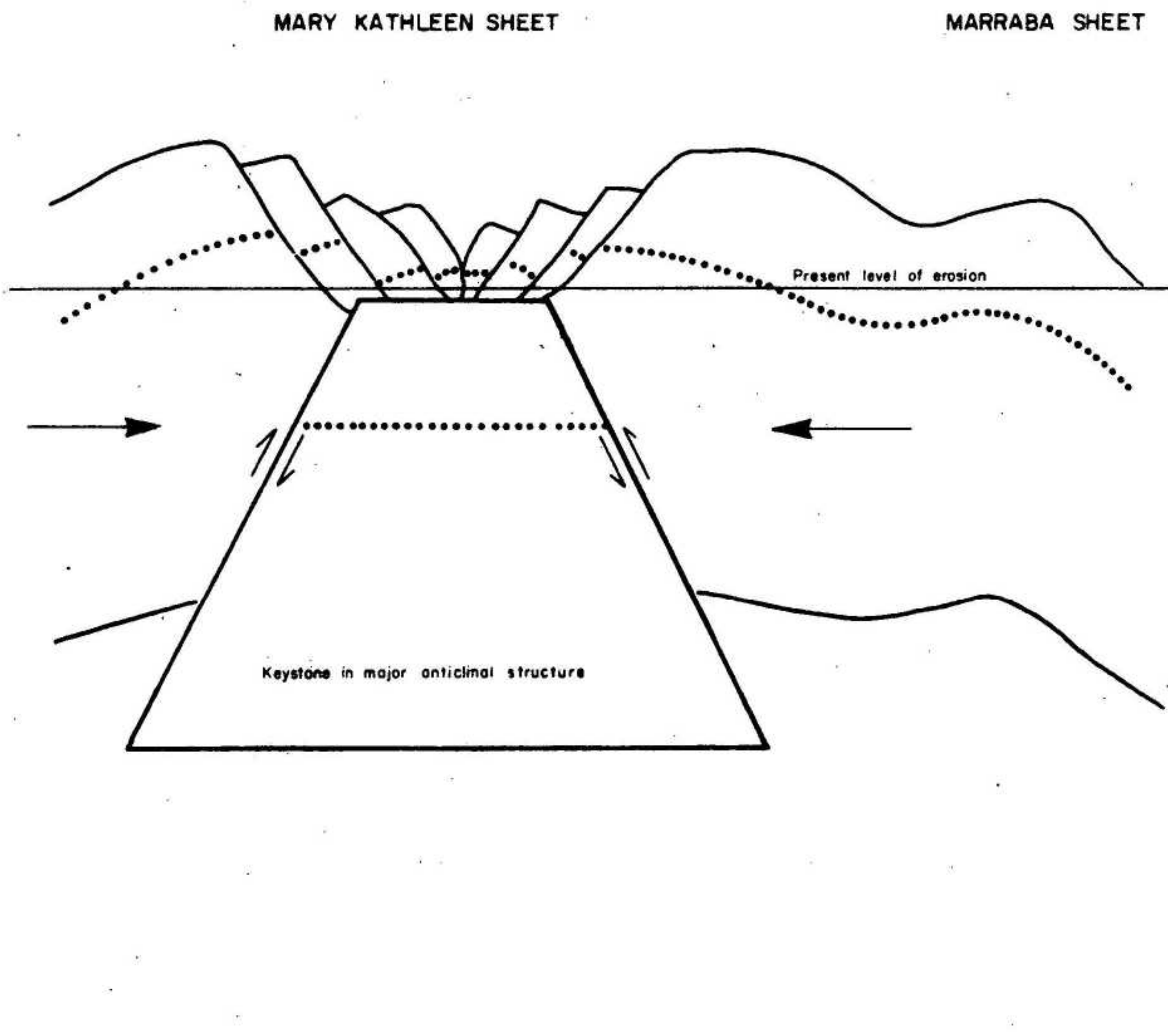
Fig. 98 Failure of Strike - Slip Tectonics.

To accompany Record No 1971/56.

F54/A2/58

## FIG. 99

Explanation of rift system on Mary Kathleen sheet, by downthrusting of keystone block



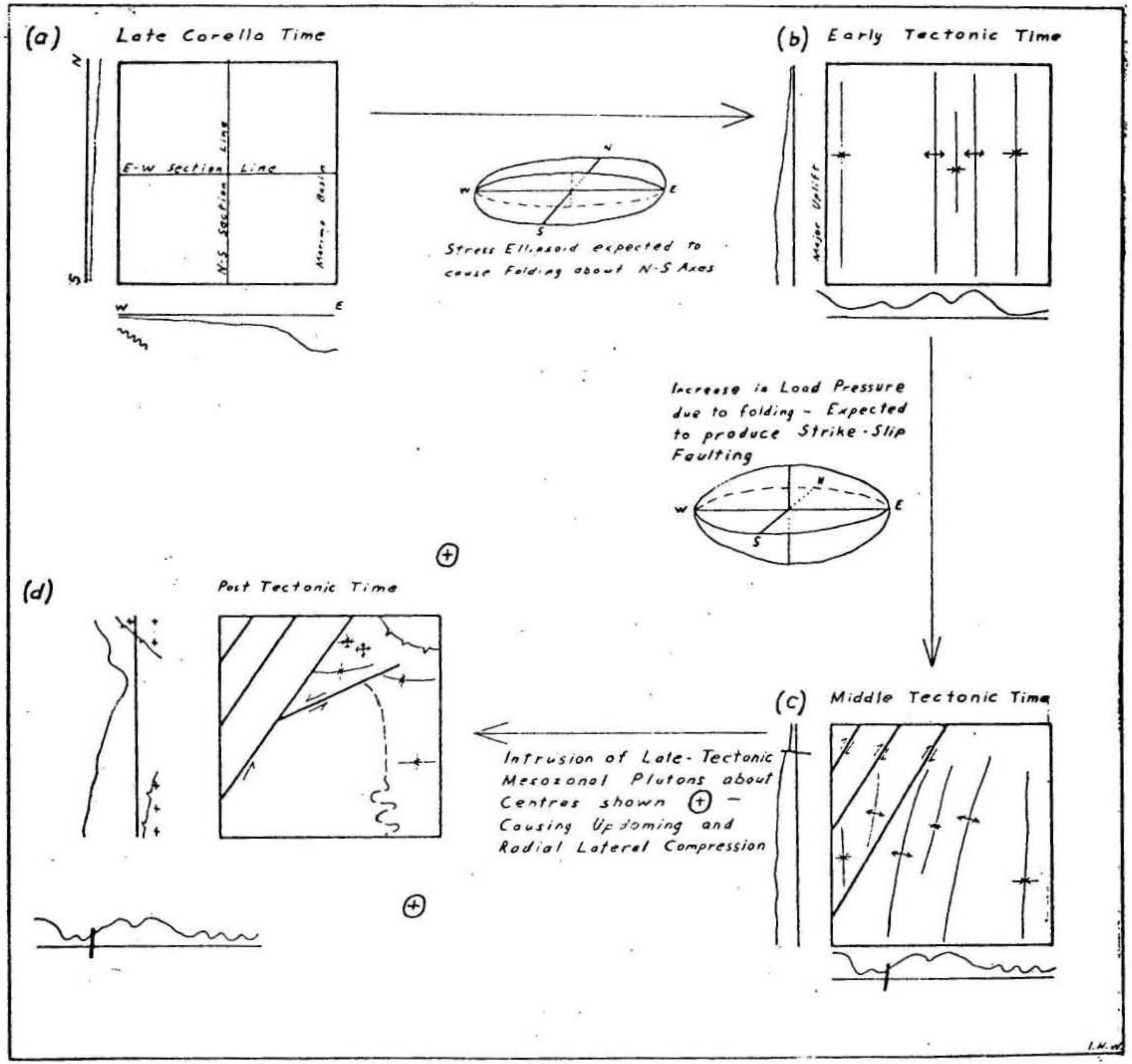



Fig 100 Hypothetical Plans and Sections to show Stages in Structural Development, Mareeba Sheet.
To accompany Record No 1971/56. F54/A3/80

(iii) Preliminary detailed regional mapping of the adjacent Mary Kathleen 1:100 000 Sheet area has shown a similarity in the pattern of normal strike-faults to the fault pattern displayed in a rift valley, although the problems of rift valley formation are not completely resolved (Freund, 1965). The area involved in the Mary Kathleen Sheet area is part of a structural high, and there is evidence of compression in an east-west direction provided by fold axes and strike-slip faulting. Under this tectonic environment the rifting may be related to reverse faults (Wayland, 1921; Willis, 1928) as shown diagrammatically in Figure 99. If this hypothesis is found incorrect the rifting may have occurred at a later time when the east-west compression no longer operated - e.g., following isostatic adjustments in the basement. In either case the occurrence of a rift does not complicate the structural development of the Marraba Sheet Area.

## Proposed Structural Development of the Marraba Sheet Area

Sedimentological considerations indicate that the Marraba Sheet area developed as a wide shelf which was subject to a transgressing and regressing sea. Sedimentary environments ranged from terrestrial to shallow-water marine, and locally, deep water conditions. Considerable volcanic activity occurred, especially in the early recorded history of the area, but there is little evidence of significant deformation until post-Corella time.

The deep-seated Wonga Granite which crops out in the west of the Sheet area was intruded early in the tectonic history of the area. This granite may have been emplaced as early as the end of Argylla time. The presence of conglomerate overlying the Argylla Formation in the Mary Kathleen Sheet area supports this contention. However, there is little or no evidence of an unconformity at this geological time within the Marraba Sheet area, except for an apparent onlap of upper Corella Formation in the northwest.

During the main tectonism the primary stress was directed in an east-west direction causing a series of north trending folds, north-east trending strike-slip faults, and possibly some reverse faulting to the south-southeast of Cloncurry along the 'Cloncurry Thrust' (Carter et al., 1961; Glikson & Derrick, 1970). Rotation of fold axes adjacent to the Ballara Corella River Fault Zone may be due to re-orientation of stress after the formation of the fault-zone. Carter et al. (1961, p. 185) explain the observed large dihedral angle facing the proposed primary stress as an effect of distortion caused by later application of a similar stress field.

Seven periods of dolerite intrusion have been recognized by Carter et al. (op. cit.), not all of which occur in the Marraba Sheet area. The orientation of these bodies is controlled by the nature of the strata and the effects of deformation, such as cleavage and jointing. The most recent dolerite dykes are younger than all structural deformation that has been detected.

Towards the end of the tectonic cycle, the Burstall and Naraku Granites were intruded. The 'Burstall Granite' had only minor structural effects, uplifting and pushing aside the adjacent metasediments. The Naraku Granite was a more significant body, which, in conjunction with the probably contemporaneous Wimberu and Williams Granites to the south, produced two areas of major updoming in the Mitakoodi Structural Area. This deformation also caused east-trending cross-folds within the Mitakoodi Area, and is the probable cause of the Butcher Bore Strike-slip Fault at the northern end of the major anticlinorium, which acted as a competent block. The eastern limb of the anticlinorium exhibits a series of tight northeast trending cross-folds which could also have been formed during this phase of deformation.

Figure 100 shows the structural development in a diagrammatic form.

## GEOLOGICAL HISTORY

Unravelling the geological history of the eastern succession of the Cloncurry Complex is hindered by complex structure, and the lack of adequate isotopic age determinations. Also, correlations across distances of the order of 20 km are hazardous in such a structurally complex area. For example, the major strike-slip Ballara-Corella River Fault between the Bulonga Anticline and the Mary Kathleen syncline could have a lateral movement of up to 15 km, taking into account its representation on the Duchess and Cloncurry 4-mile maps (Carter et al., 1961). Thus the following discussion of the geological history from the probably Archaean to Cambrian is largely conjectural. The tectonic history of the Sheet area is summarized in Table 18 and Figure 101.

Archaean rocks are not known in the Cloncurry Complex, but quartzite pebbles which may have been derived from Archaean basement are recorded from Lower Proterozoic conglomerates older than any known quartzites in the area.

The oldest rocks exposed in the Marraba sheet area are sheared acid volcanics and schistose micaceous quartzites exposed in the cores of the Bulonga and Duck Creek Anticlines, but because the quartzites are greatly deformed and poorly exposed their provenance is unknown.

While the Argylla Formation was being deposited, acid volcanism was prevalent apparently over the whole of the Marraba Sheet area, and was followed by uplift and depression which resulted in transgression and regression of the shoreline with consequent variation in sedimentation. The northwest of the Sheet area, was probably continuously above sea level as little or no sediment associated with the volcanics has been observed. Small lenses of quartzite in the northeastern and southern exposures of the Argylla Formation may be from fluvial or transgressive shore line environments. Cross-bedded feldspathic quartzite, abundant in the south, was presumably derived from the acid volcanics (both are rich in apatite and zircon), and has been transported only a short distance (labile content high). A near-shore environment is indicated by cross-bedding and ripple marks. An east-west current system is suggested by ripple marks, but ripple marks, but cross-bedding indicates a current from the northeast (Fig. 101).

TABLE 18. SUMMARY OF TECTONIC HISTORY, MARRABA SHEET AREA

| AGE | DEPOSITION | IGNEOUS EVENTS | TECTONIC EVENTS | METAMORPHISM | REMARKS |
|---|---|---|---|---|---|
| M to Cz | Sandstone, laterite development etc. | | | | Supergene enrichment of copper ore bodies. |
| | U N C O N F O R M I T Y | | | | |
| Bu | ?Quamby Conglomerate | | Development of horst-graben structures; stabilization of shelf. | | No definite evidence for upper Proterozoic age. |
| | U N C O N F O R M I T Y | | | | |
| L O W E R P R O T E R O Z O I C T O ? C A R P E N T A R I A N | | Intrusion of young dolerite dykes and plugs. | | | Post-date most retrograde metamorphism. |
| | Development of breccia in Corella Formation. | Intrusion of younger granites - (Burstall and Naraku). Intrusion of gabbro/dolerite sills, post-metamorphic. | Cross-folding (?induced by granite intrusion). | Low pressure regional and contact metamorphism adjacent to younger plutons, with further mineralisation e.g. Uranium, fluorite, copper. | Possibly granites are products of reactivation of Wonga Granite. Brecciation of Corella Formation due to cross-folding in Cloncurry Sheet area, and to folding and faulting in Marraba Sheet area. |
| | | Intrusion of dolerite into all units. ?Reactivation at depth of Wonga Granite in west. | Transcurrent faulting. Major folding with normal faulting. | (First major regional metamor- (phism, with epigenetic copper (mineralisation. | Possibly some concentration of ore minerals in black slates. Folding broad and open about north-south axes; Marimo Slate isoclinally to tightly folded. |
| | Deposition of Roxmere Quartzite | | | | |
| | C O N F O R M I T Y O R S L I G H T D I S C O N F O R M I T Y | | | | |
| | Deposition of Corella Formation, jaspilite etc., Marimo Slate. | Extrusion of pillow and amygdaloidal basalts in central and northwestern areas. | Corella Formation rests with angular unconformity on Soldiers Cap Formation to east. Increasing stability of depositional shelf. | | Cu, Pb, U, Zn deposited in trace amounts in areas of black slate. |
| | Deposition of Mitakoodi Quartzite. | Minor pulses of basalt extrusion. | | | |
| | Deposition of sediments in upper Marraba Volcanics. | | *?Isoclinal folding in adjoining Cloncurry Sheet to east, affecting Soldiers Cap Formation. No evidence to show this phase affected rocks in the Marraba Sheet. | *?Accompanied by regional metamorphism of Soldiers Cap Formation. No evidence to show this metamorphism affected the Marraba Volcanics and Argylla Formation in Marraba. Sheet | |
| | | Outpouring of Marraba Volcanics. | | | Assumes equivalence of Soldiers Cap Formation with Marraba Volcanics; latter continental, former geosynclinal. |
| | E R O S I O N I N W E S T : C O N F O R M I T Y O R D I S C O N F O R M I T Y I N E A S T | | | | |

| AGE | DEPOSITION | IGNEOUS EVENTS | TECTONIC EVENTS | METAMORPHISM | REMARKS |
|---|---|---|---|---|---|
| ?LOWER PROTEROZOIC | | Intrusion of early dolerite dykes. ?Intrusion of Wonga Granite. | | | Wonga Granite appears confined to areas of Argylla Formation in west of Sheet area. |
| | Deposition of Argylla Formation sandstones interbanded with volcanics. | Extrusion and intrusion of rhyolite, rhyodacite lavas and porphyry, some tuff. | | | |
| | | | *Isoclinal folding in adjoining Cloncurry Sheet to east, affecting the Soldiers Cap Formation. | *?Accompanied by regional metamorphism which preceded deposition of Argylla Formation and Marraba Volcanics. | Assumes Soldiers Cap Formation is not equivalent to Marraba Volcanics. |

* These are alternatives; age determination will elucidate the problem, but the nature of the rocks involved, e.g., basic volcanics, schists, and quartzite, does not favour accurate determination.

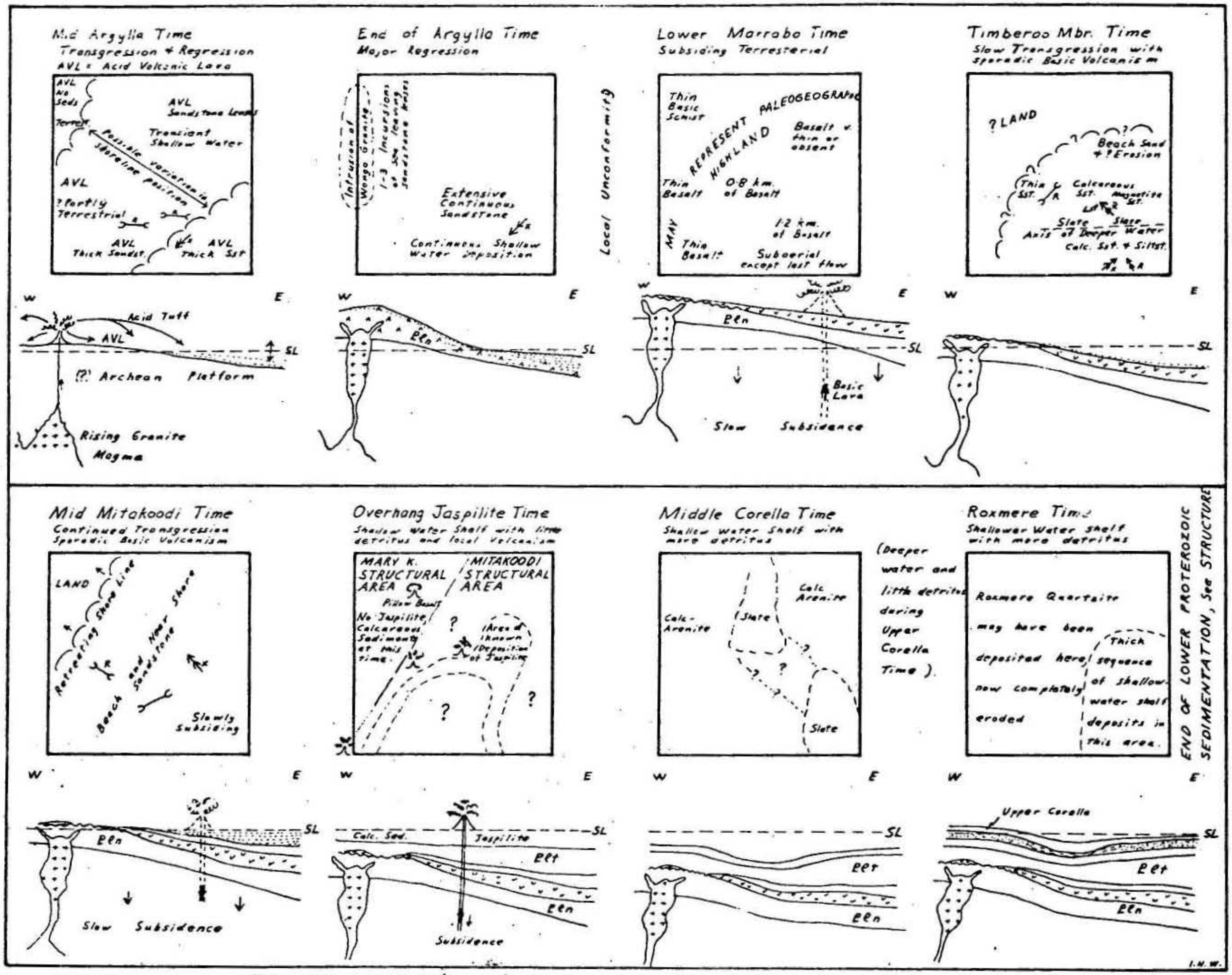



FIGURE 101 . Schematic Reconstructions of Paleogeographies during Lower Proterozoic in Marraba Sheet.

To accompany Record No 1971/56. F54/A2/61

Sediments were much thicker and more abundant near the end of the deposition of the Argylla Formation, especially in the southeast where current direction was from the northeast. Some thin quartzite beds in the northwest and west also indicate that the whole Sheet area was submerged at times. Erosion was active to the west of Mary Kathleen as evidenced by a thick conglomerate at the base of quartzite units (Ballara Quartzite) which overlie the Argylla Formation, and this uplift and erosion in the west at a time of continued deposition elsewhere in the Marraba Sheet area is consistent with intrusion of the Wonga Granite along the western boundary of the Sheet.

A possibly complete lithological record of sedimentation since Argylla time is preserved in the Duck Creek Anticline. There is an abrupt change from the feldspathic quartzite deposited by the regressing sea at the top of the Argylla Formation to the basic lavas of the 'Cone Creek Volcanic Member' of the Marraba Volcanics. About 50 flows of basalt were poured out; amygdaloidal flow tops are well preserved. The amygdales, the insignificant amount of sediment with the flows, and the absence of pillow structures in all but the upper flows suggest that the flows were subaerial. The source of the basalts has not been located, but it was probably near or in the southern part of the Marraba Sheet area, because the basalt flows thin out laterally; e.g., in the northeast, basalt is almost completely absent in the Chum anticline sequence. Westward across the Duck Creek Anticline the basalt member thins from 1 200 m to less than 1 000 m and then pinches out completely. Further west and northwest thin basic schists in acid gneiss and schist are possible lateral equivalents of the Duck Creek sequence. To the south the Marraba volcanics continue approximately 80 km to the edge of the outcropping Proterozoic rock. Some dolerite dykes and sills in the Argylla Formation may have been emplaced during this period of basic extrusion.

The incursion of the sea towards the end of the deposition of the 'Cone Creek Volcanic Member' was accompanied by one violent eruption resulting in widespread deposition of basic agglomerate and tuff, followed by a period of decreased volcanic activity. During this period a conformable sequence of sediments was deposited, beginning with a thin calcareous fine-grained sandstone ('Mount Start Member'), then a sequence of slate, calcareous siltstone and calcareous and arkosic sandstone ('Timberoo Member'). This is overlain by the Mitakoodi Quartzite which grades from medium-grained arkosic quartzite to fine-grained feldspathic sandstone and siltstone. There are several basalt flows within each member of the Marraba Volcanics and the Mitakoodi Quartzite.

The source of detritus in this sequence is not fully established; palaeocurrent directions are partly conflicting, as shown on Figure 101, but the overall impression is of drainage from the south. The presence of magnetite-rich bands in the sandstones is interpreted as showing that at some time, basalt had been exposed and partly eroded during this period. The main quartzose and feldspathic detritus is more mature than that in the quartzites below the basalt, indicating a greater distance of transport.

The nature of the sedimentary environment was apparently quite varied during this period. The 'Mount Start Member' is fine-grained, cherty, and calcareous in part, indicating that the environment was near-shore and possibly close to thermal springs which were a source of silica. The calcareous siltstone of the 'Timberoo Member' is more typical of an offshore shelf environment with carbonate provinces and some deeper troughs in which carbonaceous and pyritic shales were deposited. Thicker sedimentary sequences in the east suggest a faster rate of subsidence there. These lateral and vertical variations in the environment indicate mild tectonic activity.

The lowest sandstone in the Mitakoodi Quartzite is arkosic to sublabile, indicating proximity to an acid igneous terrain. Also, as the sandstone is devoid of calcareous material, strongly cross-bedded, and ripple marked, it is inferred to have been formed as a shore-line deposit, representing a change to a shallow water environment. The thickness of this unit in the Marraba Sheet area suggests a prolonged stillstand or gradual subsidence of the land. Evidence of progressive onlap of the Ballara Quartzite on the Mary Kathleen Sheet area to the west could be related to gradual subsidence, and this model is supported by the gradational reduction in grain-size from the base to the top of the formation. Spilitic, possibly submarine, volcanism took place sporadically during this time.

In the Marraba Sheet area the boundary between the Mitakoodi Quartzite and the 'Overhang Jaspilite' is an abrupt but conformable change from fine-grained feldspathic siltstone and buff shale to laminated limestone, jaspilite, and chert. The jaspilite is restricted to the southern and central part of the Sheet area, being absent from the sequence to the west. Another jaspilite in the Soldiers Cap Formation on the Cloncurry 1:100 000 Sheet to the east (Glikson & Derrick, 1970) is almost certainly older than the 'Overhang Jaspilite'.

Banded iron formations are thought to indicate a particular sedimentary environment in the Proterozoic and have special significance as a world 'marker bed' at about 1 800 m.y. (Rankama, pers. comm.). This is comparable to the age of the oldest granites found in the area and is older than the granites which intrude the overlying Corella Formation. The deposits are characterized by the paucity of detrital material (mostly quartz) and the precipitation of ?colloidal iron and silica which indicate a shelf environment. The deposition apparently took place below wave base because of the absence of sedimentary structures in the rocks. The probable conclusion is that during this period the sea completely covered much or all the Marraba Sheet area and adjacent land had mature morphology.

The transgressing shore line of Mitakoodi time had probably moved well to the west by this time and because of facies changes laminated calcareous marls and silts were probably being synchronously deposited to the west of Mary Kathleen. These adjacent areas may have been separated by a further 10 km or more at this time and this may explain the change in sedimentary environment. Another possible explanation for the restriction of the jaspilite is that it was formed by exhalations from volcanoes.

Basic volcanic activity continued intermittently from Marraba time until the early to middle Corella time in the vicinity of Butcher Creek. Dolerite dykes and sills probably related to these extrusions are found in older rocks.

There is no marked difference in the sedimentary conditions at the beginning of Corella time from those that had prevailed during 'Overhang Jaspilite' time. The middle Corella rocks, however, are much richer in detrital material, which indicates either the presence of an eroding land surface nearby or a marked increase in sediment transport which may have resulted from a climatic change. Carbonaceous shale was deposited in deeper troughs and impure calcareous siltstone and calcarenite continued to be deposited in shallower water. The Marimo Slate is one large sedimentary unit that probably formed in this environment at this time. Current directions in the 'Toby Barty Sandstone Member' are from the south and south-east. Minor volcanic activity occurred near Butcher Creek and in the north-west of the Marraba Sheet area, where submarine pillow basalts were extruded in both areas.

Agglomerate has been recorded in the Corella Formation near the Corella River, but its stratigraphic position has not been determined because of the complicated faulting in this area. The volcanic pile may have been a highland at the time of deposition of the surrounding rocks.

In late Corella time there was a reversion to conditions favouring chemical precipitation, and laminated limestone and calcareous marls were widely deposited.

The Corella Formation is overlain conformably or disconformably by impure fine-grained feldspathic sandstone - the Roxmere Quartzite. The source could be acid and minor basic igneous rocks or reworked quartzo-feldspathic sediments. Transport was probably sufficiently slow for partial degradation of the more labile minerals to take place. Cross-bedding and ripple marks are not common, but indicate a shallow water environment. This appears to have been the final sedimentation of the Lower Proterozoic to Carpentarian sequence in the Marraba Sheet area.

The cessation of sedimentation marks the uplift associated with the first major period of deformation and metamorphism of the area. Broad open folds with north-trending axes developed, and axial plane slaty cleavage was developed in the basic volcanics and slates. Hypabyssal intrusion of acid lavas in extensive sills took place within the Argylla Formation in the south and in the Corella Formation (e.g., 'Tommy Creek Microgranite'). About this time the rocks of the Sheet area were metamorphosed to the lower green-schist to middle amphibolite facies, and continued deformation produced the northeast-trending dextral strike-slip faults in the west. Intrusion of the post-kinematic Naraku and 'Burstall Granites' complicated the structures, and produced contact metamorphic aureoles.

Uplift associated with granite intrusion was followed by a period of erosion and some faulting. The Quamby Conglomerate represents a graben deposit in the relatively stable continental environment. Erosion continued into Phanerozoic time, and the Cambrian erosion surface was onlapped by middle Cambrian limestone that probably covered all the Marraba Sheet area. Some reactivation of old fault lines occurred at this time. Subsequent uplift tilted this Cambrian surface upwards in the north, and the Cambrian has consequently been completely eroded from the area. A Mesozoic or Tertiary erosion surface is represented in the southeast of the area. Tectonism has been almost absent since this time.

## GENERAL ECONOMIC GEOLOGY

Mineral production from the Precambrian of northwest Queensland from 1867 to 1970 has been worth about 1 500 million dollars. A summary of the production of the whole area up to 1959 can be found in Carter et al. (1961). This report deals with the Marraba 1:100 000 Sheet area, which lies within the Cloncurry Gold and Mineral Field. A large number of economic minerals occur in the Sheet area, but only copper, uranium, calcite, and gold have been produced in important quantities. The most profitable mineral has been uranium, which was mined at Mary Kathleen from 1957 to 1963. Copper production up to October 1970, is listed in Table 20.

### Mining and Exploration History

1861 Burke and Wills noted possible gold-bearing quartz in the Selwyn Ranges to the South. Copper was discovered near Cloncurry by John McKinlay.

1866 Ernest Henry mistook iron ore of Black Mountain (Mount Leviathan) for copper.

1867 Henry discovered Great Australia copper deposit, and by befriending the local aboriginals was led to the major outcropping copper lodes in the district.

1867–1872 Gold discoveries south and east of the Marraba Sheet area. Several minor gold rushes took place, but lack of water was a serious problem.

Gold diggings in the Marraba Sheet area were at Bull Creek, Chinaman's Creek, Butcher Bore, and the Duck Creek areas.

1875 Copper discovered near Duck Creek.

Transport cost limited production to ore richer than 30 percent copper.

1880 Proposal to build railway line from Cloncurry to the Gulf of Carpentaria.

1886 New proposal to build railway line to Normanton was accepted. Line to Croydon built instead.

| | |
|---|---|
| 1889 | Cloncurry Gold Field declared. |
| 1890's | Low metal prices reduced activity on the field. |
| 1891-92 | Gold prospecting near the Gorge - Fine Gold Gully. |
| 1898 | Increasing copper prices. |
| 1899 | Cloncurry Gold and Mineral Field declared. |
| 1901-02 | Low metal prices and drought. |
| 1903 | Gold fields of Metabeleland Ltd purchased leases near Duck Creek. |
| 1905 | Willcocks Cloncurry Copper Syndicate began work on leases at Duck Creek and Timberoo.<br><br>More capital being invested and growth in number of companies active in area, e.g.:<br>Celestial Copper and Option Co. (Celestial).<br>Federal Reward Copper Co. (Federal)<br>Leichhardt-Cloncurry Co. (Ivanhoe), and<br>North Queensland Exploration Co. (Mount Lloyd, Ready Rhino, Junction, Forget-me-not). |
| 1907 | Reverbatory furnace built at Slaty Creek, and blast furnace at Mount Start. |
| 1908 | Railway line links Cloncurry to Townsville.<br><br>Queensland Copper Freeholds Ltd takes leases in Duck Creek area. |
| 1918 | Fall in copper prices and industrial trouble. |
| 1919 | Slight revival. |
| 1920 | Copper smelting ceased.<br><br>Gouger activities and tributing continued at small workings. |
| 1927-30 | Federal was producing copper. |
| 1930's | Little mining activity. |
| 1935-40 | AGGSNA did some reconnaissance geological mapping of Marraba Sheet area, and described Federal copper mine. |
| 1947 | Broken Hill South applied for a 1595 sq. mile Authority-to-Prospect near Marraba Sheet area. |
| 1951-57 | Combined BMR-GSQ field parties carried out first systematic geological mapping in the area, and some pilot geochemical and geophysical surveys. |

1953 Private companies allowed to mine uranium.

1954 Extensive uranium search leading to the discovery of the Mary Kathleen deposit and several hundred uranium prospects in the Marraba Sheet.

1950's to present Much company exploration.

1957-63 Mary Kathleen in production.

1969 Current program of detailed regional mapping by BMR-GSQ commenced.

## Mineral Exploration

### The Prospectors

The gold rushes between 1867 and 1872 brought men with some experience in mining to the district. The result was increased prospecting for other minerals besides gold. Rises in the price of copper were one of the strongest influences on mining activity (Fig. 102). There are still some people employed as prospectors by companies exploring the area at present. The most recent resurgence of activity by the individual prospector came in 1954, during the search for uranium.

### The Government

In the 1880's the Queensland Government recognized the growing importance of the mineralized area, and directed R.L. Jack to examine the district with reference to building a railway to the coast. Subsequent reports on mining activities were made by officers of GSQ, and several geological maps were prepared. The Commonwealth Government selected the Cloncurry area for study by AGGSNA in 1935, and they pioneered the use of air-photography in mapping as well as the use of geochemical and geophysical methods in the search for minerals. In 1950 it was decided to systematically map the area, and work began on the Cloncurry 4-mile Sheet in 1952 by a joint BMR-GSQ field party. Companies then had ready access to geological maps as an aid to exploration. The present detailed regional mapping program is a further refinement of the geological mapping of the area.

### The Exploration Companies

Increasing world demand for metals in the early 1950's and the resultant increase in prices, provided sufficient incentive for the larger mining companies to investigate the potential of northwest Queensland. Recognition of the magnitude of the Mount Isa ore bodies and the large number of copper occurrences was an additional incentive for a large-scale systematic search by the companies. In 1947 the Zinc Corporation Ltd took out an Authority to Prospect surrounding the Mount Isa leases, and Broken Hill South Ltd took out five areas between Duchess and Dobbyn, including areas just south and west of the Marraba Sheet area. Mount Isa Mines Ltd (MIM) began a wider exploration programme the following year.

TABLE 19. Work done by Companies on Authorities to Prospect

| Authority Number | | 12 | 84 | 97 | 101 | 128 | 204 | 222 | 232 | 359 | 361 | 362 | 380 | 471 | 495 | 533 | 539 | 575 | 585 | 622 | 646+ | 657+ | 700+ | 701+ | 709+ | 723+ | 740+ | 749+ | 781 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Company | TAMCO | MIM | RIO TINTO | RIO TINTO | RIO TINTO | RIO TINTO | CARP EXP | NORANDA PLACER AUSMINDA | CRA | CARP EXP | KENN ECOTT | KENN ECOTT | CRA | AUSTRAL LONG-REACH | PLACER | MKU | W NUCL | W NUCL | W NUCL | CRA | NICKEL MINES | BRIGGATE INVEST | MINE FIELDS | FIRST INVEST & EXP | PLACER | CARP EXP | CARP EXP | CARP EXP | CARP EXP |
| AIR PHOTOGRAPHS | | | | | | | X | | | X | | | | | | | | | | | | | | | | | | | |
| PHOTO GEOLOGICAL MAP | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | |
| GEOLOGICAL MAP | X | X | | | X | | X | | | X | | | | X | X | | X | X | | | | | | | | | | | |
| DETAILED GEOLOGICAL MAPS OF PROSPECTS | X | | | | | | X | | | | X | | | X | X | | X | X | | | | | | | | | | | |
| STREAM SEDIMENT SAMPLING | | | | | | | | X | X | | X | X | X | | X | X | X | X | | | | | | | | | | | |
| DETAILED GEOCHEM. | X | | | | | X | | X | | | | | X | | | X | X | X | | X* | | | | | | | | | |
| COSTEANING | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| DRILLING Rotary and Percussion | | | | | | | X | | | | | | | X | X | | X | X | | X | | | | | | | | | |
| SHAFTS AND ADITS | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| AIR MAGNETOMETER | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | |
| AIR ELECTROMAG. | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | |
| AIR SCINTILLOMETER | | | X | | | | | | | | | | | | | | | | | X | | | | | | | | | |
| GROUND GEOPHYS. Electromagnetic | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | |
| Magnetic | | | | | | | X | | | | | | | | X | | | | | | | | | | | | | | |
| IP | X | | | | | X | | | | | | | | | X | | | | | | | | | | | | | | |
| SP | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | |
| Radioactivity | | | | | | | X | | | | | | | | | X | | X | | X | | | | | | | | | |
| ANOMALY EVALUATION | X | | X | | X | | | X | | | X | X | X | | | X | | | | | | | | | | | | | |
| DISCUSSION OF MINERALIZATION | X | | | | X | | X | | | | X | X | | | | X | X | | | | | | | | | | | | |
| GENERAL GEOLOGY | X | | | | X | X | X | | X | X | X | X | | | | | X | | | | | | | | | | | | |
| PROSPECT EVALUATION | X | | | | X | X | X | | | | X | X | | | X | | X | | | | | | | | | | | | |

+ Reports not available Dec '70
* Water Bore Analyses

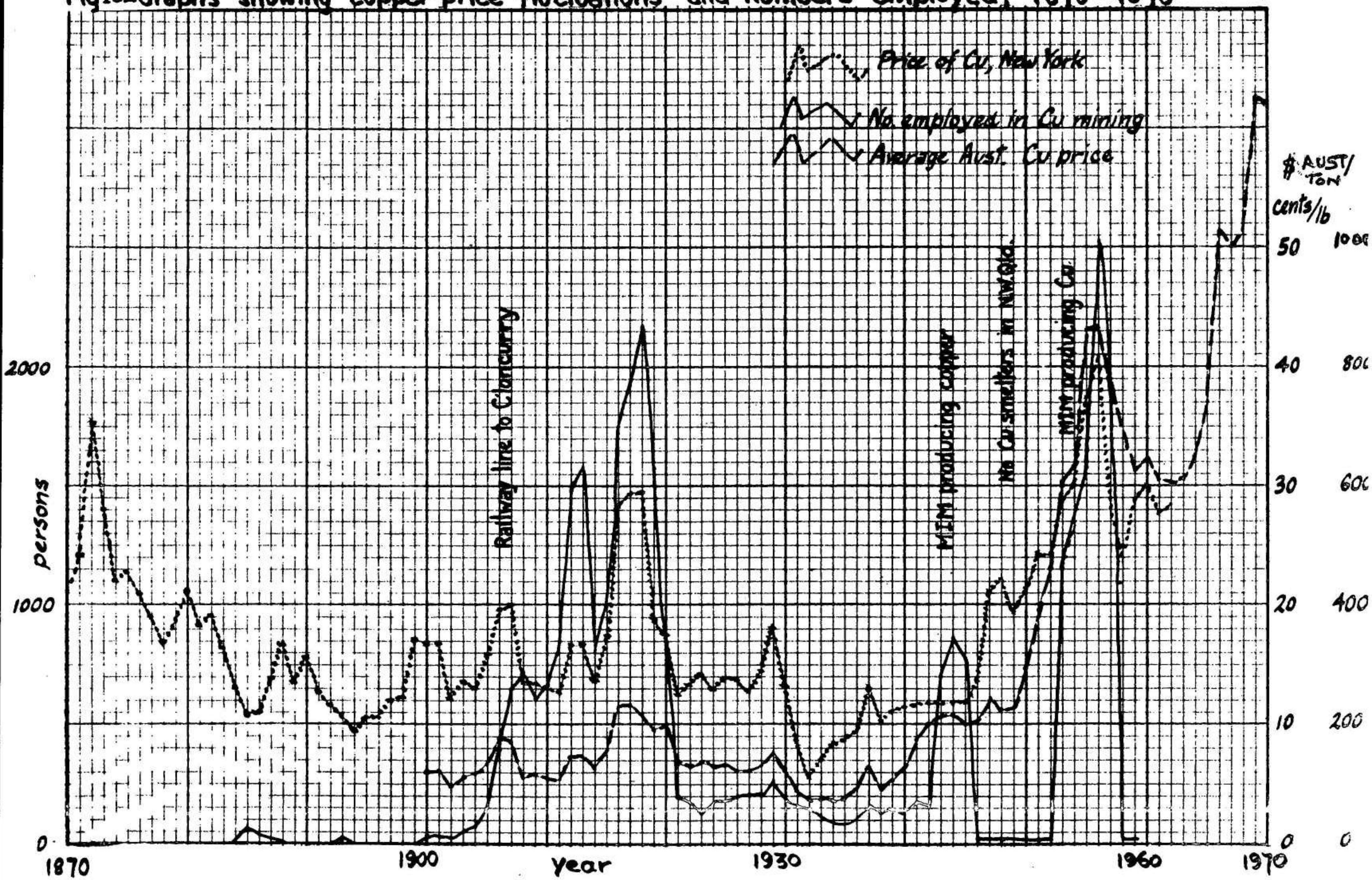
TABLE 20: COPPER PRODUCTION FROM MINES IN THE MARRABA 1:100 000 SHEET FOR 1959 to 13 DECEMBER 1970

| Name of Mine | M.L. No. | Location (Carter et al., 1961, p 300) | Ore (tons) | Copper (tons) | Average Ore Grade % | Years of Production |
|---|---|---|---|---|---|---|
| Albert Hill | 6542 | Cloncurry | 61.4 | 3.9 | 6.3 | 69, 70 |
| Alone Hand | 5785 | Marraba | 16.9 | 1.7 | 10.0 | 67, 70 |
| Apple Pie | (3920 5884 | Argylla | 417.7 | 28.0 | 6.7 | 64, 66, 67, 68, 69 |
| Apple Pie Extd. | 3971 | " | 3.4 | 0.6 | 17.6 | 63, |
| Apple Pie No. 2 | ? | " | 97.7 | 3.5 | 3.6 | 67, |
| Big Jump | 6164 | Marraba | 48.5 | 1.3 | 2.7 | 68, |
| Black Slate | 6216 | " | 29.0 | 2.3 | 7.9 | 68, |
| Bobby Rod | 6211 | Ballara | 303.3 | 20.8 | 6.9 | 68, 69, 70 |
| Bronzewing | 6356 | Marraba | 61.9 | 2.9 | 4.7 | 69, |
| Bulonga | 6192 | Ballara | 718.3 | 29.0 | 4.0 | 68, 69, 70 |
| Bulonga No. 1 | 6192 | " | 7.8 | 0.5 | 6.4 | 69, 70 |
| Cameronian | 6259 | Argylla | 121.4 | 8.5 | 7.0 | 68, 69 |
| Chance | 5007 | Ballara | 43.9 | 4.9 | 11.2 | 64, |
| Chum | 5429 | Cloncurry | 261.9 | 13.5 | 5.2 | 66, 68, 69 |
| Dundee No. 1 | 6114 | | 32.1 | 3.0 | 9.3 | 68, |
| Embla Ridge | 5144 | Marraba | 26.4 | 0.8 | 3.0 | 68, |
| Ethelene | 5434 | Cloncurry | 27.4 | 1.4 | 5.1 | 68, |
| Even Steven | 7897 | Ballara | 145.5 | 22.0 | 15.1 | 70, |
| Fairfield | 5430 | Cloncurry | 751.4 | 47.4 | 6.3 | 68, 69, 70 |

| Name of Mine | M.L. No. | Location (Carter et al., 1961, p 300) | Ore (tons) | Copper (tons) | Average Ore Grade % | Years of Production |
|---|---|---|---|---|---|---|
| Federal | (6395 (5848 | Cloncurry | 373.8 | 30.2 | 8.1 | 66, 67, 68, 69, 70 |
| Jo Jo | 6041 | Argylla | 145.1 | 7.6 | 5.2 | 67, 68 |
| Jubilee | 3997 | Ballara | 1774.8 | 152.4 | 8.6 | 62, 63, 66, 67, 68, 69, 70 |
| Jubilee North | 5190 | " | 324.3 | 20.9 | 6.4 | 68, 69, 70 |
| Junction | 5719 | " | 5.5 | 0.5 | 9.1 | 66, 69 |
| Lady Vera | 5839 | Argylla | 182.2 | 6.6 | 3.6 | 70 |
| Lake Side | 6154 | Ballara | 29.8 | 2.0 | 6.7 | 70 |
| Lake view | 5720 | " | 1210.5 | 73.8 | 6.1 | 65, 66, 67, 68, 69 |
| Lake view No. 1 | ? | Ballara | 7.4 | 0.7 | 9.5 | 67 |
| Magpie | 3854 | Cloncurry | 28.6 | 2.8 | 9.8 | 70 |
| Mona | | " | 33.8 | 2.8 | 8.3 | 69 |
| Mother's Valley | 6181 | Marraba | 21.6 | 1.5 | 6.9 | 68, 70 |
| Mt Colin | 5603 | Argylla | 443.0 | 30.1 | 6.8 | 65, 66, 67 |
| Mt Linsay | 5404 | " | 1871.4 | 216.7 | 11.6 | 61, 62, 66, 67, 68, 70 |
| Mt Linsay Extd | 5418 | " | 334.3 | 34.0 | 10.2 | 63, 67, 68 |
| Mt Linsay South | 5615 | " | 27.7 | 2.3 | 8.3 | 67 |
| Mt McNamara | | Marraba | 88.2 | 3.6 | 4.1 | 69 |
| Narraballa | 5960 | " | 6.9 | 1.0 | 14.5 | 67 |
| Pearl | 6256 | Ballara | 59.3 | 3.1 | 5.2 | 68, 70 |
| Pommern (& No. 2) | 6321 | Ballara | 176.5 | 13.5 | 7.6 | 70 |
| Red Sierra South | 5787 | Marraba | 104.7 | 1.5 | 1.4 | 68 |

| Name of Mine | M.L. No. | Location (Carter *et al.*, 1961, p 300) | Ore (tons) | Copper (tons) | Average Ore Grade % | Years of Production |
|---|---|---|---|---|---|---|
| Riena Adriana | 6241 | Argylla | 270.8 | 15.0 | 5.5 | 68, 69 |
| Roos | 6063 | Ballara | 22.5 | 1.4 | 6.2 | 68, 69 |
| Sunday's Folly | 6261 | | 53.0 | 4.1 | 7.7 | 68, 69, 70 |
| Telegraph | | Marraba | 120.9 | 9.9 | 8.2 | 69 |
| Timberoo | 6322 | Marraba | 56.5 | 9.0 | 15.9 | 69, 70 |
| Toby Barty | 5455 | Marraba | 92.3 | 3.4 | 3.7 | 66, 67, 68 |
| Tom Cat | 5929 | Argylla | 460.1 | 25.0 | 5.4 | 66, 67, 68, 69 |
| Trafalgar | 5399 | Ballara | 1758.6 | 104.4 | 5.9 | 66, 67, 68, 69 |
| Wonder Valley | 5815 | Cloncurry | 29.7 | 4.6 | 15.5 | 62, 63, 69, 70 |
| Wollondonga | 4866 | Argylla | 411.6 | 19.2 | 4.7 | 68, 69 |

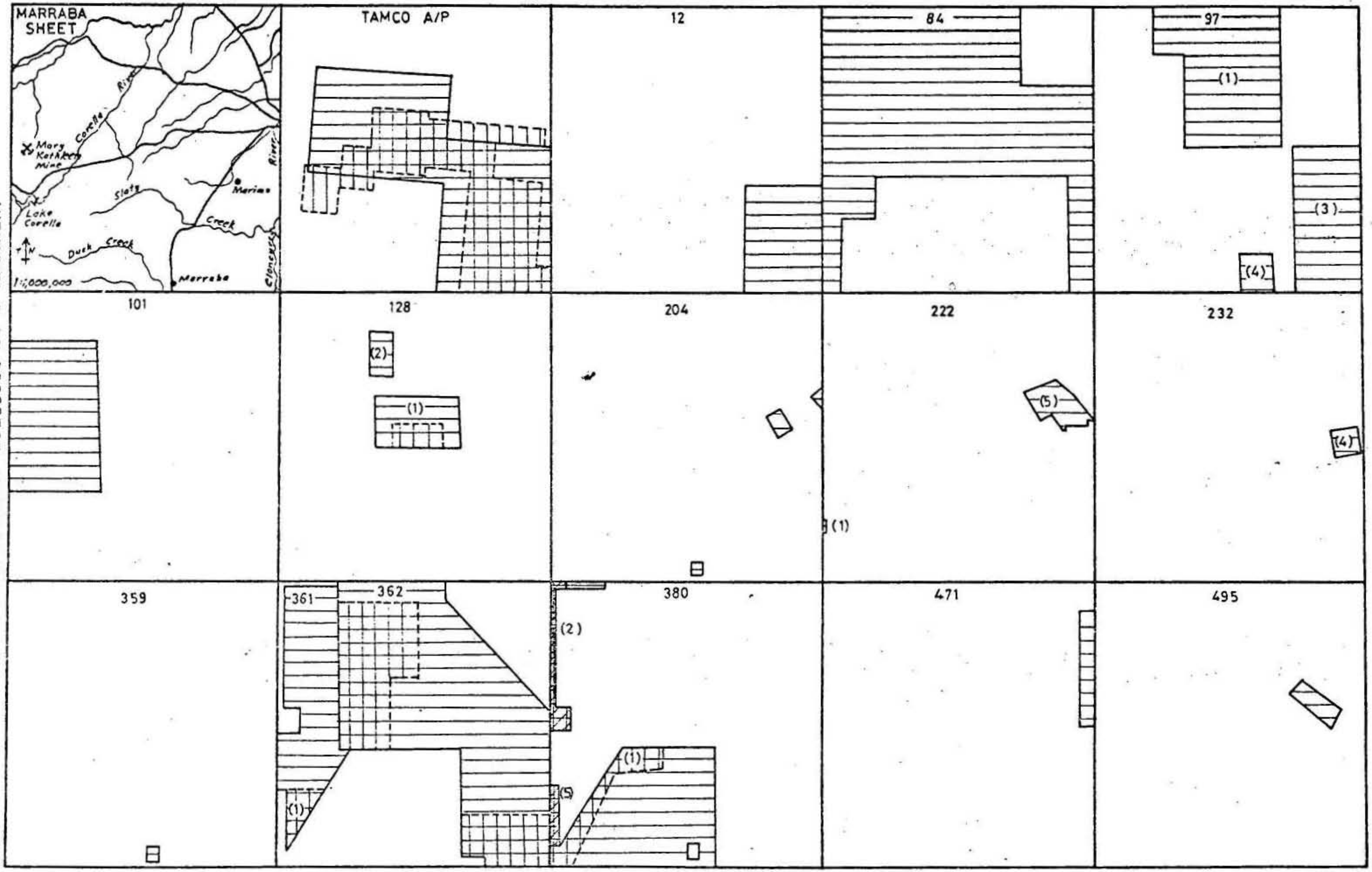
Fig 102 Graphs showing copper price fluctuations and numbers employed, 1870-1970



To accompany Record No. 1971/56.

AUTHORITIES TO PROSPECT, MARRABA SHEET AREA.

FIG. 103 a

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To accompany Record No. 1971/56.

AUTHORITIES TO PROSPECT, MARRABA SHEET AREA

Fig. 103b

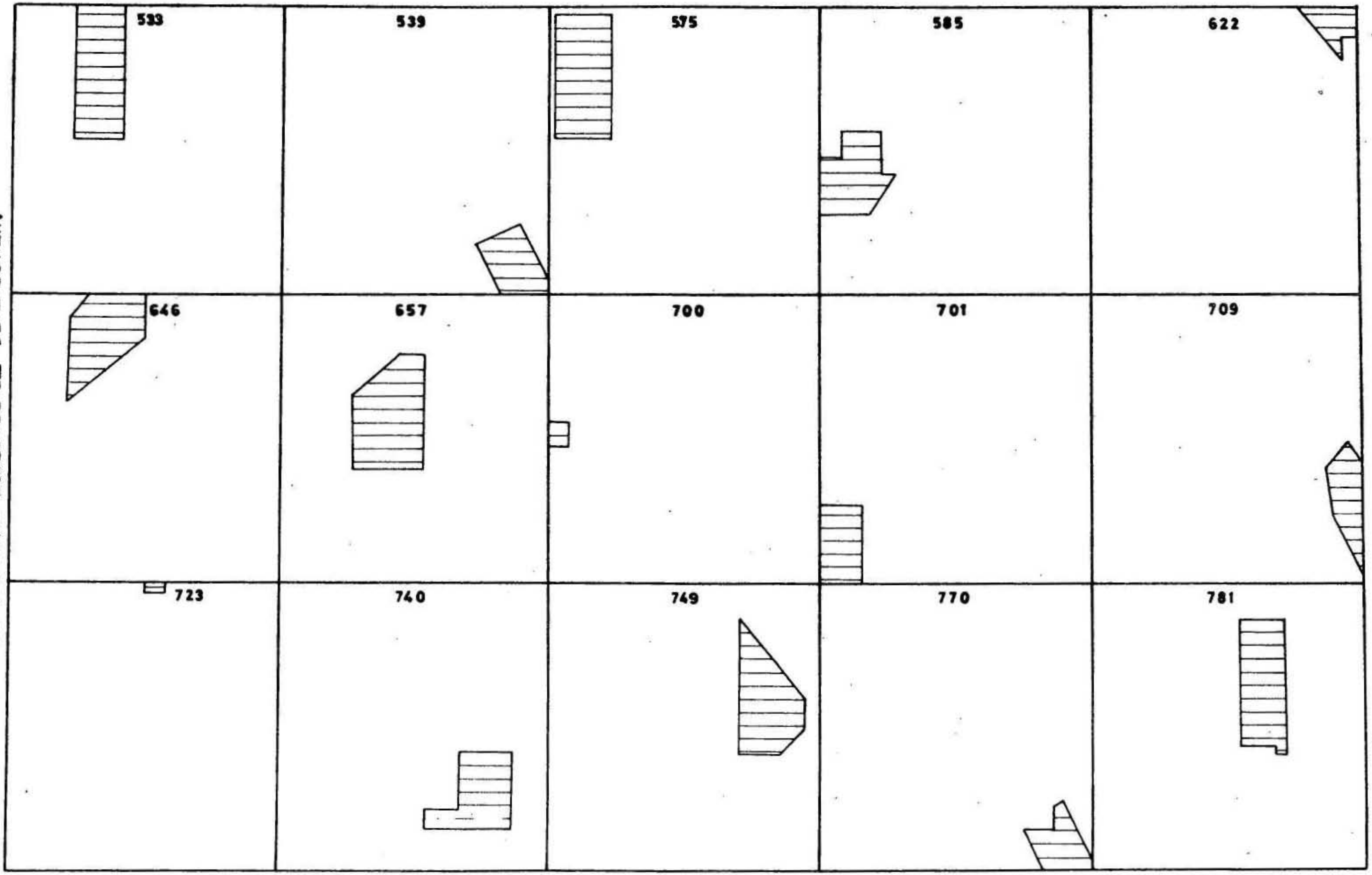


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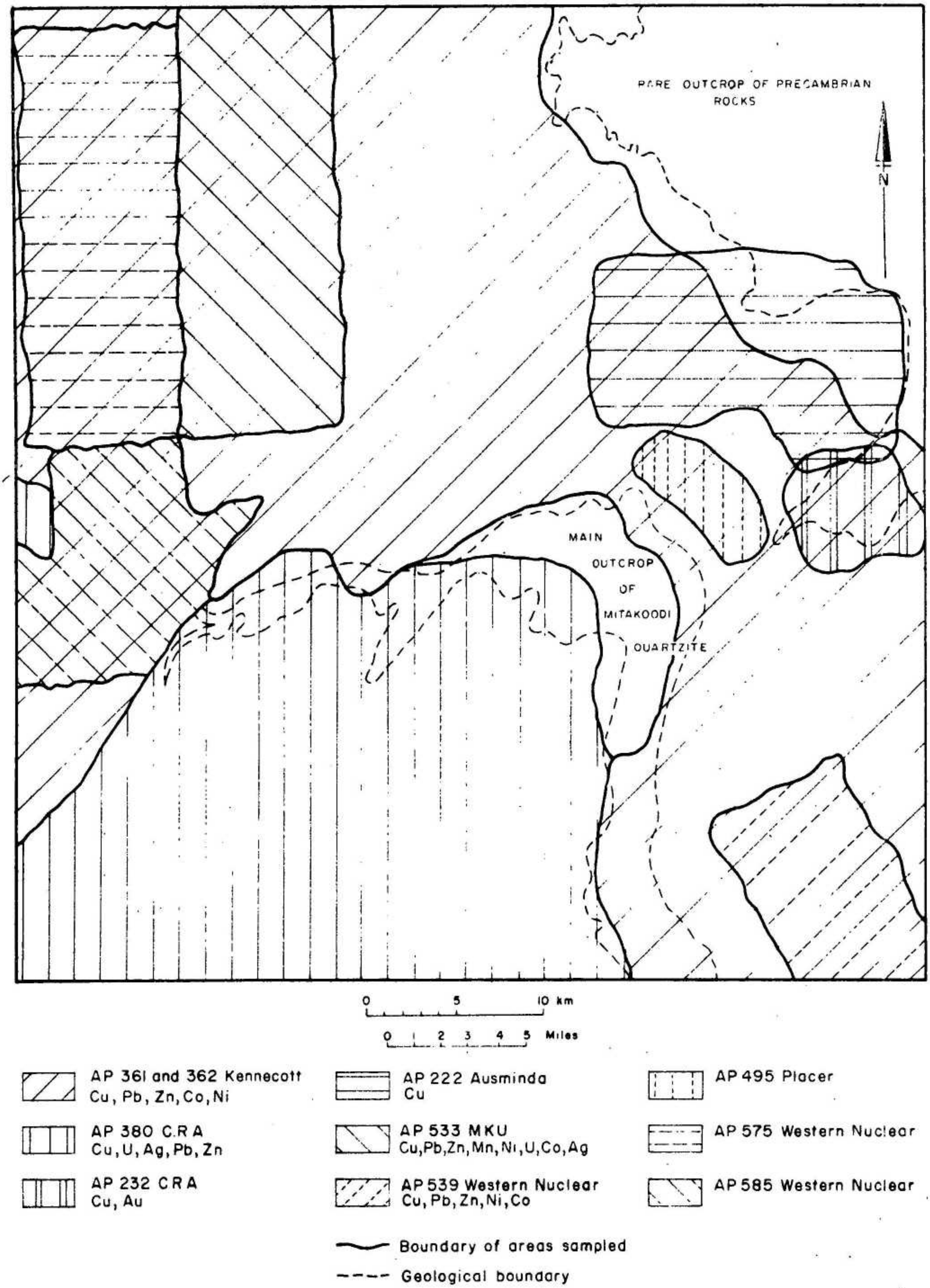
Fig 104 Geochemical stream sediment sampling, Marraba 1:100 000 Sheet area




*To accompany Record 1971/56*

*F54/A2/83*

The first Authority to Prospect in the Marraba Sheet area was taken out by Broken Hill South in 1947, but no reports on these areas exist. In 1953 Titanium Alloys Manufacturing Co. (Tamco), a subsidiary of National Lead Co. was granted a large ATP, and this and 29 subsequent Authorities to Prospect taken out over parts of the Marraba area up to November, 1970, are shown in Figures 103a and b. Table 19 summarizes the exploration techniques employed by the companies who held each Authority.

The exploration motives of companies active in the Marraba Sheet have changed as external conditions varied, and it is possible to recognize four periods in company exploration:

(i) The early companies (TAMCO and MIM) were searching for lead-zinc. Following the location of lead-zinc, geochemical anomalies in carbonaceous shale north and south of Mount Isa, and in the Dugald River area by the BMR (Debnam, 1953) these companies took out ground that encompassed large areas of carbonaceous shale (Ivanac, 1953a, b; 1954a, b, c, d; Pennebaker, 1955; Quirk, 1953; Allen, 1956, Knight, 1955). Their methods involved geological mapping, selecting prospects, detailed geochemistry and geophysics, and some diamond drilling.

(ii) The easing of government restrictions on the mining of uranium in 1953 resulted in extensive surface exploration by syndicates and individuals. The discovery of uranium in 1954 at Skal (north of Mount Isa) in a sequence of metamorphosed sediments and basalts influenced Mount Isa Mines Ltd to undertake an airborne scintillometer survey concentrating on the Eastern Creek Volcanics and equivalent 'greenstones' which included the Marraba Volcanics in the Marraba Sheet area (Bennett, 1955). Rio Tinto Australian Exploration used a helicopter in their scintillometer survey of Authority to prospect 84(M) which covered most of the Corella Formation (Searl & McCarthy, 1958).

BMR investigated the country rocks adjacent to granite intrusions, and did some tests with an airborne scintillograph (Parkinson, 1956). As a result of these surveys covering northwest Queensland, about 1 000 radio-active anomalies were located by surface or airborne exploration; about 100 of these were located in the western half of the Marraba Sheet area.

(iii) Copper was the next "boom" mineral, and several companies undertook large-scale geochemical surveys in the Marraba Sheet area. Stream sediment samples were analysed for copper and in some cases for uranium, silver, lead, zinc, cobalt, nickel, and gold. Numerous anomalies were located and investigated. Companies involved in this activity since 1966 have included Ausminda, Conzinc Rio Tinto Australia Ltd, Kennecott, and Western Nuclear. Figure 104 shows the areas and types of geochemical surveys carried out.

(iv) A continuing upward trend at the Stock Exchange from the late 60's to mid-1970 was responsible for numerous new companies entering the mining and exploration industry. The intensity of the rush for land by both new and established companies in the Marraba Sheet area and the surrounding country can be gauged by the increase in the number of applications for Authorities to Prospect. In the years 1953 to 1968 only 18 Authorities were granted in the Marraba area, half of these being granted in the last two years of the period. However, in the following year 10 authorities were granted, as well as many hundreds of leases.

This activity was Australia-wide, and one of its effects was to overtax the capacity of the Queensland Department of Mines. Delays of up to one year were common between the application for and the granting of an Authority to Prospect. In this interval genuine prospectors and shrewd "Land Merchants" pegged leases in areas with better economic potential. As leases took only a month for approval, the company that had applied for an Authority to Prospect often found that it had lost much of the promising land, thus adding greatly to exploration costs because of the high prices of options over the unexplored leases. Two solutions to this problem developed: a company wishing to explore a large area would peg a solid block of adjoining leases at the maximum size of 320 acres (approx. 1.28 $Km^2$), but at a considerable cost for survey and lease fees. The second approach was for the company to take out options only over known producing mines, and in some cases to extend the size of these leases.

The techniques used by the exploration companies (Table 19) can be divided into large-scale and detailed methods. The large-scale methods have included geological mapping and stream sediment geochemistry and to a lesser extent airborne magnetometer, electromagnetic, and multiband gamma-ray spectrometry surveys and regional gravity surveys. Air-photography has been widely used, and a summary of the coverage of Marraba Sheet area can be found in Figure 2. Air-photography has been used for the preparation of photogeological maps, and as a basis for geological mapping. Coloured air-photography has been a great asset in the present geological mapping, because quartz veins, gossans, calcsilicate rocks, carbonaceous slate, and prospective rock types (e.g., dolerite) can be clearly and quickly distinguished. The detailed techniques used by companies have involved detailed mapping of workings and prospects, geophysical investigations, geochemical techniques such as soil sampling and costeaning, and percussion and diamond drilling (see Table 19).

Our observations of mines in the Marraba Sheet area indicate that the earlier workings which were restricted to shafts and hand-cut costeans have rapidly been covered by the natural vegetation. Even the copper lodes which produced more than 500 tonnes of ore (i.e., Federal, Mount McNammara, and Chinaman) have reverted towards their original condition during the last 50 years. Larger mining ventures that have taken place more recently include the "limestone" quarries and the Overhang manganese mine which have produced very little waste rock, and the Mary Kathleen open cut which has been carefully planned by practical use of much of the 7 million tonnes of waste rock (e.g., as foundations and road metal), and by adequate provisions for treatment and plant tailings. Recent exploration has involved extensive use of bulldozers for costeaning and cutting more elaborate access tracks, especially to drilling sites. In many cases this activity has been excessive in comparison to the apparent size of the prospects.

## Conclusions

To date, large-scale exploration has failed to find any worthwhile deposits within the Marraba Sheet area. This is partly due to the nature of mineralization in the area, which is discussed in the following section. The early prospectors found the obvious exposed secondary copper deposits, and ferruginous zones were investigated as possible gossans (e.g., Mount Isa Mines work on the 'Overhang Jaspilite', which was thought to be a gossan equivalent to the gossan at Mount Isa (Allen, 1956; Knight, 1953)). Geochemical techniques have provided information only on exposed mineralization, and geophysical techniques are not yet sufficiently sensitive to adequately define hidden ore bodies in the type of environment represented by the Cloncurry - Mount Isa area. It is hoped that detailed geological mapping may provide sufficient control to allow meaningful interpretation of geochemical and more detailed geophysical results. This, together with a better understanding of the controls of mineralization, could help in thelocation of the two most obvious exploration targets which suggest themselves, i.e., large low-grade deposits at or near the surface, and relatively small, rich, buried deposits.

## DETAILED ECONOMIC GEOLOGY

A wide variety of minerals has been found in the Sheet area. The value of production shows uranium as the most important mineral, followed by copper, calcite, gold, manganese, cobalt, bismuth, and baryte. Other deposits include iron ore and subeconomic fluorite. The type of mineralization is closely related to the geological formations, e.g., copper deposits are more abundant in the Marraba Volcanics and younger formations, whereas lead-zinc and uranium occurrences are restricted to certain parts of the Corella Formation and its equivalents. A number of metals and their ores that are found in the Marraba Sheet area are discussed in alphabetical order below. This is followed by a section on non-metallic minerals.

### Metallic Minerals

#### Antimony

Antimony is rare, but minor amounts of tetrahedrite have been recorded from the Rainbow and Chinaman copper mines in the Marraba area (Dunstan, 1913).

#### Arsenic

Arsenic is associated with cobalt, for example at the Success copper and cobalt mine. Arsenopyrite is widespread in the Kuridala area (Rayner, 1938; Rayner & Nye, 1936), but in this Sheet area the only occurrence known is fine-grained arsenopyrite in porphyritic rhyolite, 2 km northwest of Milo.

#### Barium

Baryte is almost completely restricted to the 'Overhang Jaspilite' in which it occurs as veins up to 2 m wide and several hundred metres long. Numerous veins are found in the valley to the west of the Overhang manganese deposit, and one large vein has been mined in the vicinity of Butcher Creek just south of the Barkly Highway, where only a few hundred kilogrammes were extracted from an open pit. Here the baryte forms massive aggregates in breccia, and strain lamellae in the baryte rhombs suggest that faulting accompanied baryte crystallization. The deposit extends for 35 m along a fault ridge, and tongues of baryte extend across the ridge to the south.

#### Bismuth

Carter et al. (1961) state that bismuth is found in a few places in the south-central sections of the Cloncurry Mineral field closely associated with gold, and that the only production has come from the Lone Hand (?Alone Hand) mine. This mine is situated near the southern Marraba Sheet, boundary 3 km west of Marraba rail siding. The production of this mine from 1931-36 period was 59 tonnes of ore yielding 0.52 tonnes of bismuth, 2.8 tonnes of copper, and 907 g of gold. The gossan contained copper carbonates and secondary sulphides, and the primary ore consisted of chalcopyrite, pyrite, bismuthinite, and a little siderite in a gangue of siderite, quartz, and hematite.

The country rock is metabasalt, and the deposit is in a shear-zone striking 023°, and dipping 46° to the east. The deposit was worked to a depth of about 30 m and over a strike width of 30 cm to 1 m (Shepherd, 1932a).

Another record of bismuthinite within the area is from Slaty Creek, north of Marraba. Native bismuth has been reported from a quartz leader at the Two Mile diggings (Rands, 1895), as well as the Soldiers Cap area (Cloncurry 1:250 000 Sheet).

Cobalt

Cobalt deposits are virtually confined to a north-trending belt from Kajabbi to Selwyn which includes Mona Cobalt mine 1 km from the Federal copper mine (Brooks, 1957) and the Success mine in the Sheet area. The latter produced 5.4 tonnes of ore from 1929 to 1931. Carter et al. (1961) concluded that there was no stratigraphic control, but noted a close association with basic igneous rocks now recognized as dolerites. Strike faults and shears have localized the deposits at the contact of rock types of different competence.

Copper is commonly associated with the cobalt deposits. At the Success mine cobaltite was associated with chalcocite, bornite, chalcopyrite, pyrite, and small quantities of nickel (0.57% Ni) (Rayner, 1938).

Copper

Carter et al. (1961, p. 203) gave a valuable summary of the history and production of copper in northwest Queensland.

Production of copper from the Marraba Sheet area began in the early 1880's from deposits in the Duck Creek area. There was increased activity from 1906 in the anticipation that rail facilities would greatly reduce transport costs. Most of the larger deposits within the area were discovered and worked during this boom period, which continued until 1920. Subsequent production was sporadic, being controlled by prices and the presence of a copper smelter at Mount Isa from 1943-46. The reserves of the major mines at their time of closure (Nye & Rayner, 1940) were the prime targets for exploration companies in the period 1947-1954, and in 1953 the completion of the new copper smelter at Mount Isa resulted in a revival of copper mining.

The total production of copper from the Cloncurry and Mount Isa Mineral Fields to the end of 1969 was 958 754 tonnes, eight-ninths of which was produced from Mount Isa. The largest copper producers to October 1970, in the Marraba area have been the Federal (1 021 tonnes), Mount McNammara (622), Mount Linsay (257), Trafalgar (172), Timberoo (139), Dolomite (132), Success (108), Asia (107), Pioneer (93), and Diagonal (58). The grade of ore produced to 1920 averaged 25 percent copper; Timberoo, Mount Mindie, and Success produced much richer ore (about 35%). Several shipments from Timberoo contained 45 percent copper. Most of the recent ore has assayed between 5 and 12 percent copper (see Table 20).

Fig. 105 Comb-structured quartz crystals in siliceous hematite, 1.5 km northeast of Pioneer Chief mine, Duck Creek area
M 909/22A GMD

Fig. 106 Zoned vein containing quartz core and carbonate margin, with streakes of black powdery hematite after ?pyrite. Location 3 km west of Ida mine
GA 2698 GMD

Distribution

Copper is widely distributed throughout the Sheet area. Mines are concentrated in the Marraba Volcanics near Duck Creek to the west of Marraba siding, and at the Timberoo group (of mines) of Ball (1908), to the north. There are other groups of workings located in the Corella Formation, such as the Chum and Federal groups to the northwest of Cloncurry, and near the western margin of the sheet in a linear belt of deposits extending from Wollondonga to Trafalgar. South and southwest of Cloncurry, copper deposits occur in the Marimo Slate. Some characteristics of these groups are listed below.

(a) Marraba Volcanics (Duck Creek-Timberoo area)

With only one or two exceptions, the deposits in this group are in quartz veins which trend from $35^{\circ}$ to $110^{\circ}$, with a maximum at about $85^{\circ}$. These veins are from 1 to 10 m thick, and commonly show boudinage and en echelon structures; they dip steeply to the south in most cases, and intrude amygdaloidal and massive basalt. Dolerite is also associated with the veins.

Most of the quartz veins contain massive milky quartz with mineralized fractures, quartz crystals showing comb structures (Fig. 105), siliceous limonite gangue (a fine-grained flinty brown rock), and masses of siderocarbonate (brown calcite). Some of the veins show a marked zonation (Fig. 106) from quartz cores to carbonate margins. Both footwall and hangingwall of the quartz reefs consist of chlorite schist and phyllonite with fine-scale quartz veining. Further details of individual mines or prospects are listed in Appendix 2. The major copper minerals in this group are malachite, chalcocite, and minor chalcopyrite.

(b) Corella Formation

The abundance of copper deposits in the Corella Formation reflects the number of small dolerite sills and pipes intruding the Formation, particularly in the area of the Chum group. Along the western margin of the area, both dolerite and granite bodies are closely associated with mineralization. Calcite is a widespread gangue in these deposits, and malachite and chalcopyrite are the major copper minerals. Apart from deposits in slate at the Federal mine, there are two other occurrences of copper which are possibly syngenetic and apparently unrelated to igneous bodies. One occurs 3.5 km north of Timberu homestead, along the Timberu-Wollondonga track, and consists of sporadically mineralized scapolite-calcite granofels. The main ore minerals are chalcopyrite, chalcocite, native copper, tenorite, covellite, cuprite, and malachite, forming blebs 1 to 4 mm across. The zone of mineralization is about 10 m thick, and extends sporadically along strike for 300-400 m, but could extend for many kilometres. Chip and grab sample assays range from 0.1 to 0.5 percent Cu and the zone is considered prospective.

The other is in limestone in the Mary Kathleen syncline; chalcopyrite and pyrite are widely disseminated in a zone 400 m long and 10 m thick, just east of Elaine Dorothy. Altered dolerite cutting the limestone has recrystallized the chalcopyrite into larger blebs at the contact.

(c) Marimo Slate

Copper deposits in the Marimo Slate are notably different from those in other areas and environments. They are fairly small, and are confined to silicified zones or fault and fracture-zones in slate. Narrow quartz reefs in the ore-zone contain mainly malachite, and the wall rock commonly contains azurite, malachite, and chrysocolla. To date only minor sulphide mineralization has been intersected by drilling, and continuation of the secondary mineralization below the water table is slight (Crabb, pers. comm.). In the Red Sierra South group there is a marked transition from leached kaolinitic hanging wall shale to mineralized quartz reef, to azurite-bearing carbonaceous black shale footwall (Fig. 107).

The degree of silicification in slate is probably greater than elsewhere, and is reflected by the abundance of chrysocolla in the secondary copper mineral suite in many of the deposits, e.g., Black Slate, Sweet William. Native copper occurs in black slate at the Young Australia mine, in the Malbon 1:100 000 Sheet area, and appears to be related to graphite rich microshears in the ore-zone (Crabb, pers. comm.). Similar relations could occur in carbonaceous slates in the Marimo area.

Surface expression of copper deposits

Mineralization in the Duck Creek area and Timberoo group is associated with quartz veins which are upstanding because of their greater resistance to weathering than the surrounding basic volcanics. Similar but smaller-scale expression is found in the 'Wakeful Basalt Member' of the Mitakoodi Quartzite. Within the Corella Formation copper is generally associated with calcite veins which do not have any marked relief. In slate of the middle Corella Formation and the Marimo Slate, deposits range from coatings and minor veins in virtually unaltered slate, to large, upstanding, silicified fault zones rich in iron oxides and hydroxides (e.g., Mount McNamara).

Carter et al. (1961) report that gossans occur at many deposits, but have poorly developed boxworks. They attribute this to the low grade of the primary ore bodies. Limonite (some manganiferous) and quartz (in many cases chert replacing calcite) are commonly associated with lode outcrop. Malachite, chrysocolla, and azurite commonly occur at the surface.

Secondary Ores

Secondary ores have been the most productive in the Marraba Sheet area, and are considerably richer than the primary ores. The depth of the oxidized zone depends on the water table, and varies in different localities from 10 m to 100 m but is typically in the range 30 to 45 m. The zones of secondary enrichment are very close to present or fossil water tables, and occur irregularly as small pockets rather than continuous zones.

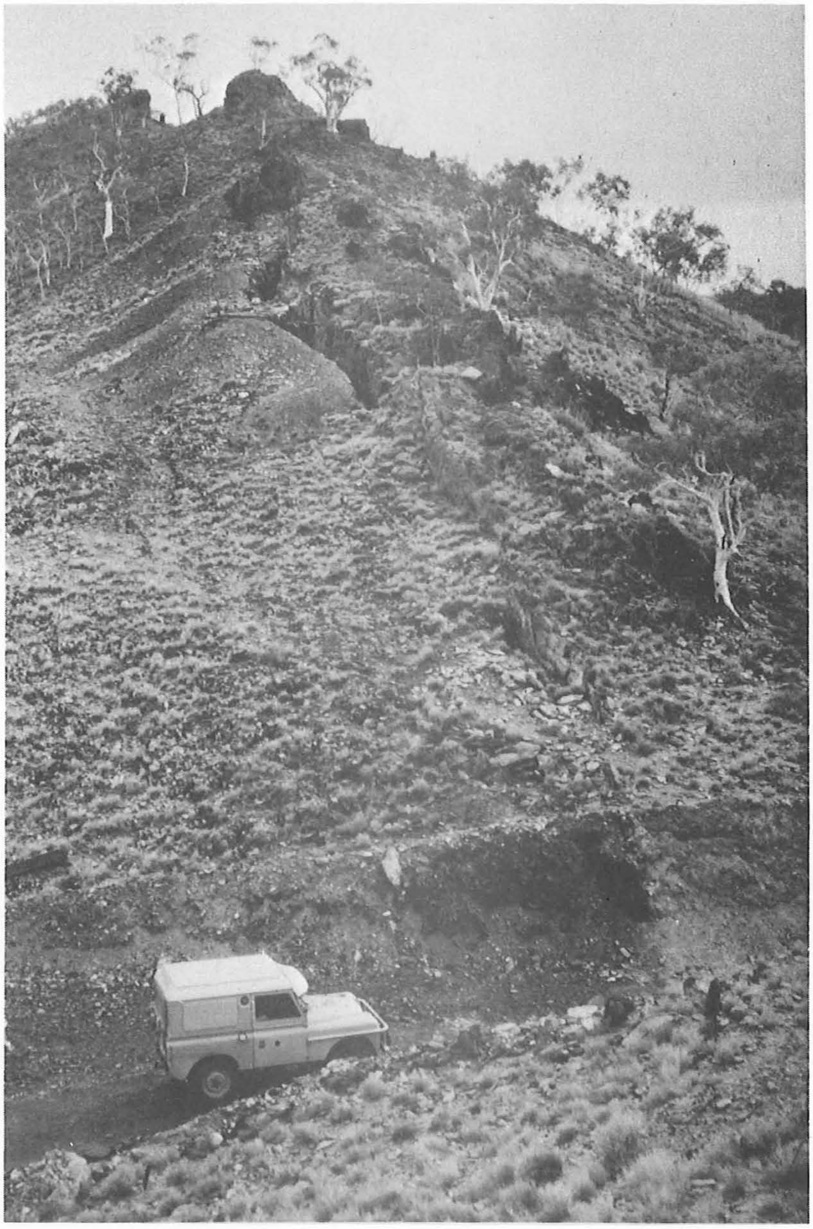


Fig. 107 Lode and workings at Red Sierra South copper mine; hanging wall (right) is bleached and kaolinitic and footwall (left) is black and carbonaceous

GA2736 GMD

The common minerals are malachite, chrysocolla, chalcocite, azurite and cuprite, although native copper, bornite, tenorite, and covellite occur in minor amounts in some deposits. Typical associations are fine-grained chalcocite-malachite aggregates and cuprite-limonite ('tile') ores. Gangue minerals are commonly quartz, limonite, and calcite.

Primary Ores

Most of the earlier mines did not penetrate the primary zone because of lower grade. The primary ore is essentially chalcopyrite with varying small amounts of pyrite, and rarely exceeds 5 percent copper. The gangue minerals are quartz and ?calcite.

Controls of Mineralization

No single control of mineralization is evident and most deposits are controlled by combinations of lithology, stratigraphy, and structure.

Stratigraphic Control

Copper mineralization is distributed widely throughout the Sheet area, but the Argylla Formation, Roxmere Quartzite, and arenaceous units of the Mitakoodi Quartzite are almost devoid of known copper deposits. One stratum which is an exception to this generalization is the uppermost part of the Argylla Formation near the western border of the area, which contains the Jubilee and Lakeview mines. The mineralized zone is within a few metres of the unconformity between the Argylla Formation and Corella Formation, and is very prominent in the adjoining Mary Kathleen Sheet area, where the Corella Formation is partly equivalent to the Ballara Quartzite.

Units such as the 'Cone Creek Volcanic Member' and the 'Wakeful Basalt Member' contain large numbers of mines, prospects, and mineral occurrences. Although dolerite dykes intruding these units play a major role in the formation of economic deposits, the local chalcopyrite-bearing basalt country rock could have augmented the copper originating from dolerites.

Slate and limestone of the Marimo Slate and Corella Formation provide some lithostratigraphic control of mineralization, and some characteristics of these deposits have been described above. In the absence of igneous bodies intruding slate, it is possible that copper was incorporated in trace amounts of slate (and limestone) during deposition, and later concentrated by structural controls and supergene processes.

Mineralogical Control

Large calcite veins and masses which are widespread in the area provide a favourable host for precipitation of copper minerals from mineralizing fluids. Chalcopyrite occurs as nodules with minor malachite, and the presence of chalcopyrite at the surface of many calcite deposits, and the lack of supergene enrichment, reflect the non-reactive nature of the calcite under dry climatic conditions.

The presence or absence of evaporite minerals (e.g., halite) in calcareous rocks of the Corella Formation may have contributed indirectly to ore formation, as assimilation of such material by dolerite, etc., could produce highly salite hydrothermal fluids, which are commonly associated with ore deposition.

Structural Control

Many ore deposits are restricted to faults and shear-zones. Faults with a northerly trend seem to be preferred by mineralization, except in the Duck Creek area, where quartz-filled shears trending 85° are commonly mineralized. Location of ore-deposits along these faults is often controlled by transverse faults with displacements of a few metres (e.g., in the Marimo Slate).

Mineralogy

The primary copper mineralization generally consists of simple sulphides of iron and copper; these are accompanied by complex arsenides and antimonides in some deposits. The resulting oxidized minerals are thus relatively simple. Enriched sulphides, oxides and carbonates of copper are common, together with hydrated silicates, sulphates, and phosphates. Gangue minerals are usually quartz or calcite or both, but dolomite, siderite, kaolin, chlorite, hematite, sericite, biotite, actinolite, scapolite, magnetite, diopside, tourmaline, fluorite, apatite, psilomelane, baryte, epidote, garnet, and sphene occur in some deposits.

Ore Genesis

Previous authors have resorted to a wide variety of theories to explain the copper deposits of the Cloncurry - Mount Isa area. It has not been possible to exclude some of these theories, as mining has rarely proceeded below the supergene zone, resulting in a lack of details of the primary ore. Supergene enrichment is displayed by almost all deposits, but the existing evidence indicates that most primary deposits were epigenetic. Theories belonging to the following classes are discussed below:

(i) magmatic
(ii) hydrothermal
(iii) contact metamorphic
(iv) regional metamorphic
(v) sedimentological, and
(vi) structural.

(i) Magmatic

Copper concentrations of up to 1 320 ppm occur in basic igneous rocks (Table G, Appendix 2). Hand-specimen and polished section studies of the Marraba Volcanics and dolerite dykes have established the presence of blebs of sulphide minerals which probably formed as an immiscible sulphide phase. Because copper is a chalcophile element, it will be preferentially concentrated (partitioned) in the sulphide phase of the melt (Wager & Brown, 1968). The copper-rich sulphide phase could have been separated from the crystallizing silicate phase by filter-press action (Park & MacDiarmid, 1964) and deposited in adjacent fractures. If this action was accompanied by introduction of silica or calcite it could adequately account for numerous mineralized veins in which the copper is present as relatively simple sulphides.

The granites of the region contain less copper than do the basic intrusive rocks, and rarely contain visible sulphide minerals. The absence of ferromagnesian minerals that could take up some copper in the lattice (e.g. pyroxene) leads to its concentration in the melt phase as crystallization proceeds, and it may therefore move with hydrothermal fluids.

(ii) Hydrothermal

As crystallization of an igneous rock nears completion, the vapour pressure of the magma increases, forcing volatile material out into country rock. Fractures ranging from cooling joints to major lineaments are the conduits for these hydrothermal fluids. Decreasing temperature away from the intrusion leads to precipitation of hydrothermal minerals; pressure and the chemistry of the country rock would have some control on the minerals deposits.

Throughout the Marraba Volcanics, dolerite dykes cut the amygdaloidal basalt, and the dykes are cut by quartz veins. Many of these veins are mineralized, and it is suggested that the primary copper mineral was mainly chalcopyrite, and that the veins were emplaced as a result of hydrothermal activity from dolerite. The presence of minor amounts of tourmaline, bismuthinite, molybdenite, scheelite, cobaltite and tetrahedrite are compatible with a hydrothermal mode of origin and suggest that the veins were rather high-temperature and high-pressure types belonging to the hypothermal or mesothermal zones (Park & MacDiarmid, 1964, p. 12). Many of the minor minerals listed above are also commonly associated with acid dykes etc., none of which are found in the Marraba Volcanics.

Hydrothermal emanations from the 'Burstall Granite' may be responsible for copper mineralization, especially in the Wollondonga area. This area contains numerous fine-grained acid rocks and pegmatites, and could represent thin cover above the cupola of an acid pluton. Mineralized breccia pipes or porphyry-copper type deposits could possibly exist in this area.

The abundance of metallic chalcocite (which is apparently of primary origin) in the Mary Kathleen area, and minor occurrences in the basalt member of the Mitakoodi Quartzite, suggest low-temperature deposition (epi-or telethermal). However, no tendency for these deposits to be strata-bound has been noted.

(iii) Contact metamorphic deposits

These are similar to hydrothermal deposits in that the volatiles may be forced through earlier-crystallized margins of plutons, and permeate porous country rock. This results in uniform dissemination and subsequent concentration of ore minerals in favourable rocks (limestone) or structural settings (fault intersections, saddle reefs). These concentrations would be difficult to distinguish from hydrothermal deposits.

One local variation of this concept is that the vapours may encounter evaporite deposits, thereby generating saline fluids which act as strong solvents (Ellis, 1967), scavenging copper from carbonaceous shale in restricted basins and from other rocks rich in copper, e.g., basic lavas. The abundance of scapolite over most of the Sheet area is considered to be supporting evidence for the former presence of evaporites in the younger Lower Proterozoic sediments in this area.

Where large dolerite dykes intrude limestone, the limestone may be mobilized - perhaps partly dissolved by the volatiles, and later reconstituted and redeposited. That these deposits have formed after most of the dolerite has been intruded is inferred from the presence of blocks of dolerite within calcite at most of the limestone mines in the area, e.g., Wilgar. Extensive zones of (?)sidero-calcite around these blocks suggest that conditions were such that some redistribution of iron could take place. Chalcopyrite is found as large irregular masses in these limestone deposits.

(iv) Regional metamorphism

Regional metamorphism causes the breakdown and reconstitution of silicate and other minerals. If these originally contain absorbed or lattice-bound copper, it is possible that the newly formed minerals could not accept all the available copper in their lattices. Experimental evidence suggests it is unlikely that ionic diffusion alone could lead to concentration of copper deposits of economic size (Bateman, 1959). However, loss of volatiles may accompany thermal and regional metamorphism, and substances such as $CO_2$, $H_2O$, $Cl_2$, and NaCl could transport copper and other elements to locations favouring precipitation. Ball (1908) considered that regional metamorphism had concentrated copper from "originally cupriferous igneous rocks".

Intense regional metamorphism can also lead to partial melting. If the rock contained copper, the resulting magma could be enriched in copper. Alternatively, a granitic magma may be enriched by assimilation of basic rocks. These processes could have occurred in the Cloncurry Mount Isa district, but poor spatial correlation between granites and copper deposits has already been noted: the exception is the 'Burstall Granite".

(v) Sedimentological

Copper is ubiquitous in sedimentary environments, although concentrations are usually low, e.g., 30 ppb in ocean water (Goldberg, 1965). The concentration of copper entering a sedimentary environment could be increased by detritus from copper-rich terrains (e.g., basalt) or by juvenile waters from nearby contemporaneous volcanic activity. It is difficult to verify if such processes operated in the Cloncurry Mount Isa area, but the ideas have not been rejected as there was widespread basic volcanic activity in the Marraba Sheet area from Marraba Volcanics time until middle Corella time and the equivalent Marimo Slate (e.g., agglomerate in the Ballara-Corella Fault Zone and tuffs near Butcher Bore).

Two particular sedimentary environments that produce sediments enriched in copper are the Red Sea type (Bischoff & Manheim, 1969) and the black-slate (Vine & Tourtelot, 1970) type. The red Sea type is known to occur only in major rift systems, e.g., the Red Sea and the East Pacific Rise (White, 1968) and penecontemporaneous structures of this type were not recognized in the Marraba Sheet area. The black-slate environment is widespread, and has been recorded from a variety of basins with restricted circulation. Several authors have suggested that restricted basins have been responsible for sulphide mineralization in the Cloncurry Complex, e.g., Smith (1969) who suggested penecontemporaneous faulting in the Mount Isa area. Other suggestions have involved hypothetical basins behind barrier reefs, but no reefs have been recognized by the present authors as the 'reef breccia' in the Corella Formation is held to be tectonic, and it shows no correlation with copper concentration. Most of the restricted basins in the Marraba Sheet area were confined to narrow sea-floor depressions, and only minor contemporaneous faulting was associated with them.

Copper may have been precipitated directly in the restricted environment, perhaps as a result of bacterial action, or it may have been absorbed on organic material in the sediment. Goldschmidt (1954) has observed that black shales have abnormally high copper contents (20-300 ppm), and Vine & Tourtelot (1970) give a median value of 70 ppm. The graphitic slates of the Marimo Slate and the middle Corella Formation have copper values of about 45 ppm, allowing the possibility that they were the source beds for the copper deposits. Redistribution of copper has resulted from regional metamorphism, passage of hydrothermal fluids or cognate waters, or extended periods of weathering or both.

(vi) Structural

Folding and faulting can cause mobilization of sulphides and carbonates, and this may have allowed small sulphide grains in the limestones to aggregate into larger masses. Many small copper nodules have been seen in fault-zones in the Corella Formation, e.g., 2-5 km east of the Federal copper mine in the Marimo Slate, small northwest trending fractures and north-trending shear planes are important localizers of copper mineralization.

## Gold

Gold was discovered at several localities in northwest Queensland in 1867. The Soldiers Cap district in the Cloncurry 1:100 000 Sheet area was a major producer of reef gold from 1867 to 1943. The discovery of alluvial gold in 1872 at the Top Camp diggings along the Cloncurry River, a few kilometers south of the Marraba Sheet boundary resulted in a short lived goldrush. Gold was discovered in quartz veins in the Duck Creek area in 1878 (ARDM,* 1878). In 1891, prospecting for alluvial gold was carried out near The Gorge. Other alluvial deposits were found in the Morris Gully - Butcher Creek area, south of the present highway.

* Annual Report, Department of Mines (Qld)

The total recorded production from northwest Queensland is slightly over 2 800 kg, (102 000 oz) but it should be noted that no official production figures existed before 1878; furthermore, the production of alluvial gold may have been much greater than recorded. There has been little production since 1943. On the basis of the official figures, about three-quarters of the gold produced in the area has come from auriferous copper deposits. Almost all the copper ores contain some gold, and Nye & Rayner (1940) did a detailed study on the variation of the gold-copper ratios of the ores. Thirty-two copper mines in the Marraba Sheet area recorded gold production to 1958 (Carter et al., 1961). The largest producers (production in grammes of gold) have been Mount McNammara (3884 g), Federal (1417 g), Lone Hand (907 g), Trafalgar (765 g), Dolomite 794 g), and Pioneer (545 g), an additional 1050 g were produced from the Marraba-Longara area, and 1163 g produced from the Yoomoo area.

The gold is presumably of hydrothermal origin because of its association with copper sulphides, and to a lesser extent with bismuth minerals and scheelite. The main gangue minerals are quartz and hematite. In the oxidized zone gold tends to be unaffected,and it has been recorded from gossans and boxworks in some localities. The placer deposits are derived partly from nearby weathered veins.

Ilmenite

Subhedral crystals of ilmenite up to 3 cm across have been found near the headwaters of Lake Corella. The ilmenite occurs in quartzofeldspathic veins and pegmatite cutting psammitic biotite schist, and is of mineralogical interest only.

Iron

The larger deposits take the form of conspicuous reddish black ridges. In 1866, Henry discovered and named Mount Leviathan, 3 km southwest of Cloncurry. Lees (1907) quotes the reserves at Mount Leviathan and nearby Mount Pisa (Pisa Hill) as 10 million and 1 million tons, respectively. Smaller masses of specularitic hematite occur along Slaty Creek about 2 km east of the Malbon road, and 4.5 km south-southeast of Marimo siding. A zone of small, isolated limonite-magnetite-hematite bodies extends south from the Slaty Creek deposit, passing about 2 km west of Mount McNamara, and extending almost to the wouthern boundary of the area. A similar but smaller zone about 1 km east of the Corella Dam wall extends north-south for 2 km. These zones are thought to be fault-controlled because of their linearity, and because most faults in the area show minor iron mineralization. Quartz-feldspar-hematite veins 1 to 60 cm thick occur near Slaty Creek in the upper Corella Formation and in the Mitakoodi Quartzite outlier south of Boomerang waterhole.

TABLE 21: Assays of Manganese Ores from Overhang

| | 1. | 2. | 3. | 4. |
|---|---|---|---|---|
| Mn% | 43.6 | 53.3 | 49.6 | |
| $MnO_2$ | | 73.0 | 69.8 | 48.3 |
| $SiO_2$ | 19.5 | 11.3 | 16.0 | 18.6 |
| $Fe_2O_3$ | | 4.2 | 5.5 | 4.5 |
| BaO | | 0.1 | 0.2 | |
| $K_2O$ | | 0.0001 | 0.0005 | |
| $H_2O$ | | 2.44 | 1.75 | |
| Co | 0.04 | | | |
| Ni | 0.02 | | | |

1. Representative sample of high-grade ore (Carter et al. 1961).
2. Hard, dense, vuggy, submetallic ore. (Brooks, 1962).
3. Hard, dense, massive ore (Brooks, 1962).
4. Average of production in 1958 (Brooks, 1962).

A large tonnage of low-grade iron ore occurs in the 'Overhang Jaspilite', which contains variable amounts of chert, jasper, and specularite siltstone interbedded with laminated limestone. This sedimentary deposit is of no economic importance at present.

Lead

Economic lead deposits are not known in the Marraba Sheet area. Galena has been recognized at the Mary Kathleen uranium mine and at the Alone Hand mine in the Duck Greek area. Anglesite has been found at the Yanasinga prospect (Ivanac, 1953a). Geochemical stream sediment sampling has revealed several lead anomalies which are restricted to slate in the Corella Formation near the Milo uranium prospect, the Mario Slate east of Marimo Siding, and iron-rich siltstone in the 'Overhang Jaspilite'. Ferruginous gossans are poorly developed but they contain some malachite. Carter et al. (1961) suggested that these deposits are probably of syngenetic origin.

Manganese

At least 2 877 tonnes of manganese ore were produced in the Marraba Sheet area from 1958 to 1962 (Brooks, 1962). Most production was from the Overhang mine, and one shipment of about 12 tonnes was from Mount McNamara. The material was used in the acid leach uranium treatment plant at Mary Kathleen.

The main manganese deposits lie within the Marimo Slate, and are restricted to a north-northwest trending belt extending from 3 km north of the Overhang deposit into the Malbon 1:100 000 Sheet area 3 km to the south. There is one main line of lode and several smaller sub-parallel lines. Apart from the Mount McNamara deposit, several other minor occurrences of botryoidal manganese occur within the Marimo Slate, e.g., 1 km north of the Rainbow copper mine.

The surface expression of the manganese deposits is usually marked by purplish black silicified ridges. Much of the colour is due to superficial manganese staining. Braunite, psilomelane, manganite, and pyrolusite are the main manganese minerals at the surface, and they are associated with quartz and limonite, and copper mineralization at Mount McNamara. The manganese deposits at both the Overhang and Mount McNamara are believed to have originated by enrichment of sedimentary braunite by waters moving along shear-zones. The best manganese ore occurs where a minor transverse fault cuts the shear-zone, and its grade falls off rapidly with depth. Table 20 lists some analyses of specimens from the Overhang deposit.

Molybdenum

The known occurrences of molybdenite are of mineralogical interest only. It has been recorded in some copper deposits, in the Mary Kathleen orebody, and as euhedra and bunches of crystals associated with quartz and calcite in some 'limestone' deposits such as Lime Creek (Carter et al., 1961).

Nickel

Nickel occurs in some of the small cobalt and copper deposits. Ore from the Success cobalt-copper mine contained 0.5 percent Nickel. Some ore from the Apple Pie, Asis, Cameronian, and Jubilee mines have exceeded 0.01 percent Nickel, which is the allowable limit set by Mount Isa Mines for custom copper ore (Carter et al., 1961).

Rare Earth Minerals

Allanite samples from the Mary Kathleen ore body contain 21.6 percent rare earth elements, and stillwellite from the same locality, 58 percent. Caryocerite and rinkite have also been recognized at Mary Kathleen. Other allanite occurrences are at the Elaine Dorothy lease 6 km south of the Mary Kathleen mine, and Hidden Valley, 10 km northeast of the mine. Investigations are currently being made by Mary Kathleen Uranium to determine if rare earths can be produced commercially. They are a waste product in the treatment of uranium ore, and several thousand tonnes are presently stored in the tailings dam at Mary Kathleen.

Silver

The region as a whole ranks as a major silver producer because of the silver content of the lead-zinc ores at Mount Isa. Only minor sources are known within the Marraba Sheet area, where silver is associated with some copper deposits. The Federal copper mine has produced 84 kg of silver at a grade of 6.5 g/tonne. The grades of silver from the Apple Pie and Success mines were 35 and 32 g/tonne respectively. The mineralogical form or associations of silver in these deposits is not known (Carter et al., 1961).

Thorium

A small amount of thorium occurs in the Mary Kathleen deposit in the rare earth minerals allanite and stillwellite. Absite has been recorded at several radioactive anomalies, including Three Inkspots (Carter et al., 1961).

Tungsten

Minor amounts of scheelite have been recorded from the Lone (Alone) Hand mine (Carter et al., 1961) and from Slaty Creek (Ball, 1908). Other deposits are known outside the Marraba Sheet area.

Uranium

The Mary Kathleen mine has been the major producer of uranium in Australia. From 1957 to 1962 it produced about 4 million kg of uranium oxide from 2.2 million tonnes of ore, worth about $80 million. Reserves are quoted at:

a. Indicated ore above level 200 and within the boundaries of the extended open-cut design - 6.5 m tonnes averaging 1.2 kg $U_3O_8$ per tonne.

b. Possible ore above level 200, and outside the boundaries of the extended open-cut design - 2.04 m tonnes averaging 1.2 kg $U_3O_8$ per tonne.

c. Stockpile of 480 000 tonnes, averaging 0.6 kg $U_3O_8$ per tonne.

Up to early 1972, Mary Kathleen Uranium had signed sale contracts with an American company and RTZ Mineral Services Ltd for delivery of about 2 700 tonnes of $U_3O_8$ between late 1974 and 1979, worth about $34 million (based on a price of $6.30 per lb $U_3O_8$). A further contract was written for the supply of 1 000 tonnes of $U_3O_8$ to RTZ, deliveries to begin in 1977, and most recently for 27 tonnes, delivery 1975.

Detailed information on the Mary Kathleen deposit is available in McAndrew & Scott (1955), Matheson & Searl (1956), Whittle (1960), and Hughes & Munro (1965). The deposit is located in a truncated syncline which shows some monoclinal flexuring at depth. Garnet, diopside, minor calcite, and allanite have largely replaced the country rock, which was mainly boulder conglomerate, amphibolite, and scapolite-bearing calcsilicate granofels. Remnants of clasts from the conglomerate are recognizable in the ore-zone, in which the uranium mineralization is found in massive allanite and stillwellite in joints and fractures in the skarn host, although later veins of coarse-grained allanite associated with calcite contain no uranium mineralization.

The primary uranium mineral at Mary Kathleen is uraninite, finely dispersed in allanite and stillwellite, and is associated with or dispersed in caryocerite, rinkite, pyrrhotite, pyrite, and chalcopyrite. Secondary minerals include gummite, uranophane, beta-uranotil, and minor amounts of carnotite, autunite, saleite, and other ochreous minerals (Carter et al., 1961).

The Mary Kathleen lode is a pyrometasomatic replacement deposit probably related to the 'Burstall Granite', 3 km to the east; other small skarn showings in the Mary Kathleen syncline, such as the Elaine Dorothy and Rita prospects, show minor radioactivity, and appear to have formed preferentially in calcareous granofels and limestone in the Corella Formation.

Uranium has also been mined at the Milo deposit, where flakes of torbernite occur in a kaolinitic fault zone cutting grey shale and calcareous granofels. The mineralization may be related to the nearby 'Tommy Creek Microgranite'.

In the Marimo Slate the Embla Ridge and Helafels prospects have been reported on by Woods (1969). A shaft sunk at Helafels in red-brown shales revealed that surface grades persisted at depth, suggesting that weathering has caused little redistribution of uranium.

Davidite-bearing pegmatites are found in the Wonder Valley area, and davidite-rich gravels occur in streams draining the pegmatites (West, 1969). The predominantly north-trending pegmatite dykes intrude the Corella Formation, and are probably related to the 'Burstall Granite'.

At least a hundred radioactive anomalies are known within the Marraba Sheet area, most of them in the northwest quarter. They have been found in all formations except the Roxmere Quartzite and Quamby Conglomerate, and are most abundant in the Corella Formation. Most of these are minor anomalies, and are fault-controlled or related to pegmatites containing rate earch minerals.

Zinc

No zinc mineralization has been found in the Sheet area, but zinc anomalies associated with lead anomalies in the Marimo Slate have been investigated by Tamco (Ivanac, 1953a, b, 1954a-d) Kennecott (Fitch, 1967), CRA Exploration (Muceniekas, 1967), and Western Nuclear (Woods, 1969).

Zirconium

Zircon is a common accessory mineral of the acid volcanics comprising the Argylla Formation in the Marraba Sheet area. In some thin-sections concentrations as high as 4 percent have been noted. Although no examination has been made of the alluvial deposits derived from this formation, it is considered likely that there are some zircon-rich sands in many of the streams, draining the Argylla Formation.

## Non-Metallic Minerals

Amethyst

A small deposit of low-quality amethyst, 3 km northwest of Cloncurry is situated about 200 m southwest of two prominent quartz ridges which are associated with Naraku Granite and Mitakoodi Quartzite. Figure 108 is a sketch map of the locality. The deposit forms part of a milky quartz vein adjacent to a small plug of microgranite. It is small and of poor quality but has been quarried by amateurs for lapidary purposes. The occurrence is labelled GS(A) (Gem Stones, Amethyst) on the accompanying 1:50 000 and 1:100 000 maps.

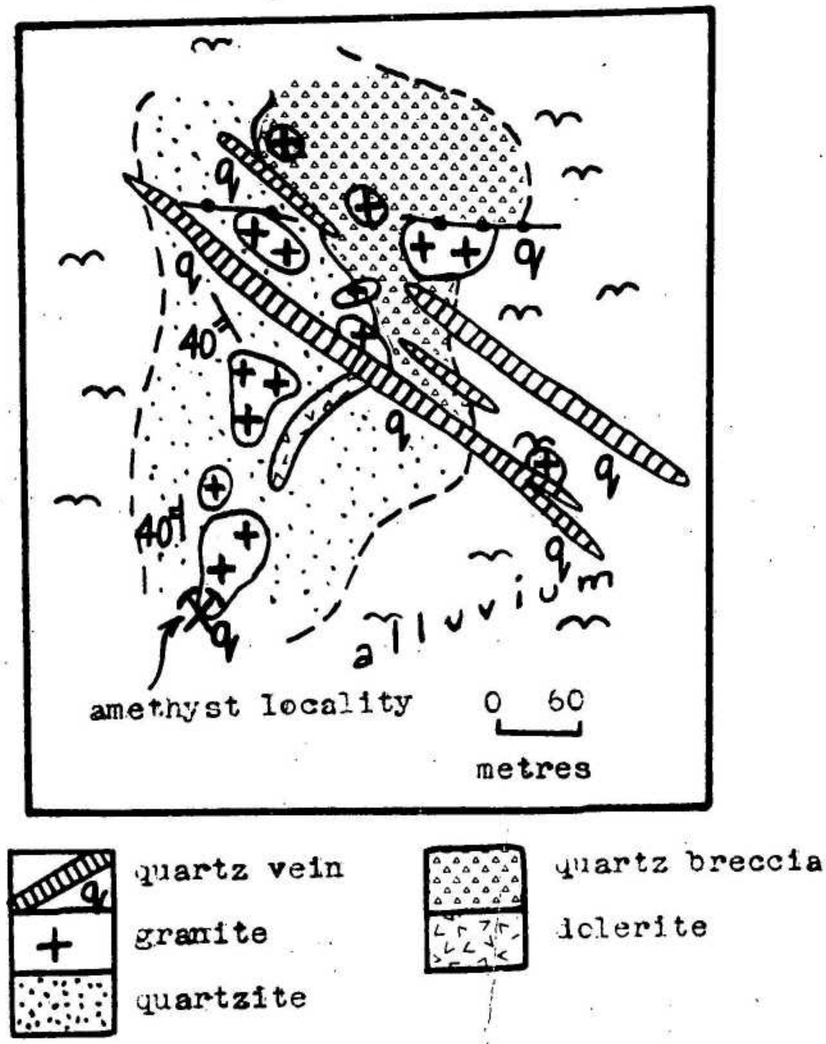
Andalusite

Only small andalusite crystals have been found in the Sheet area, and most have been completely altered to sericite.

Calcite (Limestone)

Since 1920, except for the period of Mary Kathleen production, calcite used in smelting at Mount Isa has been the most valuable mineral mined in the Sheet area. By the end of 1970 about one million tonnes of limestone had been quarried, most of this coming from the Marraba Sheet area. The major producers (production in tonnes) have been Dolomite - including Dingo and Salmon (235 000); Wilgar - also known as New Years Gift (130 000); Marimo (51 000); and Lime Creek (40 000). These deposits commonly contain unevenly distributed pockets of chalcopyrite, pyrrhotite and pyrite, and biotite, actinolite, and molybdenite at Lime Creek.

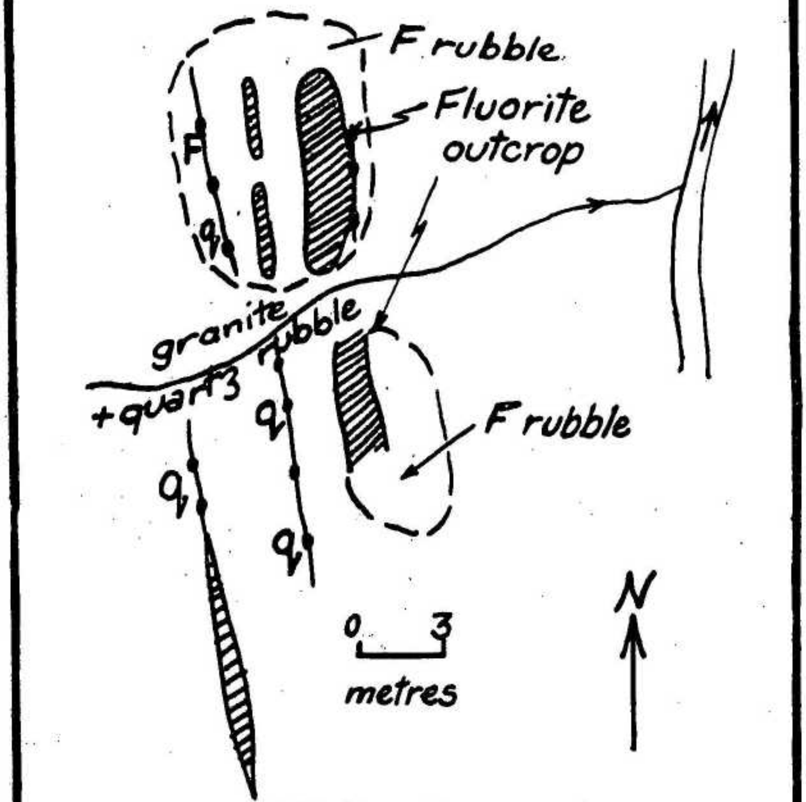
Fig 108 Sketch map of amethyst locality, 3km northwest of Cloncurry




*To accompany Record No 1971/56*

F54/A2/65

# Fig. 109 Sketch map of fluorite deposit in Burstall Granite




Locality 4km ESE Mary K open cut

*To accompany Record No 1971/58.*

F54/A2/66

The limestone forms irregular grey low-lying masses of coarsely crystalline calcite (grainsize up to 20 cm), in association with calcareous metasediments and, in many places, dolerite or amphibolite. The latter forms blocks within calcite at Wilgar and Dolomite. Several prospective deposits have been investigated by various companies, including the Kuta lease 7 km east-southeast of Mary Kathleen open cut, a vesuvianite limestone locality 4 km south of Mary Kathleen open cuty, and several leases northeast of Lime Creek, including Lime Hill and Red Rock. The Cameron leases along the Cameron Fault, 9 km north-northeast of Mary Kathleen open cut, contain abundant tremolite concretions in the limestone.

## Construction Materials

Aggregate abounds in the Precambrian belt. Most of the area is covered with a pebble-sized siliceous scree; the material for the new Mount Isa Cloncurry road was scraped up almost in situ. Mine-dump material has also been used extensively as fill. For the construction of the rock-fill Corella Dam, quarries were sited in calc-silicate rock and quartzite near the dam.

Sand and gravel deposits in the major streams should be sufficient for the foreseeable future. The presence of feldspar and mica is often a disadvantage. A large conglomeratic gravel deposit occurs near the highway, about 3 km north of Butcher Bore.

Potentially useful building and decorative stones are also plentiful in the area, and cover a wide range from sandstone, to pink and grey "granite". Many of the metamorphic rocks are aesthetically pleasing when slabbed and polished. Cambrian limestone has been used to face railway embankments on the old Ballara-Devoncourt railway line.

## Cordierite

The only uses of cordierite are as refractories or gemstones. Very little cordierite occurs in the Marraba Sheet area, andnone is of gem quality.

## Fluorite

No fluorite has been produced from the Sheet area, although it is widely distributed. Some veins have been found in the 'Burstall Granite', (Fig. 109) in which fluorite is a normal accessory mineral. These veins have been investigated by Western Nuclear, and are considered uneconomic. The largest outcropping veins are 13 m by 1.5 m and 10 m by 0.5 m (average). They trend north, and are associated with abundant minor veins of quartz, fluorite, and weathered aplite. Both green crystalline and white to purple massive fluorite are present. Minor amounts occur at the Apple Pie and Mary Kathleen mines. Other occurrences are at the Milo uranium prospect and at a locality 6 km south of Cloncurry.

Garnet

Although garnet is a common metamorphic mineral, and occasionally reaches 10 mm in diameter, transparent specimens suitable for gemstones have not been found in the area.

Graphite

Although graphite occurs in some of the slates, especially within the Marimo Slate and the Corella Formation, the mineral is very finely divided and of no commercial value. The best developed graphitic slate is near the main highway, 2.5 km northwest of Butcher Bore.

Iron Oxides

Oxides and hydrated oxides of iron manganese are common in the Sheet area, and could be a source of pigments.

Kyanite

Kyanite occurs in slate near Butcher Bore and also near Mary Kathleen. It is of mineralogical interest only.

Limestone (see Calcite)

Mica

The mica found in pegmatites within the Marraba Sheet area is vastly inferior to that found to the southwest of Mount Isa.

Quartz

The area has no exceptionally pure deposits of silica. The best silica deposits are probably those to the west of Butcher Creek on the southern side of the highway, and the large quartz vein system near Flat Top Mount, 4 km northwest of Cloncurry. The gangue of many mines in the Marraba and Marimo areas is essentially quartz, and some cherts occur in the vicinity of faults. Silica is used as a flux in copper smelting, and the Chinaman mine 2 km west-southwest of Marraba siding has produced about 1 500 tonnes of cupriferous silica flux up to early 1972.

Sillimanite

The only occurrences of sillimanite in the Marraba Sheet area are on the north shore of Lake Corella and along the pipeline to Mary Kathleen, where the mineral occurs in a sillimanite-biotite schist. The localities are of mineralogical interest only.

Sulphur

Sulphur could possibly be recovered as a by-product in the smelting of sulphide ores which are being mined in the area. At present the only smelter in the region is at Mount Isa, but even there no attempt has been made to extract sulphur dioxide from the furnace gases.

## Water

Water resources in the Sheet area are described in the Introduction.

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## APPENDIX 1

## SHORT NOTES ON MINES AND PROSPECTS

### A) DUCK CREEK AREA

ALONE HAND (Lease 6418)(VB 244787)*

A mineralized quartz-carbonate vein trends 35°, and dips 50°E. Host rock is massive and amygdaloidal basalt, showing increasing alteration towards the vein. Malachite and chalcopyrite are the main copper minerals in a gangue of siderocalcite, quartz, and limonite. Minor amounts of galena and bismuthinite are present.

BANJO (VB 167905) (L4.89.25) in Mitakoodi Quartzite Outlier

Copper mineralization is associated with a valley-forming "chlorite schist", the sheared equivalent of a metadolerite sill or metabasalt flow among strike ridges of Mitakoodi Quartzite. Two small shafts 20 m apart trending 110° have been sunk near metabasic rock.

Mineralization consists of malachite, chrysocolla, and minor azurite. Gossanous limonite and boxworks are partly silicified, as is some of the copper ore. Disseminated malachite in a dense hematite-limonite boxwork is typical. Dump material averages 4 percent Cu, and runs as high as 15 percent in parts.

The mineralized zone is silicified, confined to the metabasic rocks, and is perpendicular to the regional strike.

BRONZEWING (VB 262917)

Bronzewing, 2.5 km due west of Timberoo (Air Photo Longara Run 4 No. 84), is a small open cut following a calcite vein in basalt of the Marraba Volcanics. The main lode strikes at 65°, and dips 65-70°S. The calcite vein is 0.8 to 1 m thick, and is cut by quartz veins which appear to follow a regular joint pattern in the calcite. Mineralization is associated with quartz veins - the limestone itself is barren. The main ore minerals are chalcopyrite and malachite. The surface expression of this mineralization is a wide limonite capping on the calcite vein.

Bronzewing is a small 'one-man show' with little hope of future production.

BUNYIP (VB 269828)

A series of en echelon quartz veins trend 50°. Malachite and chrysocolla are the main copper minerals, and fine-grained chalcocite is also present. The ore occurs as small high grade pods in a gangue of siliceous limonite. The host rock is greenstone/metadolerite; some coarse-grained fawn-grey calcite is associated with the quartz. Three small costeans across the trend of the vein intersected little or no quartz, indicating the lenticular nature of the vein.

* 1000 m grid reference on 1:50 000 and 1:100 000 maps

CHINAMAN (VB 257768)

This is a large quartz vein, 150 m long, trending 55° to 65°. The vein pinches and swells, shows minor kinking along strike, is about 3 m thick, and dips 75°S. The footwall is chloritic schist with quartz veining, microcrenulation, and well developed slickensliding; hanging wall consists of schist and quartz-chlorite gneiss. Malachite and some chalcocite form coatings and small pockets in quartz, and mineralization is localized by a shallow-dipping cross-fracture. This mine has been used by Mount Isa Mines Ltd as a source of cupriferous silica flux.

COMET (UB 289934)

Comet is a small open-cut limestone mine about 5 m wide and 40 m long, 2 km north of Timberoo. It is in amphibolite, but less sheared parts appear to be dolerite, the remainder being basalt of the Marraba Volcanics. The general strike of the lode is east-west; minor malachite and bornite in quartz veins, and minor siderite are present within the limestone.

Comet, which should not be confused with the Comet mine, 3 km south of Timberoo, has not been recently worked.

COMET (VB 280882) (L.4.83.6)

Open cut trenches and a small shaft have opened up a mineralized shear-zone and quartz reef trending east-west in basic volcanic rock (Ela). The footwall is a medium-grained basic volcanic rock; the ore-zone, containing abundant milky quartz is 1 m wide, and the hanging wall consists of sheared basic volcanics and chlorite-sericite schist.

Mineralization consists mainly of malachite veins and fracture coatings, especially in quartz. Some chalcopyrite and secondary chalcocite are also present, and the quartz is limonite-stained in places.

Grades average 5 percent Cu in the working face, and up to 15 percent in patches. There is no obvious source for the mineralization, but it is probably dolerite.

DEB (HILDA) (VB 277882) (L.4.83.6)

Three small pits have been sunk on a quartz reef trending 110°, and dipping 70° to the south.

Metabasic volcanics occur on either side of this reef, but material on the hanging wall is chlorite schist formed by shearing and/or hydrothermal alteration.

The sheared material grades into unaltered metabasics over a 3 m-wide zone. Mineralization in the quartz is mainly malachite staining, fracture fillings, and veinlets. Grades average 5 percent in the half-exposed face, and up to 10 percent in parts.

Coarse-grained white calcite forms a small reef along the shear.

GAFFERTIES SHOW (VB 207978) (Fig. E.2)

| | |
|---|---|
| Location: | - L-2-101-2, 1.5 km NNE of Boomerang Waterhole. |
| Country rock: | - Amygdaloidal basalt, cleavage strike 30°, dip vertical |
| Lode: | - Calcite vein striking 35-45°; chalcopyrite-quartz veins with limonite, malachite, and chrysocolla in main ferruginous shear striking 70°. |
| Workings: | - One shaft 4 m deep underlies 70° on bearing 150°. Costeans have been bulldozed 170 m and 100 m to SW of main shaft. |
| Production: | - Not recorded. |
| Prospects: | - Several kg of rich ore lying on surface, but reserves probably do not warrant further mining. |

HECLA

Consists of a trench 20 m long in basalt; dolerite at eastern end. The mined quartz vein trends 80°; some patches of high-grade malachite, cuprite, and chalcocite were noted.

HORSESHOE (VB 254809)

This is similar to the Dawn leases; boudinaged and en echelon quartz reefs trend 65°, and dip steeply south. Wall rock consists of chlorite schist and phyllite. Malachite is the main copper mineral.

JESSIE (Lease 6419)

Jessie is located a few kilometers off the Marraba Sheet boundary 1.5 km south of Marraba siding. Mineralization is in a small quartz vein trending 80°, and dip 80° south. Limonite and coarse quartz crystals are gangue minerals. Footwall is fine-grained sandstone and siltstone; dolerite fragments are present in soil 100 m east of the small pit. Malachite, in low-grade patches, is the major copper mineral noted.

PIONEER CHIEF (Lease 6342) (VB255803)

Two shafts have been sunk to about 10 m in chlorite schist and metabasalt. Massive quartz is absent. East of the Pioneer Chief are numerous lines of quartz reefs, with common comb-structured quartz crystals in a siliceous limonite gangue with sporadic calcite.

ROOS (VB 029894) (L4.97.14)

A 2 m-wide quartz reef, striking 045°, and dipping 70° SE, extends for over 150 m. Malachite and very minor azurite form fracture coatings, minor nodules, and stains in the quartz reef. The country rock is a metadolerite, chloritic in part. A costean has been cut by grader across the reef, and at the SW end, offset to the SE, is a vertical shaft 4 m deep. As well as quartz and limonite, calcite veins are present in the gangue. Grade in the costean averages 3 percent, and runs up to 5 percent in parts.

There is very little alteration of the metadolerite, even near the quartz reef. The dolerite may be the source of copper.

SUCCESS (VB 280911)

Success is about 0.5 km southwest of Timberoo (Air Photo Longara Run 4 No. 84). A bore equipped with windmill, storage tank, and cattle trough has been established a few yards from two collapsed shafts.

The shafts, three m apart, are joined by a stope which has been worked almost to the surface. They are over 40 m deep, in biotite schist. The only sign of cobalt mineralization is small amounts of erythrite in the mullock dumps.

Success has not been recently worked. A few kilometers west of Success, two small pits in chloritic phyllite contain malachite and azurite in a quartz-siderite gangue, cut by narrow veins of pink feldspar.

THE DAWN (Lease 6428) (VB 254810)

Workings extend for about 90 m along a quartz vein trending 60° with steep southerly dip. The vein is now almost mined out. The old working at the western end is an open trench; a small shaft has been sunk from the lowest point in the trench. The most recent trench is equipped with a tripod head frame.

The country rock is phyllonitic dolerite and greenstone; on the hanging wall the greenstone is highly chloritic; the footwall consists of massive quartz with small inclusions of chlorite phyllite; malachite coatings are common. The mineralized vein is about 2.5 m thick, and has a slightly arcuate strike. Malachite is the main ore mineral, and, as at Chinaman, a series of shallow dipping shears in the quartz vein (Str. 35°, Dip 25° N) localize sporadic mineralization.

TAMBOURINE (VB 168896)

A shaft on a creek measures about 3 m x 1.5 m, and is 6 m deep. There is no evidence of mineralization. Weathered metabasalt on dump. Minerals noted in a nearby pit include malachite, chalcocite, and limonite (boxwork). A metadolerite dyke is nearby.

CELESTIAL (TELEGRAPH) (VB 238774)

Celestial or Telegraph is a small copper mine which was being worked in 1970; it belongs to the Chinaman group of mines, and is 2 km west of Chinaman in the basalt member of the Marraba Volcanics.

In 1970 a vertical shaft was sunk on a large continuous quartz vein striking at 85°, and dipping 85°S. The country rock is biotite schist striking at 54°, and dipping vertically. The wall-rocks are schistose. Rock immediately southeast of the vein is dolerite. The ore minerals - black chalcocite, malachite, and minor azurite - are associated with the quartz. At the surface the white quartz appears quite barren. The vein is probably part of the line of lode extending 2 km eastwards to Chinaman; at least 15 percussion holes have been drilled on the south side of the lode, towards the western end.

TIMBEROO (VB 294915)

Timberoo consists of three sub-parallel lodes, two being fairly straight, and the other zig-zag. The general strike of the lodes ranges from 50° to 85°, and the dip from vertical to 85°.

The ore is localized in biotite schist as veins which rapidly swell and pinch. A small amount of quartz is present in the veins, which are extremely rich; assays up to 40 percent Cu are common. The main ore is fine-grained chalcocite and malachite which is called "tile-ore" locally (sensu stricto, tile-ore is cuprite-limonite ore). Minor cuprite, chalcopyrite, and azurite are also present. The surface expression of mineralization is poor, and small nodules of mud-covered chalcocite are occasionally seen on the surface. Rarely limonite nodules containing bornite and chalcopyrite are also found in the top few metres of the lode.

A second type of mineralization associated with calcite, siderite, and quartz veining is also present, but only low grades of copper have been found in this association at Timberoo. Pyrite and lesser amounts of chalcopyrite, azurite, and malachite are present. A limonite capping at the surface marks the location of these veins.

In 1969 the mine was re-explored, and a small amount of development and mining was done. The lodes were being carefully delineated along their length, and the old shafts were being cleaned out. A small diamond drill was used to determine the extent of the lode, and closely-spaced costeans were cut by a back-hoe.

At present the mine appears to be suitable only for small-scale production; although the ore is rich, the irregular and discontinuous nature of the veins necessitates hand-picking.
Ref. Ball (1908), pp. 170-175.

MONSTEREEF(?) (VB 278883) (L4.83.7)

A vertical shaft 6 m deep is at the E end of a 1 m wide quartz reef striking 190°, and dipping 75° S. The quartz reef is 100 m long and halfway along, on the south side (hanging wall), is another vertical shaft at least

4 m deep. The quartz reef here is vertical. Metabasic volcanics are the country rock, with medium-grained metabasalt to the north (footwall) and sheared to massive metabasic to the south.

Mineralization is sparse, being mainly malachite staining and fracture coatings in quartz. Some silicified limonite occurs. Average grade is hard to assess, as there is no fresh working face, but dump material is estimated to contain about 2 percent Cu.

UNKNOWN NAME (VB 275888) (L.4.83.8)

Two small pits expose a mineralized quartz vein striking 85° and dipping 75° N.

Country rocks are metabasic volcanics (Marraba Volcanics) with a chloritised shear zone along the hanging wall, grading into unaltered metabasics. Mineralization is malachite stains and fracture coatings in quartz, and minor veinlets of azurite. There are minor amounts of limonite.

SHOWING NEAR BELFAST (VB 264816)

This is a steeply dipping quartz vein 3 m wide and 80 m long, trending 115°. There are no workings along the reef. Quartz crystals associated with grey calcite in siliceous limonite are very abundant; chalcedony is commonly associated with sporadic rich patches of malachite and fine-grained chalcocite. Massive specular hematite occurs near the western end of the reef. This prospect is possibly worth investigation by a small syndicate.

UNNAMED MINE (VB 288942)

This small mine is located 3 km north of Timberoo in the basalt member of the Marraba Volcanics (Photo L.2.96).

A shaft (about 7 m deep) has been sunk on a 50 m long quartz vein striking at 75°. The vein dips vertically and is folded near the shaft. It is brecciated in places and recemented by fine-grained cherty material. The main ore minerals are malachite, bornite, chalcopyrite, and azurite.

## B) BULONGA AREA

BULONGA (VB 004827)

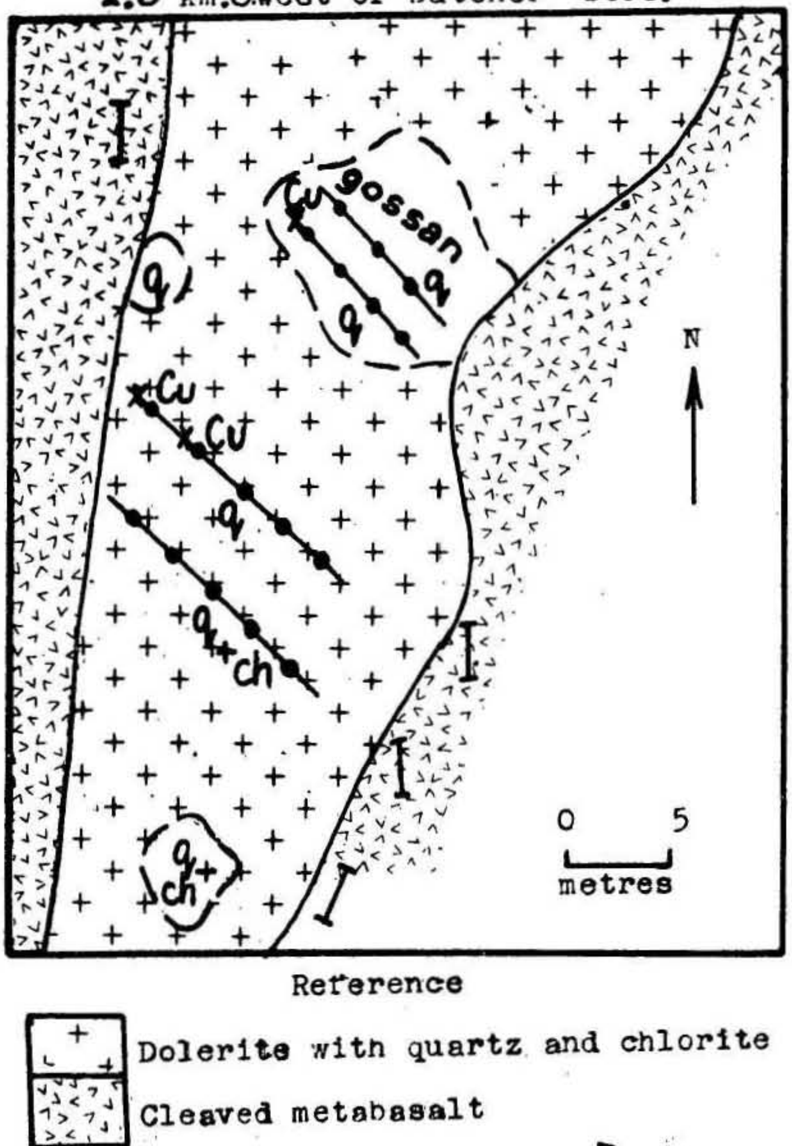
This is a series of pits and scrapings spread over an area of 0.3 $km^2$. Dolerite dykes intrude basalt, quartzite, and acid volcanics, all of which contain mineralized quartz veins. One vein, in basalt cut by dolerite, contains malachite and granular calcite aggregates.

MAIDEN SHOWING (VB 034803) 5 km SE of Bulonga

This is a calcite vein cutting dolerite and acid volcanics, and trends 70°. It ranges from zero to 1 m thick, and mineralization extends for 70 m along the vein in dolerite, and a further 45 m with quartz, in acid volcanics.

Fig. A : Sketch map of maiden copper occurrence,

2.8 km.Swest of Butcher Bore.




*To accompany Record 1971/56* *F54/A2/67*

The best values are where the vein cuts dolerite. Mineralization is finely dispersed chalcopyrite partly altered to malachite and limonite; the grains are 1-3 mm across, and an assay of typical "ore" gave 2.7 percent Cu.

This prospect is worth testing by a small syndicate.

C) SHOWINGS IN THE 'WAKEFUL BASALT MEMBER'

WAKEFUL (VC 187009) (Fig. N.1)

| | |
|---|---|
| Location: | - L-1-62-1, 3 km S of Milo. |
| Country rock: | - Thin-bedded sandstone and cherty quartzite with minor folding (? slumping).<br><br>Bedding strikes 30°, dip 55° East. Some basalt(?) and altered dolerite. In vicinity of mine the country rock is altered to creamy white micaceous sandstone and biotite schist with cleavage striking 0-10°, and dipping vertically. |
| Lode: | - Vertical shear zones trend 010° and 150°; kaolinitic and ferruginous alteration, minor brecciation and quartz veins are common. Traces of chrysocolla, azurite and malachite in veins and joint planes. |
| Workings | - An open pit 20 m x 40 m and 3 m deep has been dug to include the most sheared zone. The pit is elongated north-westerly. On the east side of the floor of the pit there is a partly caved-in shaft at least 7m deep. A series of shallow (1-2 m) pits extends north of the main pit along the shear trending 150°. |
| Production: | - Not recorded. |
| Prospects: | - Little visible mineralization remaining. |

MAIDEN SHOWING (VC 245039) 2.8 km SW of Butcher Bore.

This is shown in fig. A. Mineralization is in a dolerite dyke cutting metabasalt; a series of quartz veins up to 4 m long trends 160°. Copper is found as irregular malachite nodules in white quartz and as rich pockets of earthy cuprite. Gossanous veins with malachite showings are abundant.

## D) MARIMO SLATE AREA

**BARRONNESS** (ML 6550) (VB 439986) (Fig. B.1)

Location: - L-2-90-34, 12.5 km SSW of Cloncurry.

Country rocks: - Cream laminated siltstone, strike 080°, dip 60–70°N. Slate crops out 100 m to SW in footwall of shear.

Lode: - Quartz veins, strike 080°, dip 50–60°S. Traces of chrysocolla and malachite in veins.

Workings: - Several pits and costeans and caved-in shaft.

Prospects: - Being investigated.

**BIG JUMP** (ML 6164) (VB 407879) (Fig. B.2)

Location: - L-5-30-31, 400 m SE of Black Slate.

Country rocks: - Black carbonaceous slate, strike 160°, dip vertical. Siliceous, slightly ferruginous, vuggy altered zone of slate-siltstone.

Lode: - Silicified brecciated shear-zone; trend 145°, dip 65° W. Veins of azurite unevenly distributed.

Workings - One open pit 1-3 m deep, 2-8 m x 10 m.

Production: - 1.3 tonnes of copper from ore of average grade 2.6 percent.

Prospects: - Minor amounts of ore left in pit. Extension of lode not found, but may be on the same line of lode as Black Slate.

**BLACK SLATE** (VB 406883) (Fig. C1)

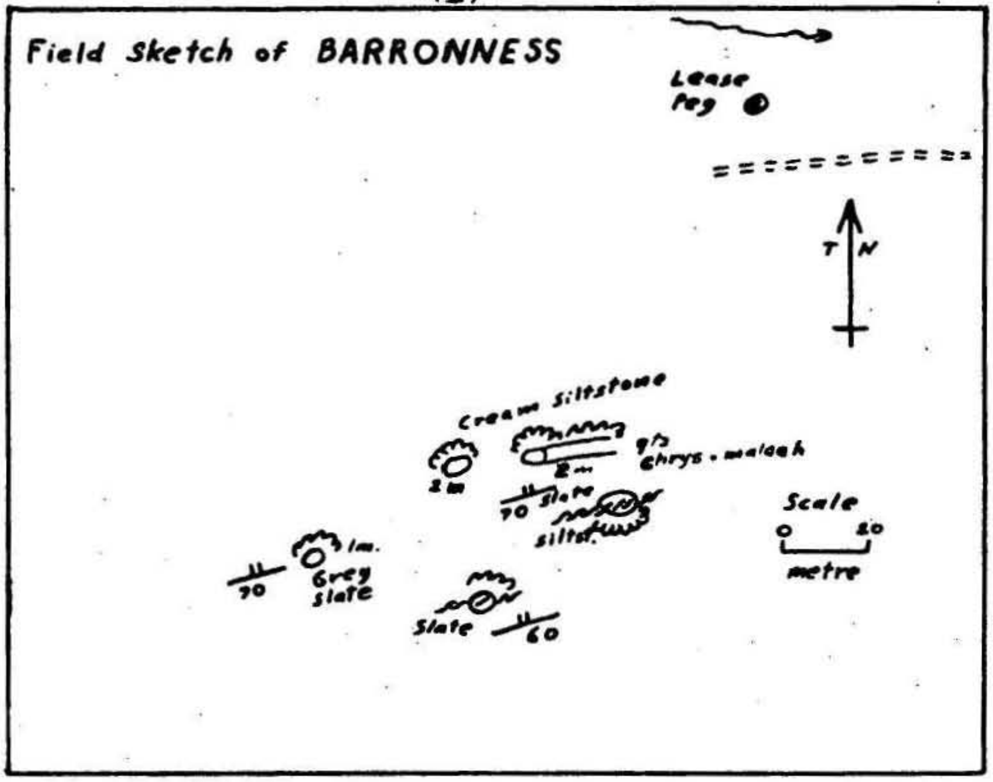
Location: - L-5-30-30, 0.5 km S of Slaty Creek, 6 km W of Cloncurry River.

Country rock: - Black fissile slate with spherical holes; cleavage strikes 160°, dip vertical.

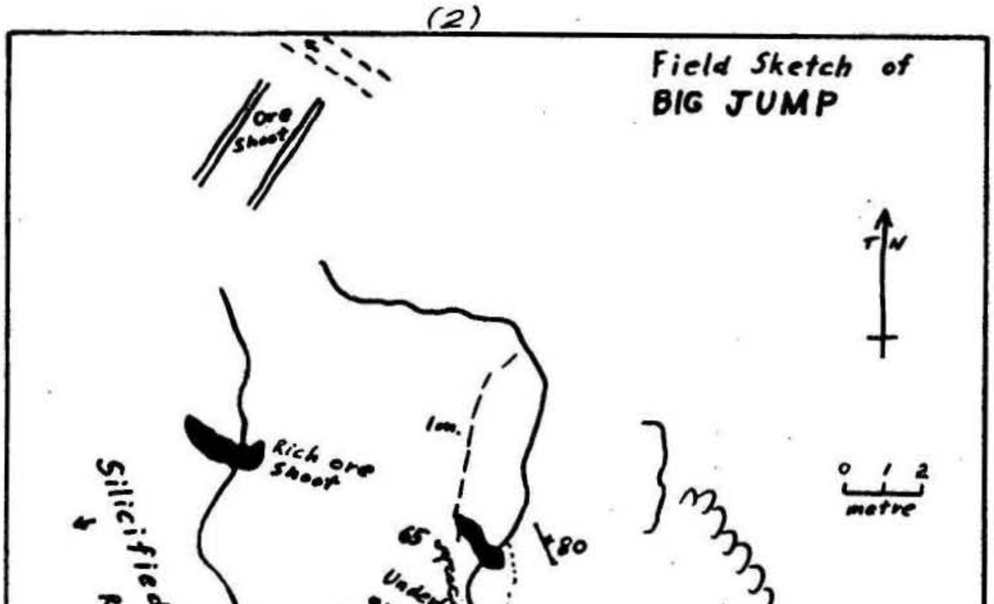
Lode: - Brecciated and slightly silicified zone about 2 m wide, strike 160°, dip vertical. Some limonite and manganese staining. Quartz rare in ore-zone, with some kaolinitic veins. Main ore mineral is chrysocolla as veins to 1 cm thick.

FIGURE B

(1)




(2)

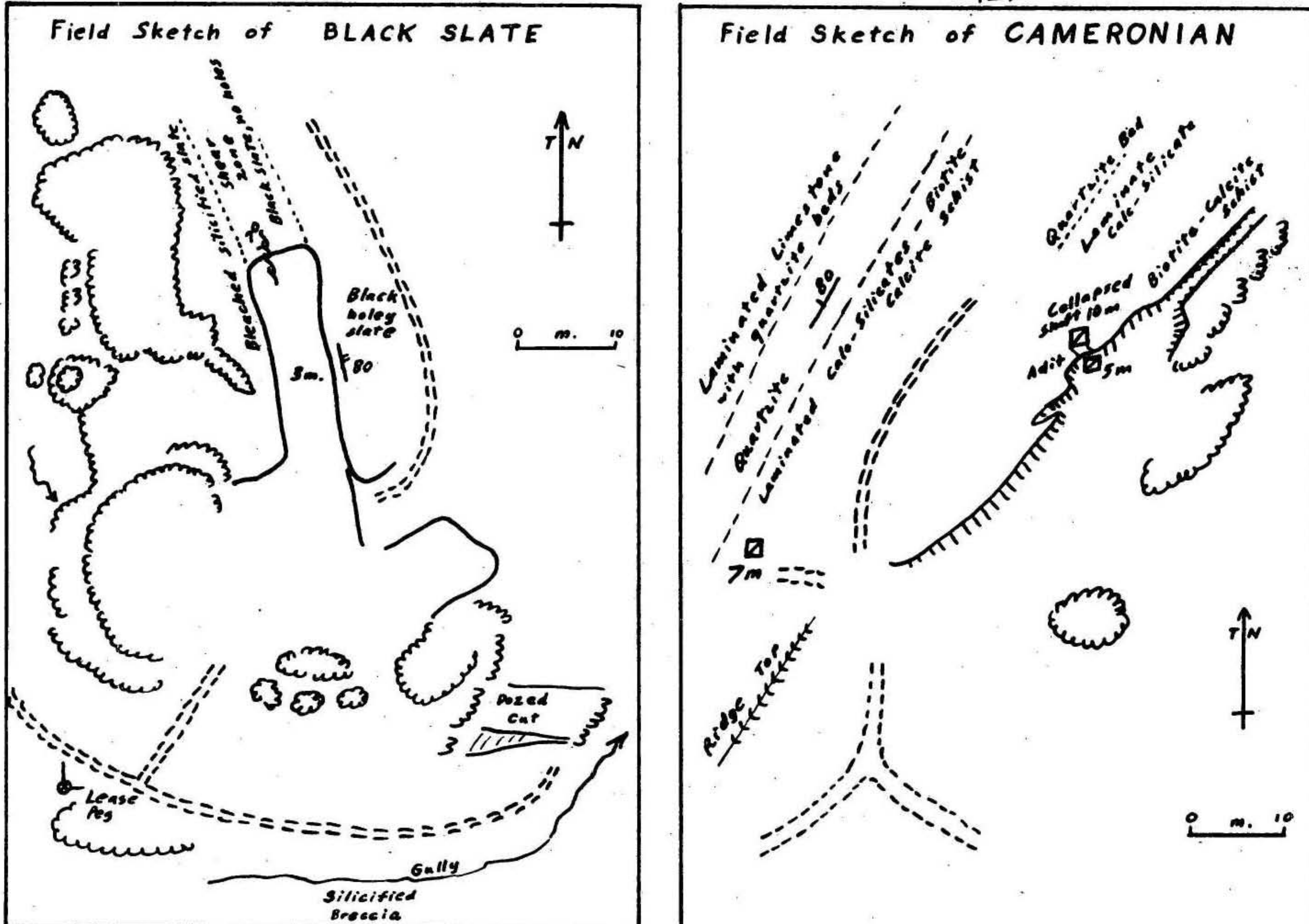



To accompany Record 1971/56.

F54/A2/68

FIGURE C

(1) (2)

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Workings: - One bulldozed cut trending 160°, 20 m x 3 m, and up to 3 m deep at northern end.

Production: - In 1968 the mine produced 2.3 tonnes of copper from ore of average grade 8 percent.

Prospects: - The silicified breccia zone extends at least 200 m to S across gully, but there is little evidence of mineralization.

GREAT WESTERN NO. 2 (VB 383830) (Fig. F.1)

Location: - L-6-50-38, 2 km NNW of Eight Mile Rock Hole.

Country rock: - Silicified grey slate to west. Cleavage strike 145° dip, 75° W. Cut by quartz veins, brecciated. Also silty slate and thin-bedded siltstone

Bedding 150°/85W,
Cleavage 150°/80/E;

minor folds plunging 40-50° to north.

Lode: - Mineralized zone is easternmost silicified strike zone. Large quartz vein with malachite mineralization cutting black carbonaceous slate which grades sharply, 3-5 m to E, into bleached laminated kaolinitic slate.

Workings: - One vertical bulldozed cut into side of ridge exposing one 5 m high face about 50 m long, and trending north-northeast (oblique to the lode).

Production: - No production.

Prospects: - Diamond drilling was done in the area during 1968-69 by Western Nuclear, but results were not considered to be of economic interest.

HELAFELS (VB 417818)

The main shaft is about 35 m deep, and situated on a ridge of subgreywacke and grey siliceous slate striking 175°, and dipping 70-80° E. The mineralized zone is within a zone of silicification 20 to 25 m wide. Small quartz veins contain minor malachite staining. The major rock type at depth is a hematitic siltstone. West of the shaft is a gossanous brecciated limonitic siltstone. This prospect has been held by Queensland Mines for uranium. (Brooks, 1960).

MARIMO GROUP (UB 593987) (Fig. H.1)

Location: - Marimo prospect is located at L-2-91-4 0.5 km ESE of Marimo siding. The other prospects in the group are located to the south of this prospect.

Country rock: - Slightly ferruginous laminated siltstone and grey silty slate, strike 170°, dip 70° W.

Lode: - Zone of limonite pseudomorphs after (?)siderite, bounded on west by large quartz veins. Rare stringers of chalcopyrite.

Workings: - Several bulldozed cuts and minor pits.
Marimo - one cut 50 m x 20 m.
Marimo South - Series of pits trending 050° on slope.
Black Diamond - one cut 50 m x 20 m, and up to 5 m deep at southern end with some minor diggings lower on western slope of ridge and along strike to the north.

L.S.D. - line of pits, along boundary between siliceous zone and ferruginous zone in grey silty slate, extends for 360 m N and 100 m S of gully where quartz vein trending 120-150° crops out.

Mt McCABE - DUCHESS 1:250 000 SHEET AREA (RC9 Cloncurry 8.82.7), 6 km S of bore on Cloncurry River at 465790.

A prominent ridge-forming fault-zone strikes 035°, and dips vertically. Mineralization is associated with breccia in this zone, and also with several minor cross-cutting shear-zones. Country rock is strongly fractured and leached slate. Specularitic hematite has formed in the fault zone with minor veins and filmy coatings of malachite and irregular limonitic boxworks. Shear zones especially are silicified and brecciated, and contain chrysocolla, malachite, and limonitic boxworks. Black $MnO_2$ staining is also common.

Several drillholes at various inclinations have been sited adjacent to these mineralized zones. Three vertical shafts to a maximum depth of 10 m are situated at the top of the ridge, and minor pits and costeans on its flank.

An obvious source of mineralization is not apparent, and there is no igneous material nearby. The highest grades come from hematitic malachite, reaching up to 5 percent Cu. Chrysocolla in slate would average 3 percent Cu.

MT McNAMARA (VB 395862) (Fig J2)

Location: - L-5-30-26 to 29, 7 km west of Cloncurry River 2.5 km south of Slaty Creek. Main copper workings on north side of ravine, manganese workings on top of southern ridge.

Country rock: - Grey to black slate, cleavage strikes 140-150°, and dips vertically to steeply west.

Lode: - Strike fault; silicified and brecciated zone up to 100 m wide, and extending for more than 1 km. Trend 160°, dip vertical to 60°E. In vicinity of main workings extensive ferruginous (fine-grained hematite) and pyrolusite staining. Some kaolinitic alteration and quartz veining. Main ore shoot is 1 m thick, and cut by minor shears trending 100-120°. Malachite was seen in surface exposures.

Workings: - Main adit is partly caved in. Stoped to the surface over much of its length. Small cave-in near entrance to southern adit.

MOTHER'S VALLEY (VB 414806) (Fig. J1)

Location: - L-7-162-33, 1.7 km east of Eight Mile Rock Hole.

Country rock: - Black silty slate, cleavage strikes 105°, dips 70°N to vertical, bedding strike 110°, dip 70°N. Sequence contains black-weathering calcareous sandstones and thin-bedded sandstone/siltstone with ripple marks and tension gashes.

Lode: - Calcite lens, strike 105°, only slight shearing. Malachite veins.

Workings: - Small bulldozed platform beside gully and a single shallow shaft, partly caved in.

Production: - 22.0 tonnes of ore yielded 1.5 tonnes of copper (1968-69).

Prospects: - Not promising. Is a known uranium anomaly.

OVERHANG (VB 364793)

Location: - L-7-158-6, 9 km E of Marraba siding.

Country rock: - Sandstone lens in slate; strike 150°, dip 75°E. Two silicified strike ridges with some brecciation on eastern edge of deposit. Cut by minor vertical shear, trending 115° with 2-3 m apparent dextral movement.

Lode: - Disseminated braunite in silty slate. Main ore body is pod at intersection of minor shear and sandstone. Pyrolusite, manganite, braunite, and trace amounts of psilomelane and cryptomelane in orebody.

Workings: - Open cut on two levels on west side of sharp ridge exposing "hanging wall" face 30 m high with about 5m overhang.

Production: - 1958-60, 2820 tonnes of manganese ore of variable quality but averaging about 48 percent $MnO_2$. May have produced up to 1962, but Records are not available.

Reserves: - About 30 000 tonnes of ore. Minor road works will restore mine to production when Mary Kathleen treatment plant is operating.

References: - Brooks, 1962; Carter et al., 1961; Dunstan, 1920.

RAINBOW (VB 353866)

Copper mineralixation occurs on a ridge in a belt of slate 30 m wide and 100 m long, trending north. A few shallow pits, costeans, and trenches cover the ridge, and shaft sinking was in progress in late 1969. Copper staining is widespread along the ridge, but economic mineralization is concentrated in narrow shear and fold-zones along the ridge crest. Quartz-malachite veins cutting kaolinized slate are subparallel to cleavage. Minor cuprite and azurite have also been noted. The deposit has been drilled by Western Nuclear, but no results are available.

RED SIERRA SOUTH (Lease 5787) (VB 408783)

Workings extend along strike trending 150° for about 100 m in shale/slate host rock. A shaft sunk at the southern end of the lode has revealed a lenticular quartz vein, 1 m thick, with malachite and azurite. The hanging (eastern) wall is generally bleached kaolinitic shale with sporadic malachite. The footwall shale is dark and carbonaceous, with azurite and minor quartz veining prominent. This lease has been drilled by Western Nuclear, but future prospects are limited. Some low grade (0.5%) sulphide ore was intersected at depth.

SWEET WILLIAM

This show is located on a north-trending slate ridge, a few kilometers off the southern Sheet boundary, 3 km southeast of Overhang. Old shafts have been exposed by trenching; a trench 4 m wide, 8 m deep, and 30 m long, mostly in black to red-grey carbonaceous slate, has exposed a mineralized zone of red, dense, hematitic shale with quartz veining. The shales show some deformation, especially along the east-dipping hanging wall.

The ore is a red-brown siliceous lode with chrysocolla and malachite forming coatings and segregations. Cuprite and tenorite are significant accessory minerals; minor pyrite is also present.

TOBY BARTY (VB 385819) (Fig. M1)

Location: - L-6-51-15, 2 km NW of Eight Mile Waterhole.

Country rock: - Brown, fine-grained ferruginous specularitic sandstone and ripple marked siltstone with conglomerate beds. Bedding near vertical, strike varies from about 145° in the south to 75° north of the mine, which is situated on a major dragfold 200 m south of a major dextral strike-slip fault trending 120°.

Lode: - Shears with some quartz veining and black ferruginous gangue, strike 150-170° and dip steeply to the east. Veins of malachite, chrysocolla, and traces of bright yellow-green coatings of a secondary uranium(?) mineral. Some disseminated malachite in shear-zones and lenses of specularitic conglomerate.

Workings: - Several bulldozed pits 4 m deep; elongated in a NNW direction; many minor costeans.

Production: - 190 tonnes of ore yielded 11 tonnes of copper and 186 g of gold.

Prospects: - Probably contains about 100 tonnes of 1 percent copper ore. It is a known radioactive anomaly.

UNNAMED DEPOSIT (Possibly Dingo: VB 376887)

Location: - L-5-28-1, on Mt McNamara track 3 km NW of Mt McNamara.

Country rock: - Grey silty slate, strike 165°, dip 75°E, and some black slate. Area is near the axis of a major anticline, and displays congruent folding.

Lode: - Minor silicified shears, brecciating silicified country rock, trends 135°, dipping 40-70°east. Traces of malachite observed.

Prospects: - Probably unproductive, as mineral occurrences are scattered.

(?)VONNIE

Location: - L-2-90-30, 12½ km SSW of Cloncurry.

Country rock: - Laminated impure sandstone and siltstone with some amphibolite, strikes 120°, dip 50° south.

| | | |
|---|---|---|
| Lode: | - | Quartz-limonite shears striking 120°. Traces of copper carbonates. |
| Workings: | - | One shaft, partly collapsed, 15 m deep. |

DEPOSITS IN THE CORELLA AND OTHER FORMATIONS

BULLOCK (VC 161169) (CR6.12.44)Plc$_2$

Several open pits and two vertical shafts delineate a mineralized zone trending 165° over a strike length greater than 150 m. Very little outcrop occurs in the soil plain, but dump material shows the country rock to be calcsilicate granofels and actinolite schist with minor calcite. Mineralization is along a shear-zone and consists of malachite, chrysocolla, minor pyrite, and trace amounts of neotocite (a Cu-Mn complex). It takes the form of filmy coatings and fracture fillings; the average grade of dump material is 3 percent Cu.

CAMERONIAN (VC 057274) Fig. C2)

| | | |
|---|---|---|
| Location: | - | CR-2-36-3, 11 km NW of Federal coppermine. |
| Country rock: | - | Laminated limestone and calcsilicate rock with quartzite interbeds, strike 040°, dip 80° NW. |
| Lode: | - | Shear-zone strikes 040°, steep NW dip. Country rock is altered to calcite-biotite schist. Ore: copper carbonates and chalcocite(?). |
| Workings: | - | Old shaft partly collapsed; adit from bulldozed platform. |
| Production: | - | 140 tonnes of ore yielding 9.5 tonnes of copper. These figures probably include production from Cameron limestone quarry. |
| Prospects: | - | Recently worked by Newmetal. |

CHUM (VC 365118 (CR7.14.16)

A mineralized zone over 100 m long, and up to 4 m wide at the surface, strikes 105-120°, and dips 80° N. This zone cuts across the NW strike of ridge-forming feldspathic quartzites to the south. An alluvial flat lies to the north. The zone contains quartz-calcite-chlorite rosettes with limonite and malachite. Gossanous limonite and malachite form nodules and disseminations at the surface, but dump material contains chalcopyrite, cuprite?, and chalcocite. A number of shafts, open pits, trenches, and costeans lie along the zone. Extensive old underground workings, including drives and stopes.

Truncation of the quartzite indicates that the zone is associated with faulting and/or shearing. No igneous material is present, but a basic intrusion could be concealed in the plain to the north.

EAGLE (VC 061276) (Fig. D)

Location: - CR-2-36-2, 11 km NW of Federal.

Country rock: - Pale laminated calcsilicate rock and biotite schist, strike 050°, dip 60° W.

Lode: - Shear trending 032°, dipping 30°W, with ferruginous and calcite gangue, some kaolinitic alteration and calcite veins.

Workings: - Old shaft on shear has been incorporated in a bulldozed cut trending 080°; cut is 4 m deep at shaft.

Prospects: - No recorded production and no evident copper mineralization.

FEDERAL AREA (VC 159223) (Fig. E1)

Location: - CR-3-80-18 to 26; group of mines in a narrow belt extending 2 km north from the old Mt Isa/Cloncurry Road along the eastern edge of an outcrop of Quamby Conglomerate about 30 km WNW of Cloncurry.

Country rock: - Grey silty and carbonaceous slate, quartz-biotite-muscovite schist, and fine-grained sandstone. Strike N to NE, dip 85°W.

Lode: - Quartz-filled shears, some calcite and kaolin. Ore minerals at surface are copper carbonates, especially azurite. Chalcocite, bornite, and chalcopyrite reported by Ball, 1908.

Workings: - Series of workings from north to south

Corella - old shaft and some recent reworking of dumps.

(?)King of Trumps - bulldozed costean covering old workings.

(?)Cloncurry - several small pits.

(?)Rita Margaret - adit into valley's east slope.
(?)Krakonas - adit into valley's east slope.

Mona - one deep shaft, currently being worked.

Federal - most recent work has been scavenging on mullock dumps, some redevelopment on old shaft, and construction of a shaker table for gold(?) extraction.

Albert Hill - one old shaft, now at east end of a large excavation and a new shaft 25 m to the northwest.

References: - Federal, Ball, 1908.

HARLIN (VC 400086)

Near the north section of a major hematite ridge is a small open pit cut into a low hillside. Mineralization along a silicified, limonitic zone trending 155° in strongly fractured feldspathic quartzite. Chrysocolla forms thin irregular veins, fracture fillings, and pockets, whereas subordinate malachite mainly forms fracture coatings. One fracture surface contained a small patch of ruby cuprite; silicification is common along fracture surfaces. Limonite staining particularly characterizes the mineralized veins.

A metabasalt crops out a few hundred metres to the west, and meta-dolerite intrudes to the S and SW (see SALMON). Strong N-trending faults could influence ore location.

HOBBY (Success) (ML6554) (VC 131256)

Location: - CR-3-80-12, 4 km NNW of Federal.

Country rock: - Slightly calcareous, thin-bedded, impure quartzite, strike 000° dip 85° W.

Lode: - Slightly siliceous and ferruginous, shear trending 065° dip vertical. Ore is chrysocolla and minor azurite and malachite.

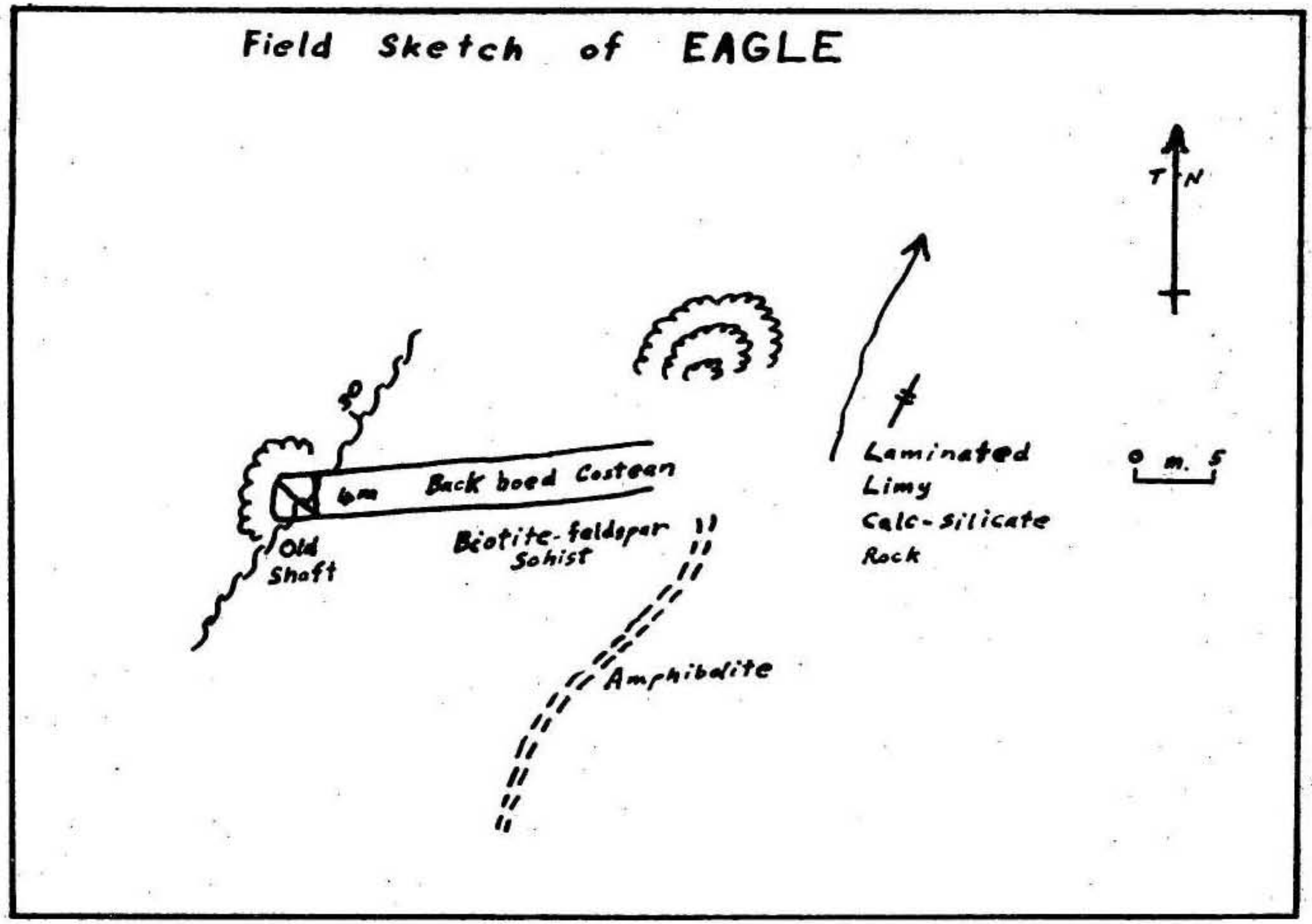
Workings: - One trench along shear, 5 m long and up to 3 m deep. One small prospecting pit 5 m to south.

Production: - Unknown.

JUBILEE (UV 965997)

This mine was one of the main small producing mines in the area, (R. Conder, lease-holder); it ceased production early in 1972. Mineralization extends along strike, trend 175°, for 200 m, with shafts at either end of the lode. The main shaft (northern end) is about 33 m deep; drives, from which

FIGURE D.

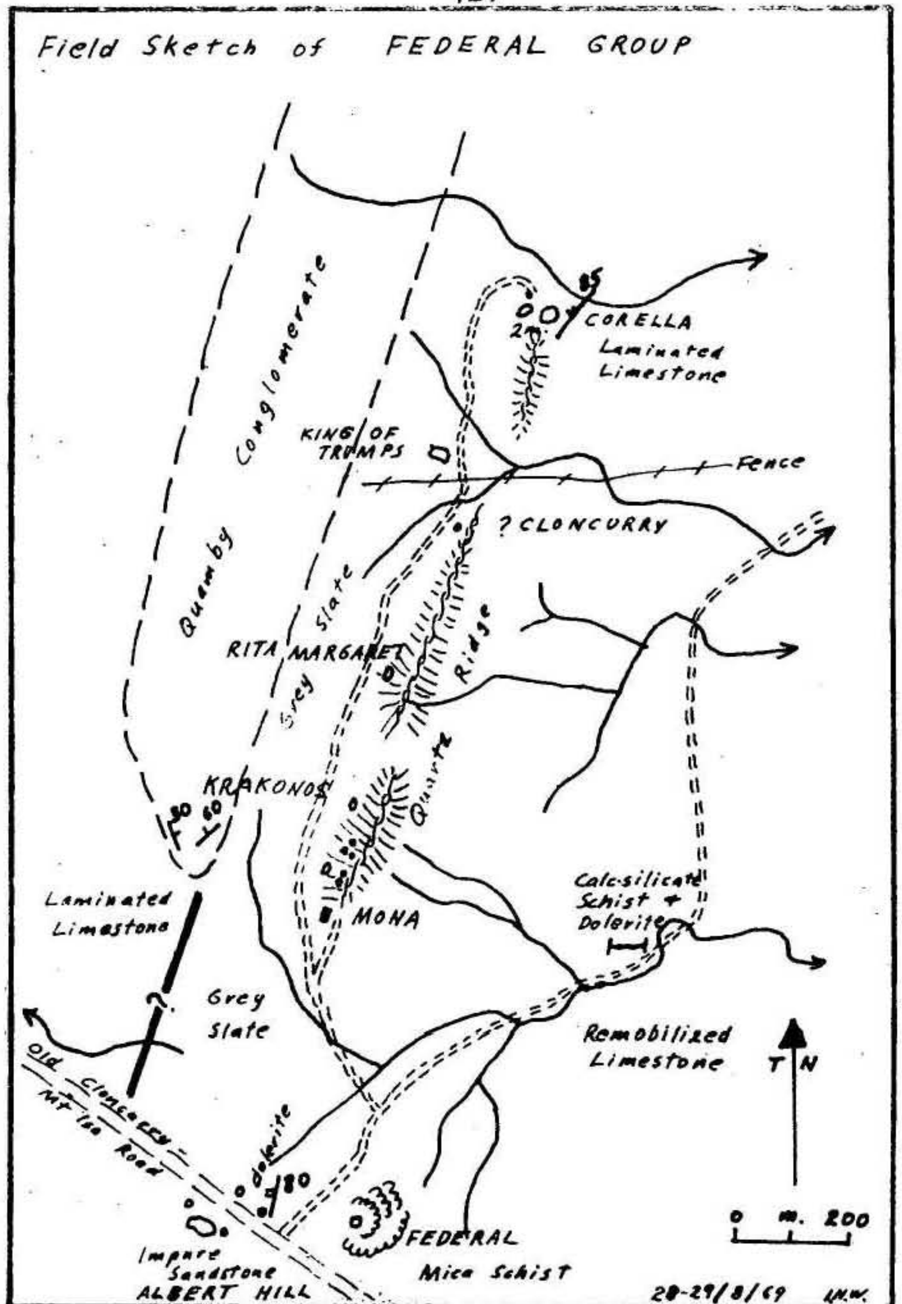



To accompany Record 1971/56.

F54/A2/70

FIGURE E.

(1)

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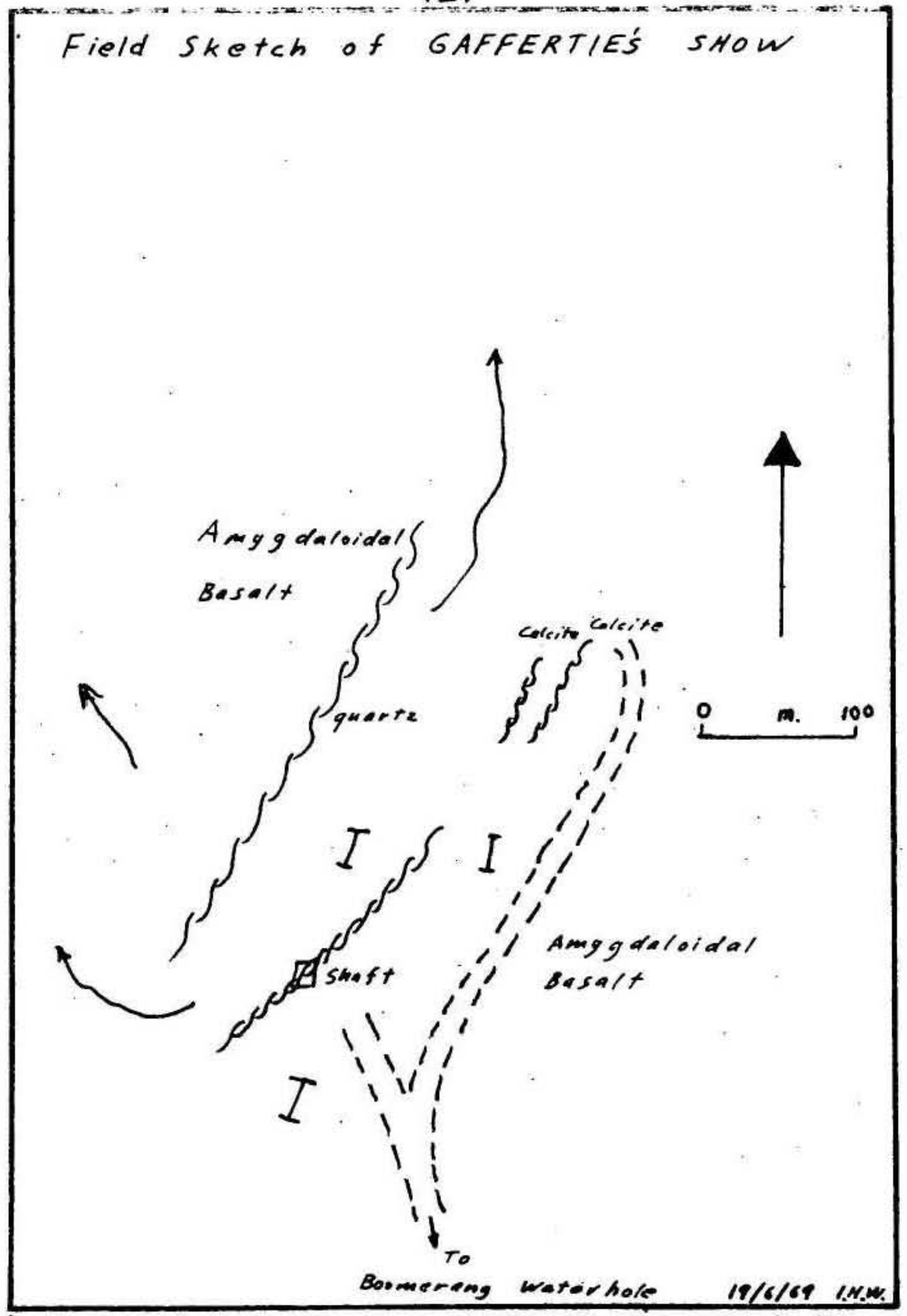
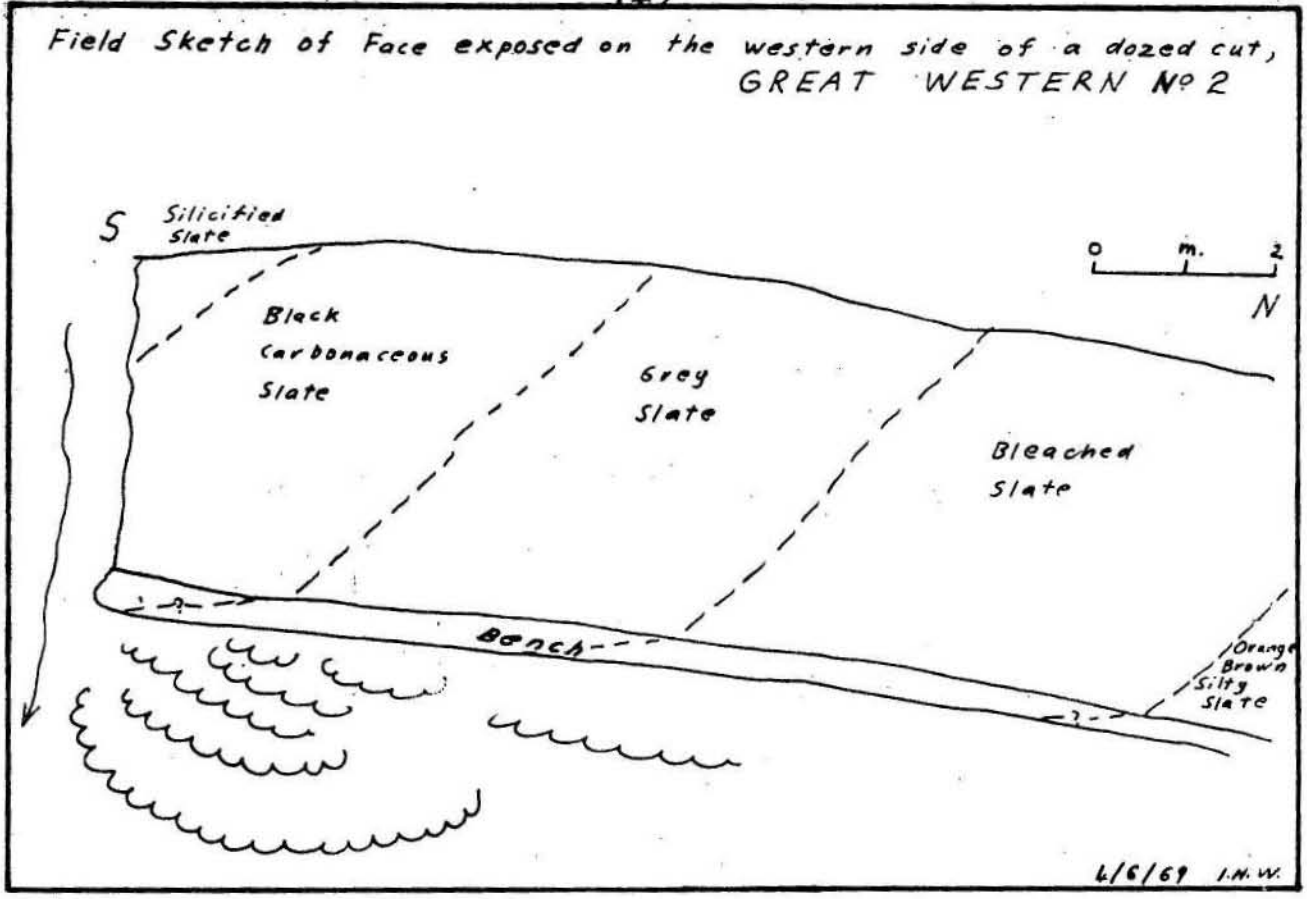



F54/A2/71

FIGURE F

(1)

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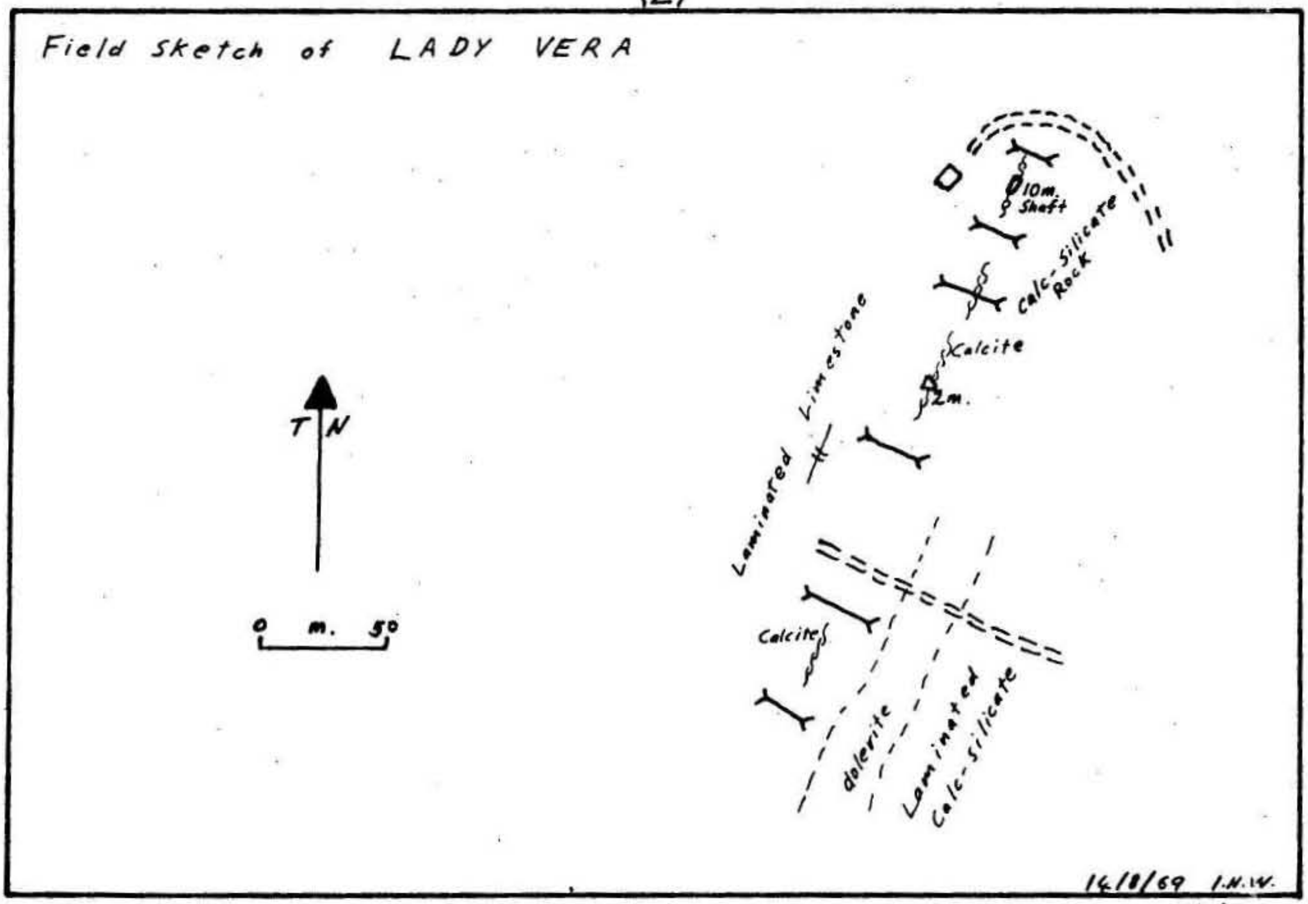
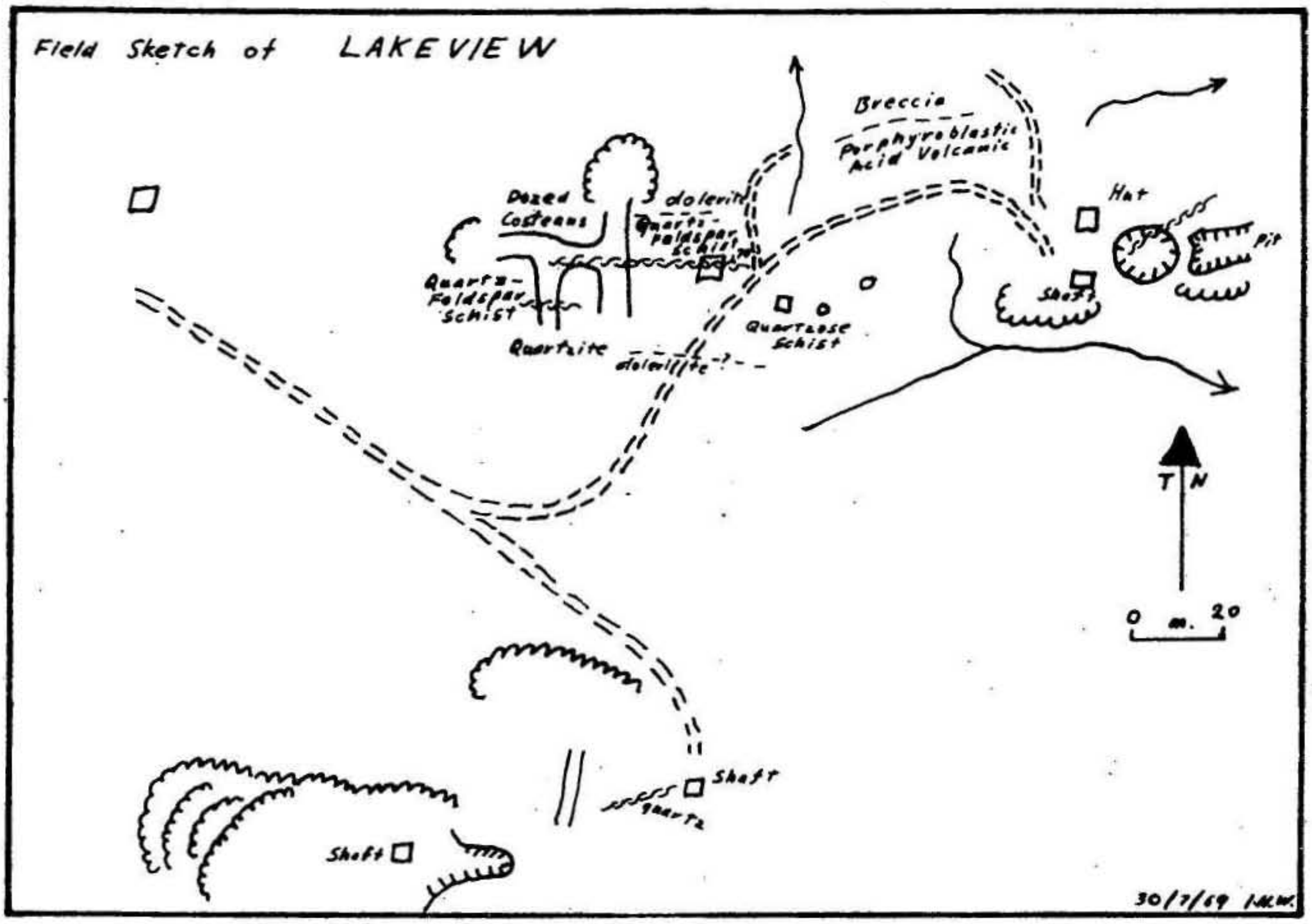



To accompany Record 1971/56.

F54/A2/72

FIGURE G.




To accompany Record 1971/56.

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stoping has been carried out, extend north and south. The deposit is grossly concordant with the country rock, which includes amphibolite, schist, mesocratic gneiss, and laminated impure quartzite. The footwall is biotite schist, and hanging wall hornblendite and amphibole gneiss. Chalcopyrite is the main ore minerals; gangue is quartz-calcite. Other minerals noted include pyrite, pyrrhotite, apatite, tourmaline, gypsum, and chalcocite. The latter is sooty, and occurs at about the 75' (22 m) level.

LADY VERA (VC 052037) (Fig. F2)

Location: - L-1-54-9, 3 km NW of Burke and Wills Memorial at Corella River Bridge.

Country rock: - Laminated limestone and calcsilicate rock intruded by dolerite. Strike 025°, dip vertical.

Lode: - Shear-zone trending 025°, some quartz veining carrying chrysocolla, malachite, and azurite. Chalcopyrite in calcite veins.

Workings: - There are 7 costeans up to 2 m deep spaced along 300 m of lode; 2 pits at the northern end, and one shaft 10 m deep.

Production: - Not recorded.

Prospects: - Currently being investigated.

LAKESIDE (UB 987947)

Location: - May be partly covered by Lake Corella. 1.75 km W of Corella Dam wall there are several small N-S elongated pits on shears in a calc-silicate granofels.

Production: - 30 tonnes of ore yielding 2.0 tonnes of copper.

LAKEVIEW (UB 985958) (Fig. G)

Location: - L-3-36-33, 2.75 km WNW of Corella Dam wall.

Country rock: - Sheared quartzo-feldspathic rock (probably porphyritic acid volcanic originally), psammitic biotite schist, and basic volcanics.

Lode: - Not well exposed at surface; at least 3 shears trending 070° to 095°, and dipping steeply to the north. Quartz veins associated with shears. Malachite is exposed in shear-zone by costeans. Chalcopyrite is main ore at depth, with pyrrhotite and rare pyrite in quartz gangue.

Workings: - Three shafts about 30-40 m deep, underground workings not examined. Large pit and (?)collapse area to E of most northerly shaft; several bull-dozed costeans to W of this shaft are the only large surface workings. Numerous small prospects pits on surrounding slopes.

Production: - 1965-69, 1236 tonnes of ore yielding 75.6 tonnes of copper.

Prospects: - Unknown, workings appear to be in good condition.

LALOR (VC 233070)

Two or three inclined holes have been drilled in mica schist, altered slate, and quartzite. The schist is possibly a sheared acid volcanic. These beds, with patchy mineralization, trend 50°, and are truncated to the northeast by a fault-zone trending 90°. A gossanous zone near the fault-line cuts across bedding.

LIME HILL (ML 5698) (UC 997196)

Location: - CR-4-68-16, 14 km NNE of Mary Kathleen open cut.

Lode: - A pod of coarse-grained calcite in biotite-quartz schist enclosed in (?)ortho-amphibolite. Mined for limestone flux.

?LONG VALLEY (UC 999251) (Fig. H2)

Location: - CR-3-88-12, 2 km N of old Mount Isa-Cloncurry Road on east side of Mary Kathleen-Dugald River access track (6 km N of Lime Hill).

Country rock: - Schistose calcsilicate rock and amphibolite striking N to NNE; dip vertical.

Lode: - Siliceous shears striking N and NW. Ore minerals azurite with some malachite.

Workings: - Several small exploratory pits.

MILO (Gooyen, Deeps) (VC 187043) (Fig. 1)

Location: - L-1-61-1, 0.5 km north of Barkly Highway, about 30 km west of Cloncurry.

Country rock: - Sequence of carbonaceous and graphitic slate and laminated carbonate/arenaceous calcsilicate rock and breccia intruded by acid volcanic rock and dolerite.

| | | |
|---|---|---|
| Lode: | - | Porous, kaolinitic, altered slate with minor quartz veining. Traces of copper mineralization, e.g. chalcopyrite associated with dolerite. Disseminated uranium mineralisation (torbernite) in kaolinitic rock. |
| Workings: | - | Bulldozed platform and several pits, adits and shafts, the deepest being over 30 m deep. |
| Production: | - | 9.4 tonnes of handpicked ore assaying 0.76% $U_3O_8$. |
| Prospects: | - | Drilling and evaluation as a copper prospect warranted. |
| References: | - | Carter et al., 1961. |

MOUNT GODKIN (VC 139277)

| | | |
|---|---|---|
| Location: | - | CR-2-40-1, 6 km NNW of Federal. |
| Country rock: | - | Calc-silicate granofels, strike 010°, dip 85°W. |
| Lode: | - | Curved shear-zone trending approximately east, and dipping 60-70° N.<br>Ferruginous and kaolinitic zones within shear; mineralization is copper carbonates and (?) chalcocite. |
| Workings: | - | One 15 m trench along shear, underlying steeply to north and stoped down 8 m. |
| Production: | - | 26 tonnes of copper ore. |
| Prospects: | - | Little trace of extensions to ore. |

MT GLORIOUS

About 1 km to the SE of Harlin is a small shaft (4 m deep) in altered dolerite. Sparse disseminations and veinlets of malachite in a limonitic quartz vein trending 320° for 40 m, and partly exposed by a small trench.

PEARL (UV 985931) (Fig. K1)

| | | |
|---|---|---|
| Location: | - | L-3-36-66, 3 km SW of Corella Dam wall on east bank of lake. |
| Country rock: | - | Laminated arenaceous calcsilicate rock and dolerite dykes. |

| | | |
|---|---|---|
| Lode: | - | Calcite veins and slightly silicified ferruginous shears trending 015°. Chalcopyrite disseminated in calcite veins; copper carbonates and limonite boxworks in ferruginous shears. |
| Workings: | - | Mined sporadically since 1905; 3 shafts at least 7 m deep, have been sunk on different shears and numerous pits and costeans have been dug on the northern and southern extensions. In 1968 back-hoeing was carried out on the two eastern shears and the collar of the most easterly shaft. |
| Production: | - | Records not complete.<br>97 tonnes of ore yielded 26.5 tonnes of copper. |
| Prospects: | - | Still numerous discontinuous pods of rich copper ore. |
| Reference: | - | Ball, 1908. |

<u>PEARL EXTENDED</u> (UB 985924)

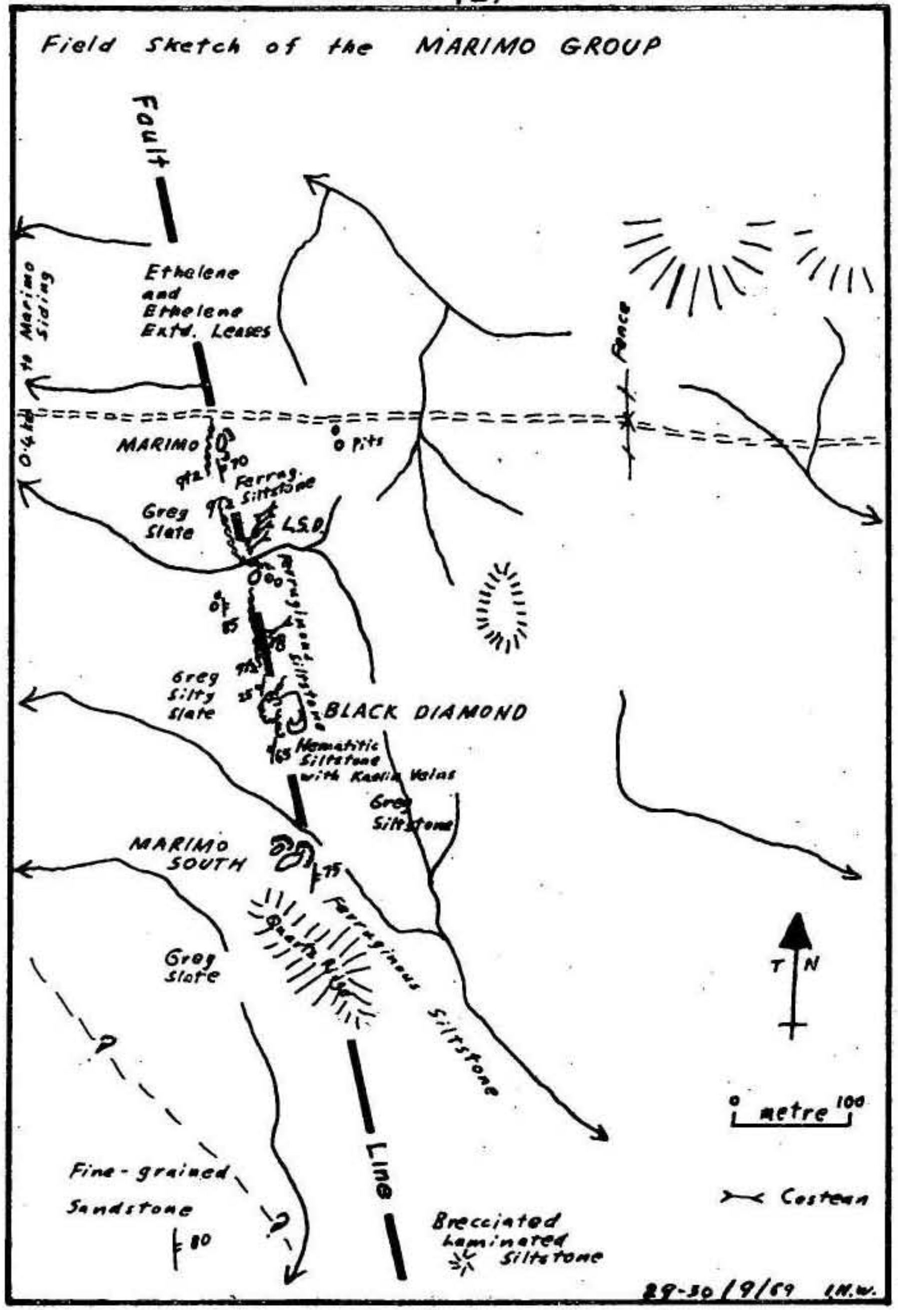
| | | |
|---|---|---|
| Location: | - | L-3-36-65, 2.5 km SW of Corella Dam wall on east shore of lake. |
| Country rock: | - | Sheared arenaceous calcsilicate rock and quartz-feldspar-biotite schist. |
| Lode: | - | A slightly silicified shear trending NNE, containing malachite staining. |
| Workings: | - | Collar of 1906 shaft caved in, and surrounding area was dug out with a backhoe about 1968. Now an open pot 20 m x 5 m and up to 3 m deep. |
| Production: | - | Records incomplete. |
| References: | - | Ball, 1908. |

<u>?BATTLE ACE</u> (VC 158182) (Fig. K2)

| | | |
|---|---|---|
| Location: | - | CR-4-80-17, 4 km S of Federal. |
| Country rock: | - | Basic schist and quartzite, strike 125°. |

FIGURE H

(1)

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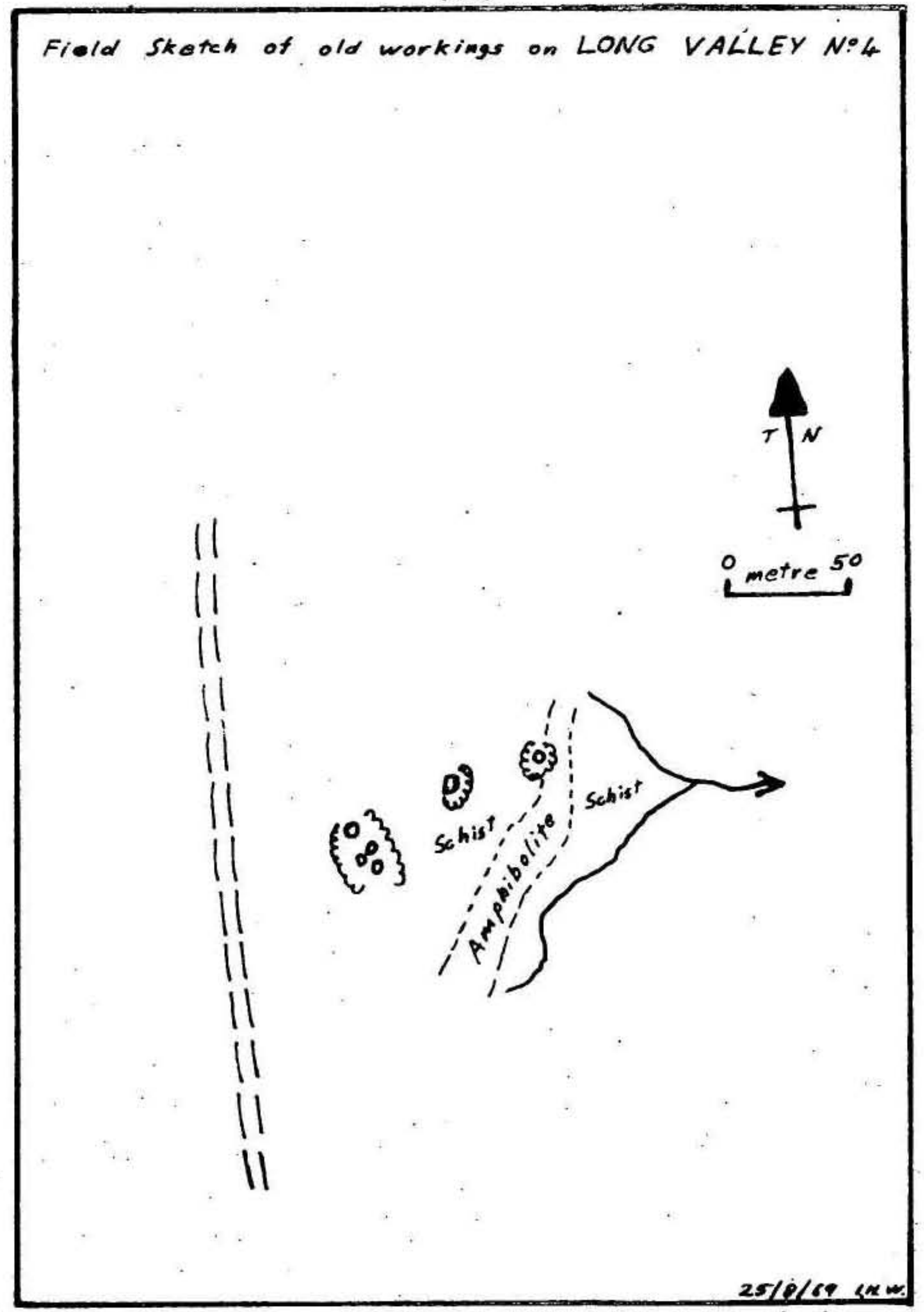
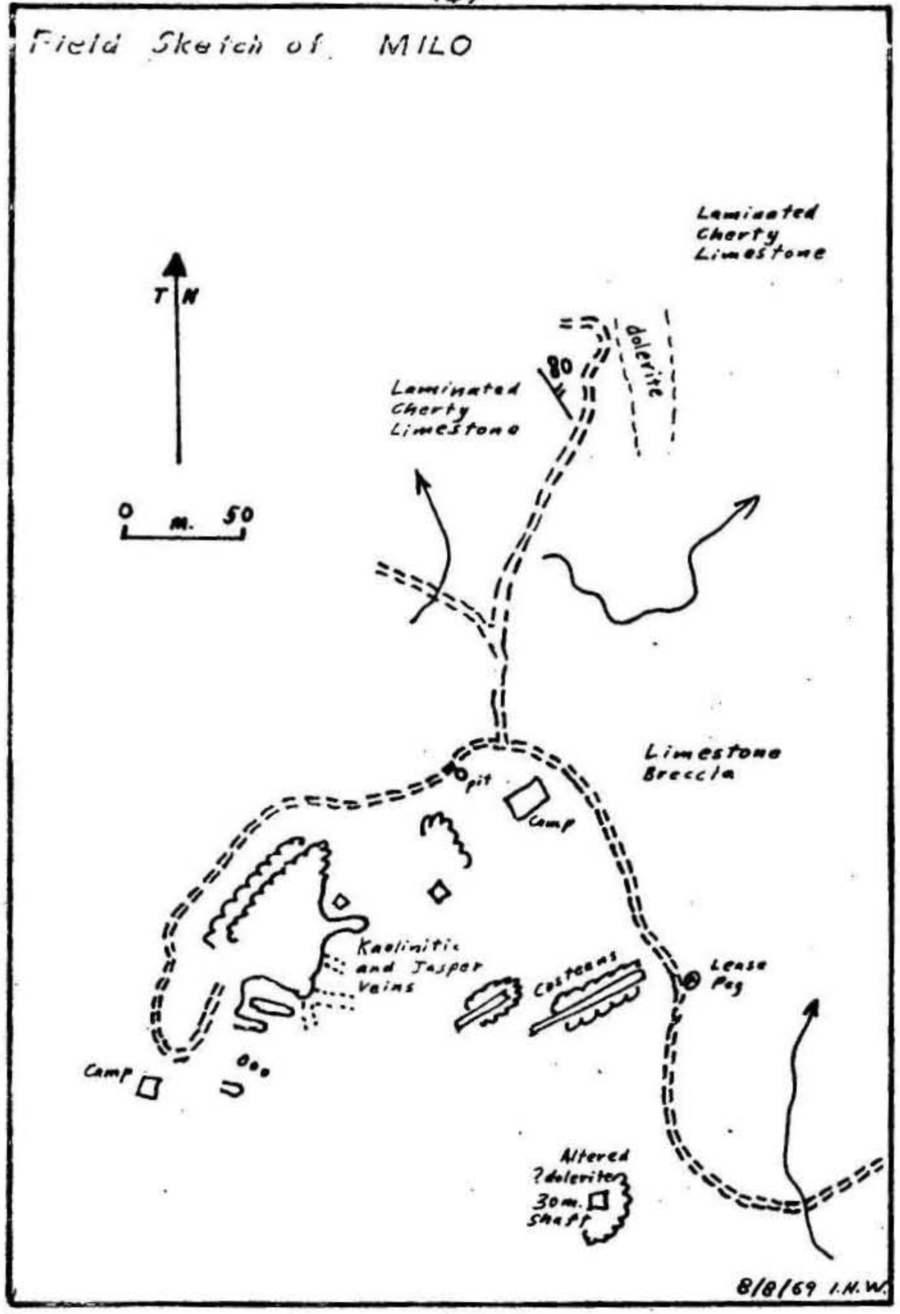



To accompany Record 1971/56.

F54/A2/72

FIGURE I

(1)

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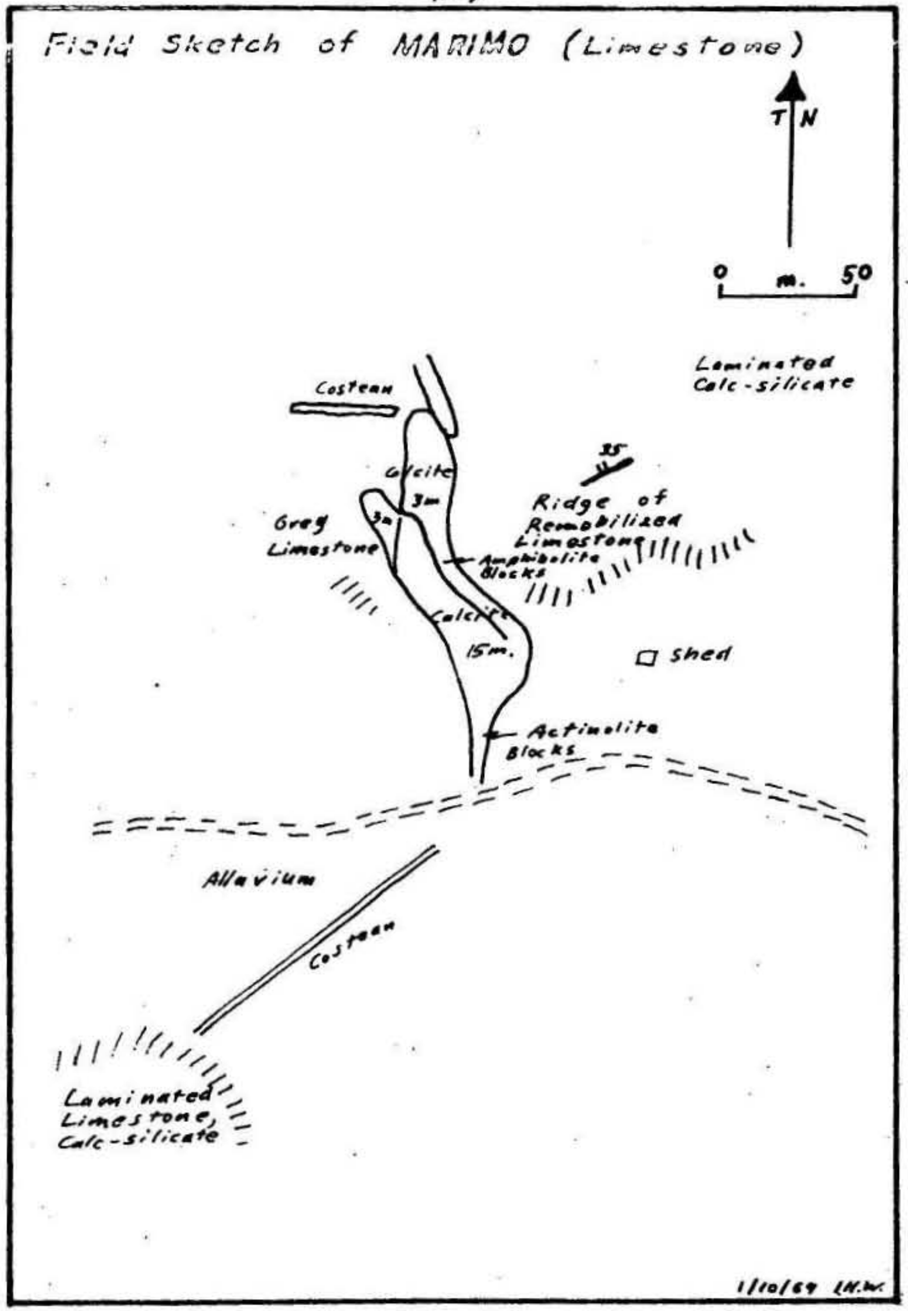
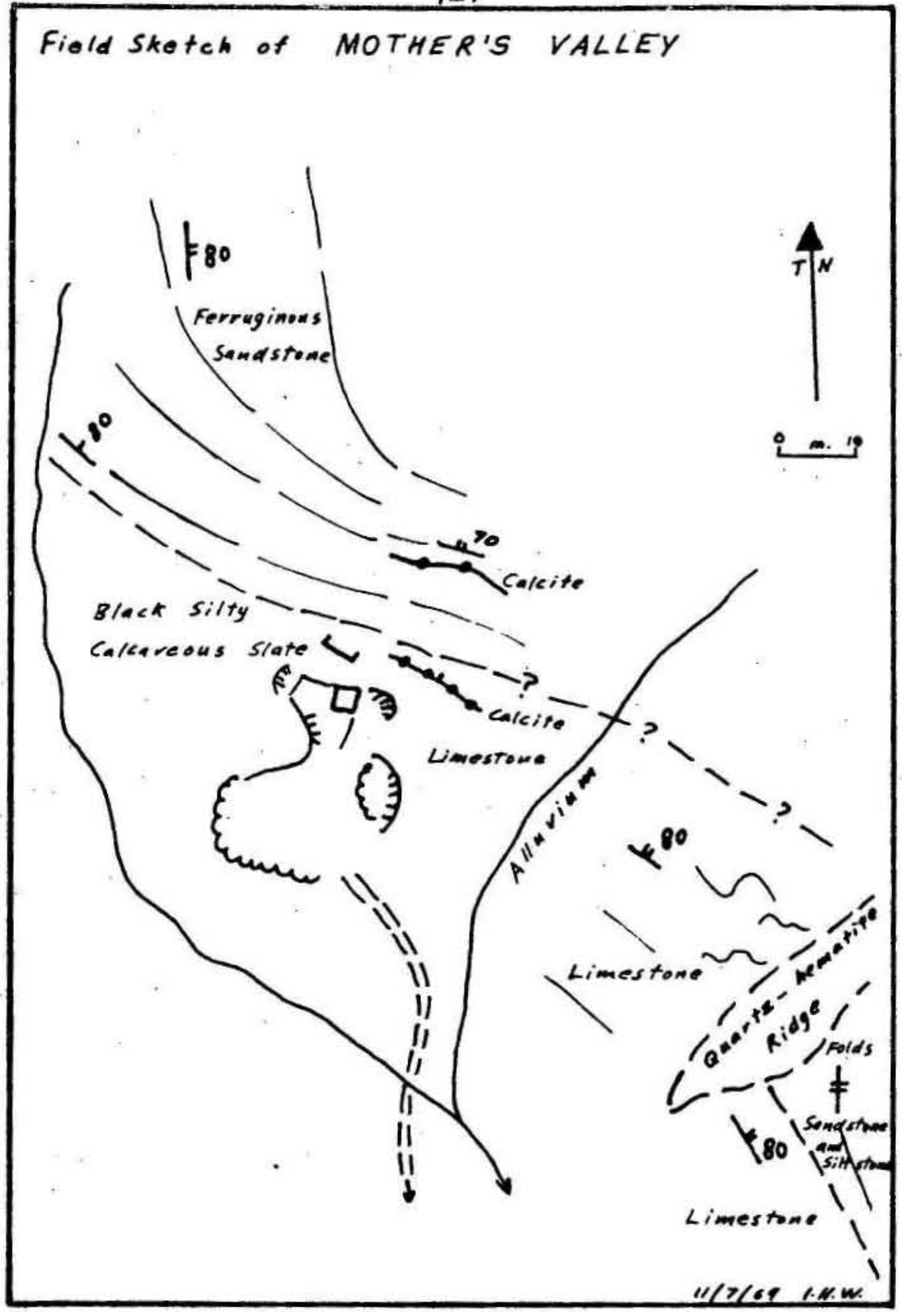



To accompany Record 1971/56.

F54/A2/75

FIGURE J

(1)

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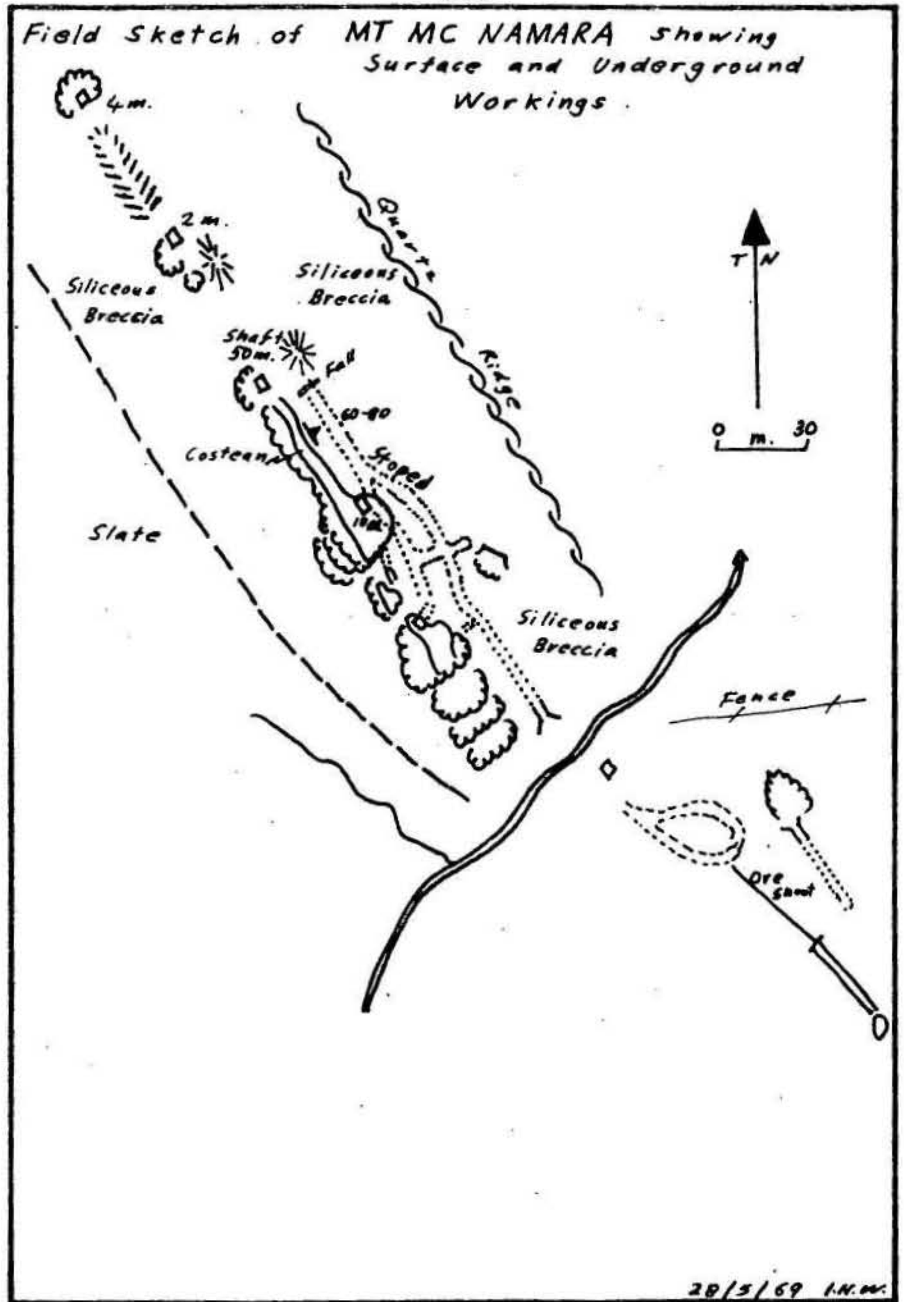
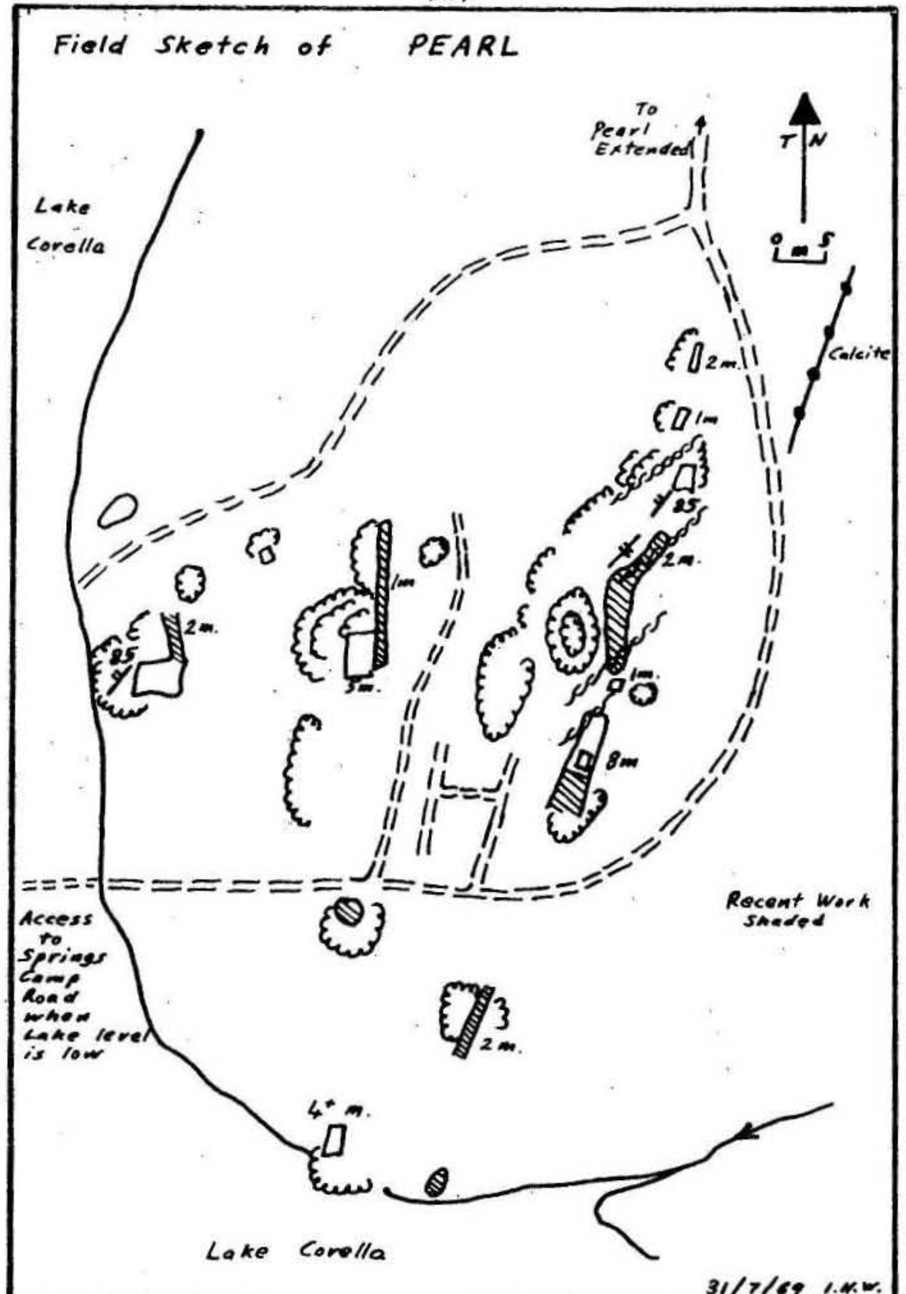



To accompany Record 1971/56.

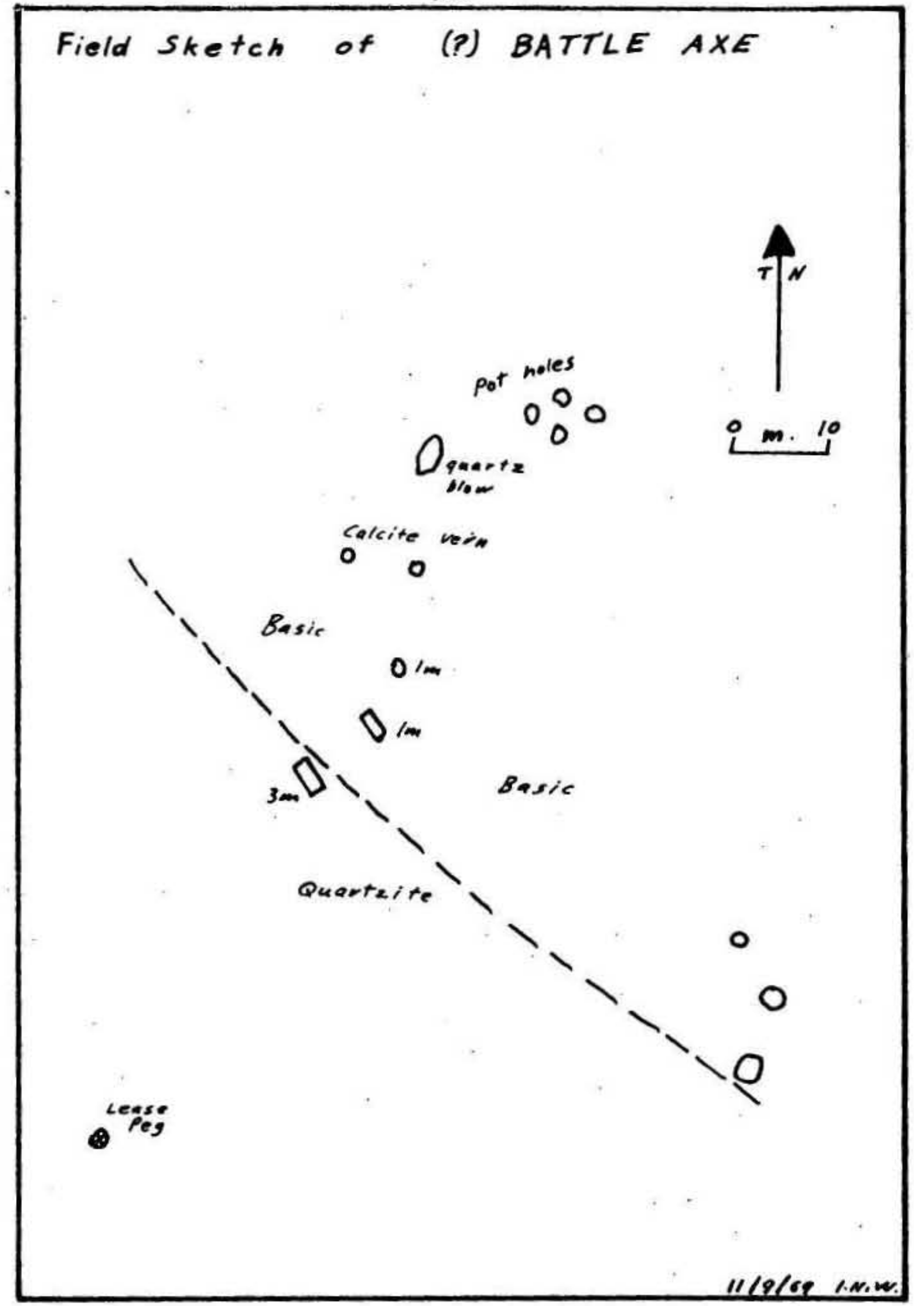
F54/A2/76

FIGURE K

(1)




(2)

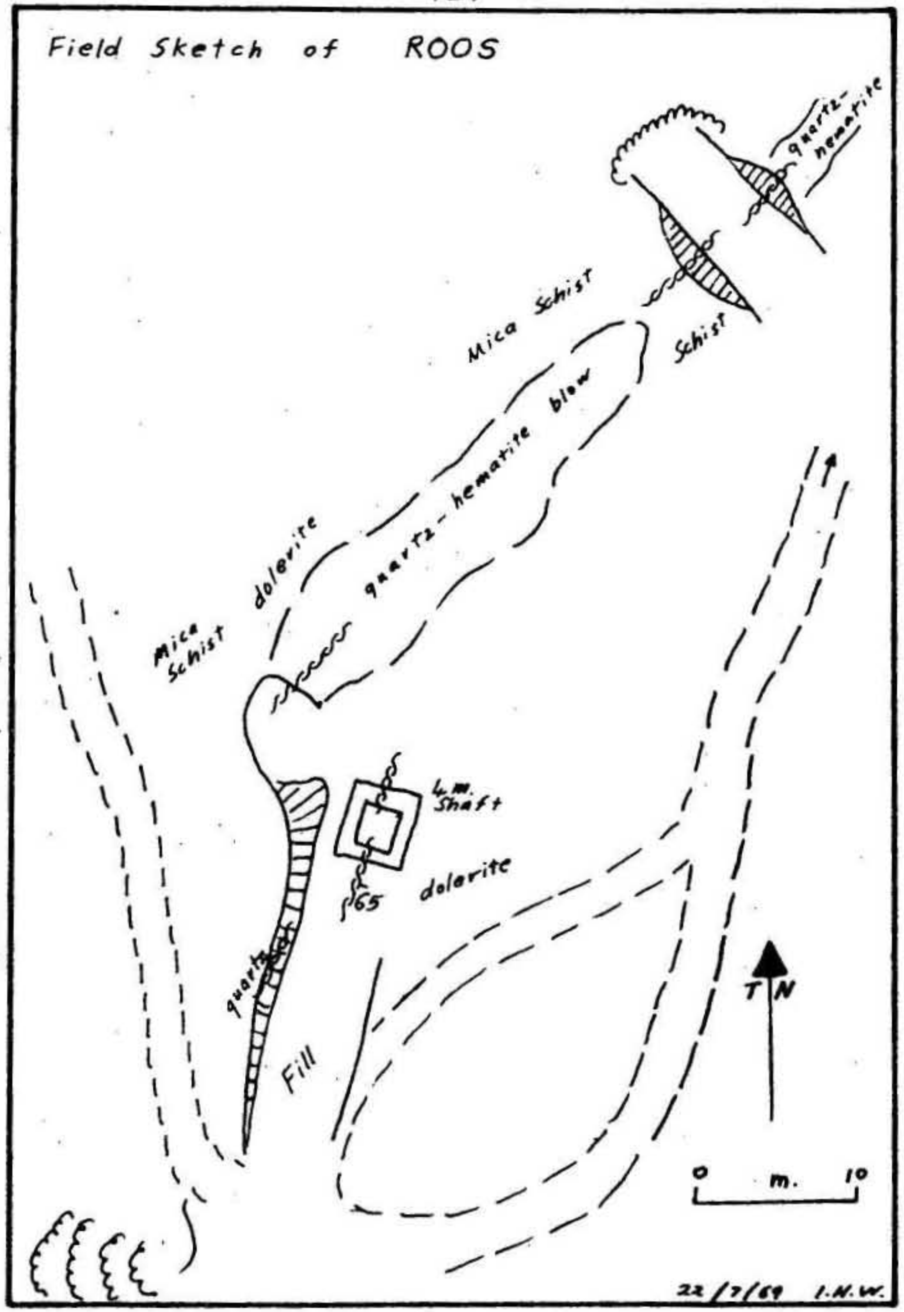



To accompany Record 1971/56.

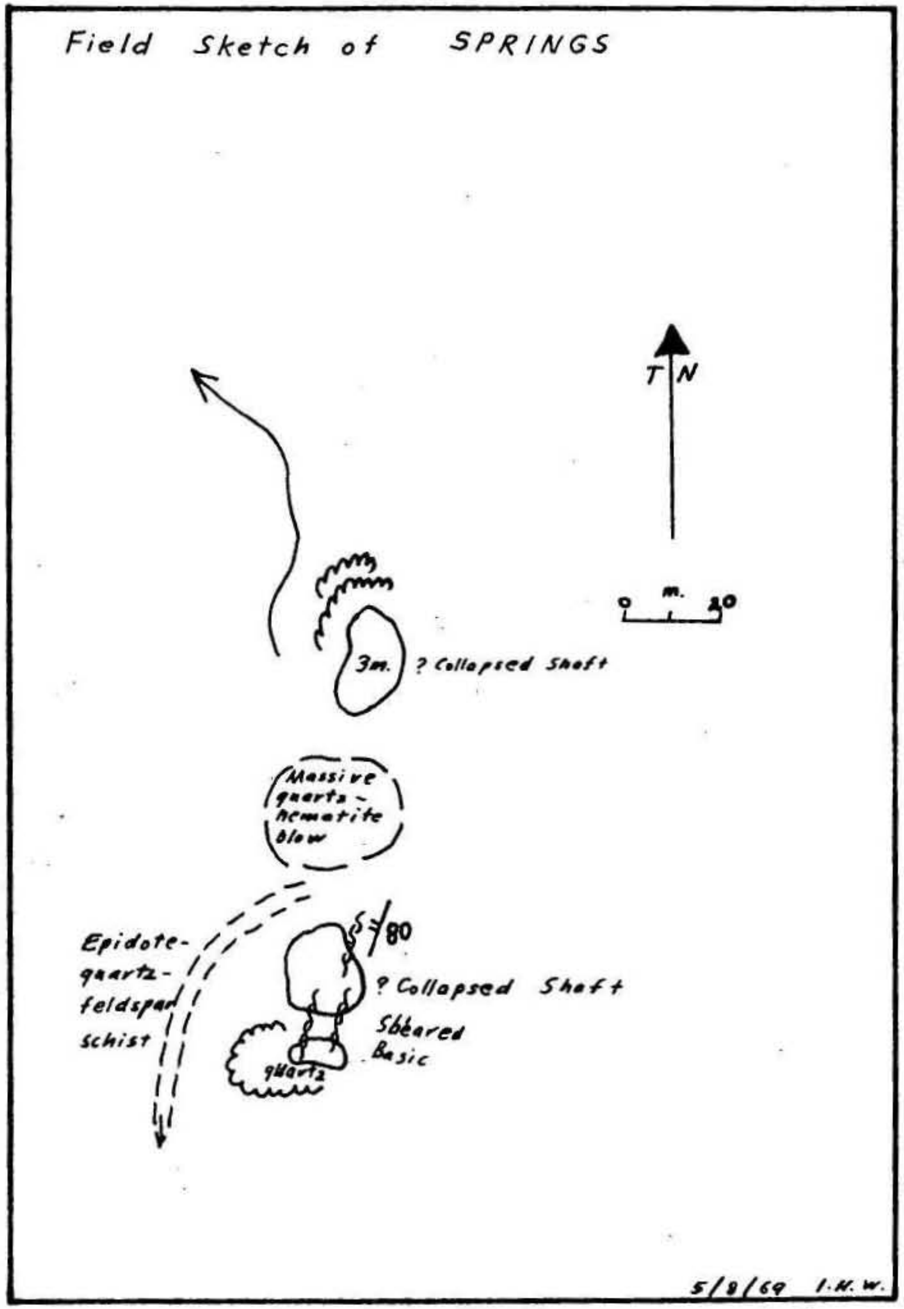
F54/A2/77

FIGURE L

(1)




(2)

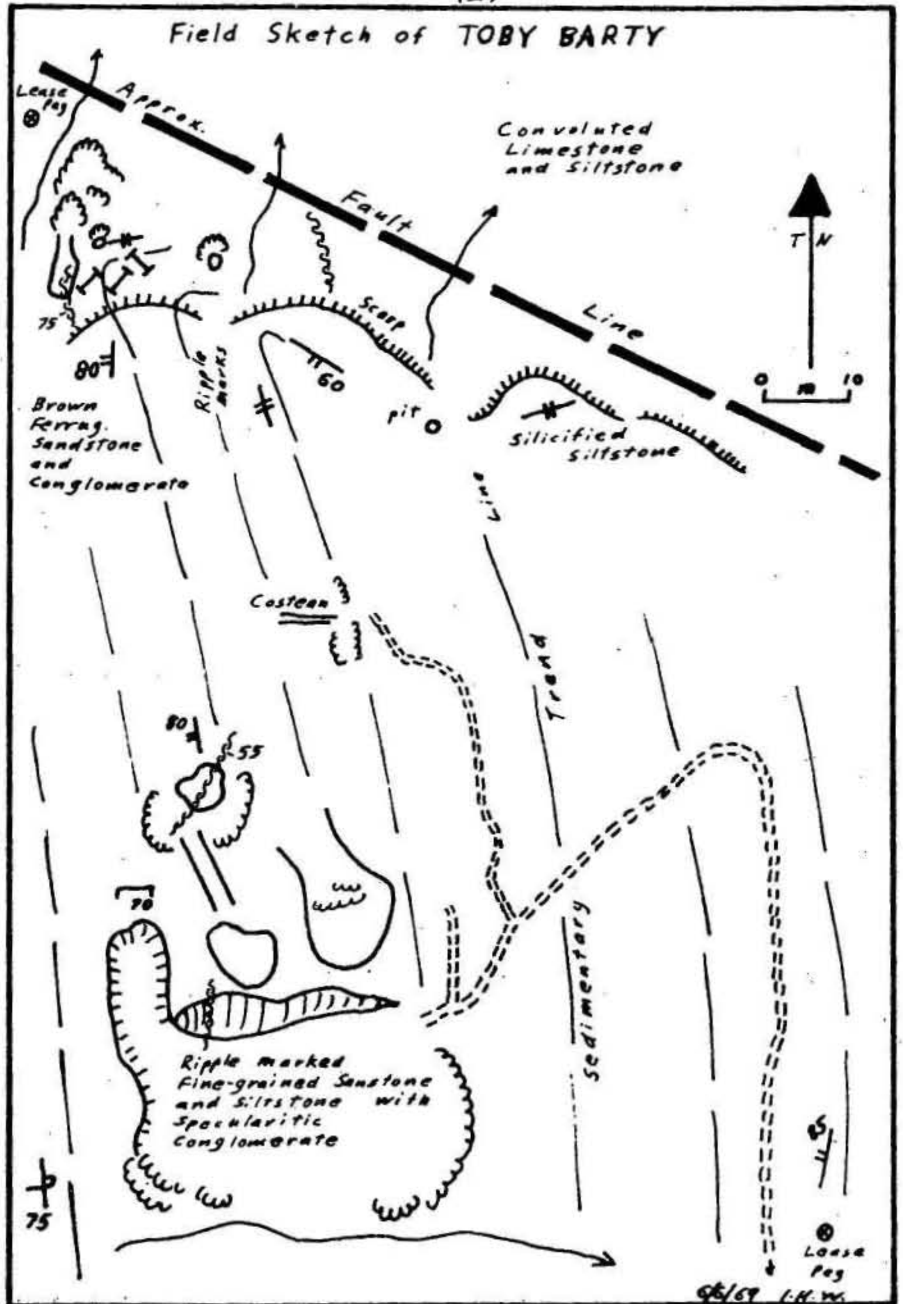



To accompany Record 1971/56.

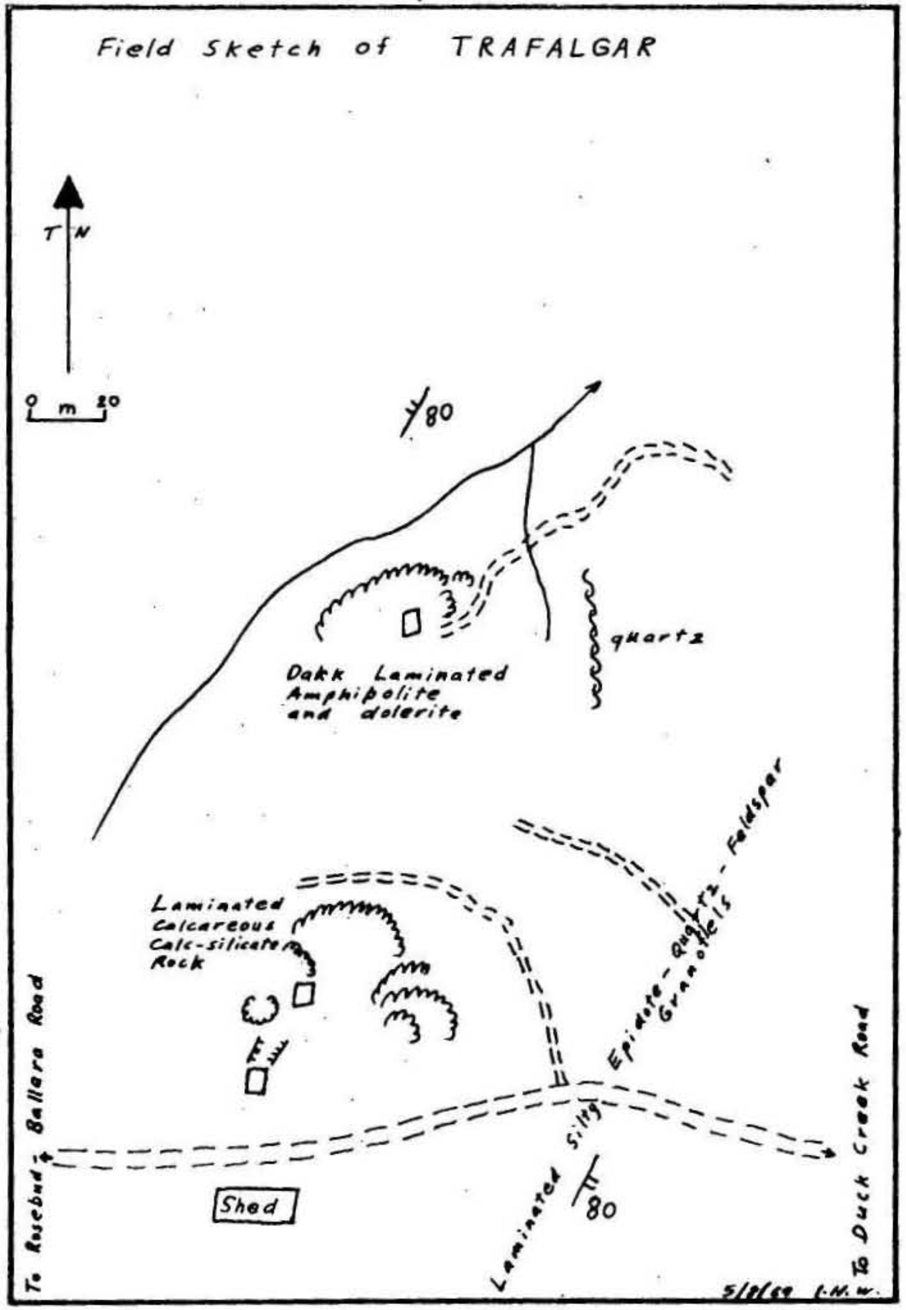
F54/A2/78

FIGURE M

(1)



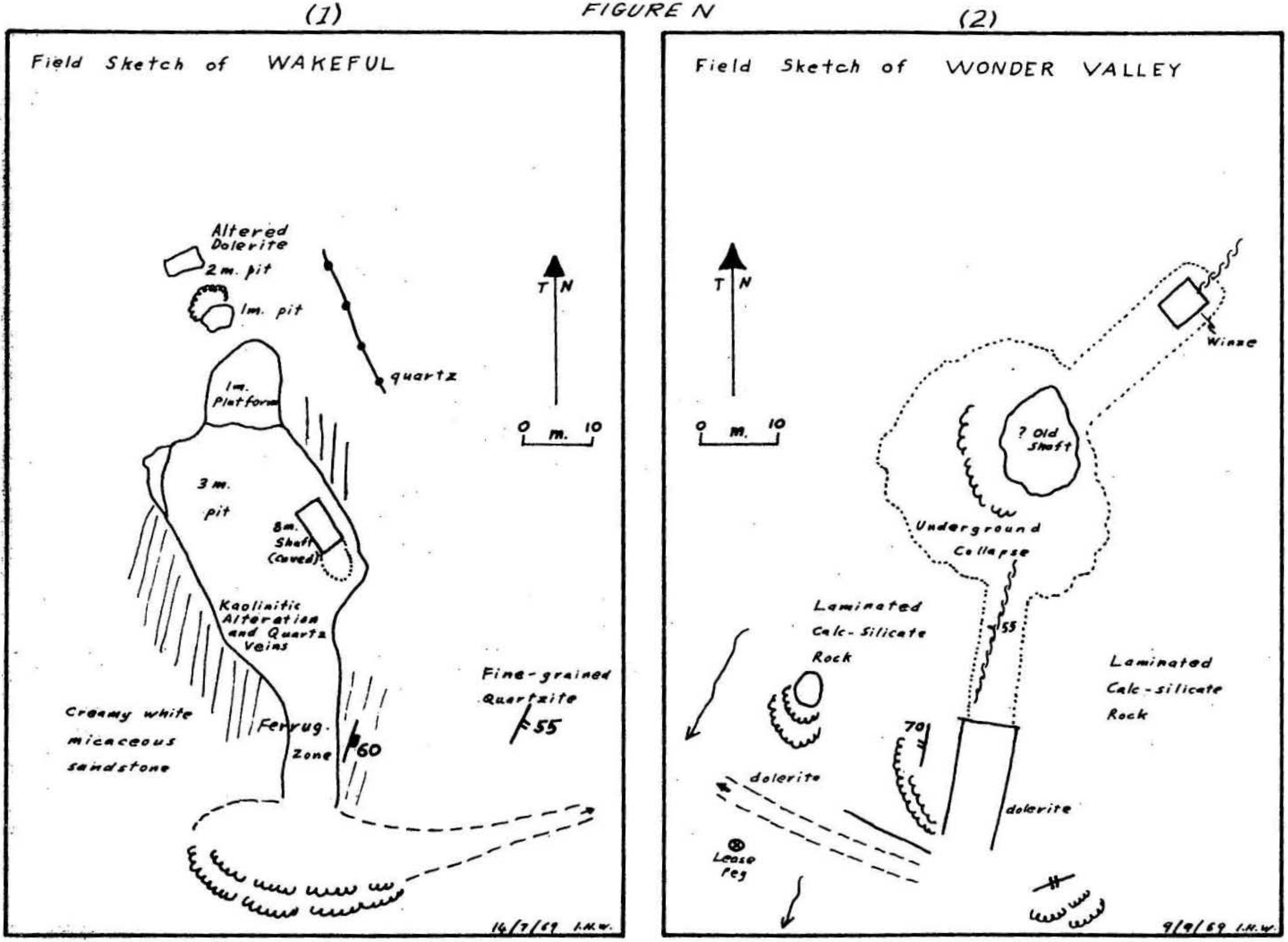

(2)




To accompany Record 1971/56.

F54/A2/79

FIGURE N




To accompany Record 1971/56.

F54/A2/80

Lode: - Calcite veins with some quartz-limonite veins in basic schist.

Workings: - 3 pits up to 3 m deep along 50 m of basic rock quartzite contact; several smaller pits to the northwest along contact.

ROSLYN PEARL (UB 989948)

Location: - L-5-36-55, 1.75 km W of Corella Dam wall.

Country rock: - Arenaceous calcsilicate granofels.

Lode: - Gossanous zone associated with a north-trending quartz vein.

Workings: - Several shallow pits extended over 100 m along strike of vein. Main workings may be submerged under lake.

SPRINGS (UB 965903) (Fig. L2)

Location: - L-4-100-6, 1 km NNE of Trafalgar on east bank of Springs Creek.

Country rock: - Schistose quartzose calcsilicate rock and amphibolite, strike 020°, dip 80°W.

Lode: - Several minor quartzose shears trending 005°, extending north and south of a quartz hematite blow showing traces of disseminated chalcopyrite. Traces of copper carbonate along shears.

Workings: - To north of quartz blow a pit 5 m deep, and to south of quartz blow 2 pits 2 - 4 m deep, evidently old (1905) shafts have fallen in.

Production: - Records probably include production from other mines in the Springs Group.

48 tonnes of 30 percent copper ore.

Prospects: - This area is currently being investigated.

TINY BOOT (VB 002940) (Also known as ELECTRA)

This is a large gossan with sporadic copper mineralization. The gossan is up to 5 m thick, and extends for 85 m on bearing 90°. The ore is malachite and chrysocolla in vuggy silicious hematite. A shaft near the eastern end is about 20 m deep. Country rock is calcsilicate granofels intruded by small granite plugs and dykes.

This zone of mineralization extends for about 1 km both east and west from shaft. Malachite nodules have been found west of the gossan in scree which obscures most of the lode. Chalcedony is present, and mineralization is localized along contacts between granite and metasediment. These small deposits are a facsimile of Mt Lindsay, and are worthy of further evaluation.

TRAFALGAR (ML5399) (UB 960892) (Fig. M2)

| | | |
|---|---|---|
| Location: | - | L-4-100-5, 7.5 km SW of Corella Dam, 0.5 km W of Springs Creek. |
| Country rock: | - | Laminated arenaceous calcsilicate schist and amphibolite. |
| Lode: | - | Calcite and quartz veins, trending NNE. Chalcopyrite veins in lode at depth. |
| Workings: | - | Worked discontinuously over from 1906 to 1969. Traces of old collapsed shaft; recent shafts more than 30 m deep. Extensive mullock heaps cover most of older workings. |
| Production: | - | 2279 tonnes of ore yielded 171 tonnes of copper. |
| Prospects: | - | Headframes still standing, and underground workings still in good condition. Investigated by Japanese interests in 1971, and a leaching operation is currently in progress (1972). |

WOLLONDONGA (VC 010118)

This show has one large shaft on eastern limit of mineralization, and some trenching 80 m to the west. The mineralized zone is localized around quartz veins and blows which occur 30 to 100 m east and south of the mine. Most of the quartz veins trend 35°, and carry abundant pyrite; locally they show en echelon structure, and mineralization is best where veins are thickest. The country rocks are calcsilicate granofels and impure laminated quartzite, with interbedded amphibolite. Main ore minerals are malachite, azurite, and chrysocolla.

WONDER VALLEY (VC 111174) (Fig. N2)

Location: - CR-5-24-25, 6.5 km SW of Federal.

Country rock: - Laminated arenaceous calcsilicate granofels, strike 000-005°, dip 70°W. Sheared basic rocks along east wall of entrance to adit.

Lode: - Major shear strikes 010-040°, dips 50-60°W. Malachite, azurite, and chrysocolla were observed, in quartz with some magnetite.

Workings: - An adit follows the shear trending 010° for 30 m, then trends 035° for a further 10 m, where there is a winze. The roof of the adit has collapsed.

Production: - 17 tonnes of ore yielded 3 tonnes of copper. Dump material would assay about 4 percent.

Prospects: - Extensions of shear are not mineralized.

SHOWING, 0.5 km west of Wollondonga (VC 005118)

A chalcocite-malachite vein, 6 cm to 20 cm thick, with minor quartz, extends for 5 m in a northerly direction, on the side of a steep hill. It lies 10 m southeast of a large quartz plug, and the host rock is altered porphyritic microgranite. About 0.3 tonnes of ore containing from 15 to 25 percent Cu, have been removed from the vein. About 80 m west are small scrapings in chalcedonic, copper-bearing gossan. Mineralization is related to the 'Burstall Granite'. This is possibly a small gouger prospect.

UNKNOWN NAME (CR7.12.25)

The same dolerite associated with mineralization at CR7.12.14 and SALMON, is the host rock at this small prospect. A small pit in basic schist contains traces of malachite. Quartz-hematite reefs striking 330° are offset in an en echelon pattern to the southeast. Faulting and shearing are evident.

UNNAMED DEPOSIT (VC 107319)

Location: - CR-1-24-2, 11 km NW of Federal, 0.5 km W of Mistake Creek.

Country rock: - Laminated porphyroblastic calcsilicate granofels, slightly brecciated, near (?)amphibolite.

| | | |
|---|---|---|
| Lode: | - | Ferruginous quartz veins trending N to NNW, and calcite and quartz-epidote veins. Quartz veins contain malachite, and calcite veins contain blebs of chrysocolla. Boxworks are very common; traces of gold have been observed. |
| Workings: | - | Scattered prospect pits and a collapsed shaft about 3 m deep. |
| Prospects: | - | Gouger's proposition only. |

UNNAMED DEPOSIT (VB 076968)

| | | |
|---|---|---|
| Location: | - | L-2-108-32, 5 km S of Burke and Wills Memorial at Corella River bridge. |
| Country rock: | - | Basalt. |
| Lode: | - | Quartz-calcite vein, striking 040°, with chalcopyrite and boxworks. Minor copper staining (malachite) in vugs in quartz. |
| Workings: | - | One prospect pit along shear, 5 m x 1 m, up to 2 m deep. |
| Prospects: | - | Vein and mineralization of small extent and low grade. |

UNKNOWN NAME (CR5.20.11)

An inclined shaft plunges 80° at 355° to 6 m depth in a mineralized quartz vein, intruding tremolite limestone. Mineralization consists of thin fracture-fillings of malachite associated with limonitic gossan. Fresh chalcopyrite occurs in dump material. Calcite forms minor veins in the ore-zone, which does not crop out. Average grade of dump material is 2 percent. The mine is held under lease.No igneous material is seen nearby; no source of mineralization is obvious.

## E) COPPER - LIMESTONE DEPOSITS

DINGO (VC 406078) (CR8.72.5)

Two open cut trenches outline the weakly mineralized pale yellow calcite reef trending 165°.

Black to brown calcareous breccia and calcareous shale trend 100°; poorly outcropping dolerite is adjacent to the calcite lenses. The open cut to the north is 100 m long, 20 m wide, and up to 10 m deep. Mineralization comprises sparsely disseminated malachite rimming residual chalcopyrite grains in limonite.

As with SALMON, the calcite has been mined for flux.

DOLOMITE (VC 419064)

This is a series of deep pits up to 100 m wide and 50 m deep; all show coarsely crystalline calcite with sporadic patches of malachite-chalcopyrite 1 to 5 cm across. All the calcite deposits are associated with calcsilicate granofels, breccia, and dolerite. Dolerite is locally veined by calcite.

LIME CREEK (VC 978182)

This major producer of limestone has not been examined in detail. There are two main pits, the southernmost now disused, possibly temporarily. The limestone lens is contained in an acid volcanic-quartzite-dolerite sequence. The southern pit has exposed a thick zone or vein of pyrrhotite - chalcopyrite trending about 55°. The sulphides intimately vein the calcite.

In the newly-opened northern pit, about 0.5 km from the southern pit, molybdenite has been found in flakes 2 cm across, together with actinolite, quartz, biotite, and sulphides. Production is currently about 2540 tonnes per month.

MARIMO (Limestone Quarry) (MacDonald's Quarry) (VB 475963) (Fig. I2)

Location: - L-2-88-1, 14 km SW of Cloncurry, 7 km ESE of Marimo siding.

Country rock: - Grey laminated calcsilicate rock, which is partly mobilized, and dolerite.

Ore body: - Large mass of mobilized limestone (coarse-grained calcite) with blocks of dolerite and actinolite pods.

Workings: - Open pit 150 m x 30 m with two levels at 3 m and 15 m. Costeans have been dug to N and S of pit.

Production: - 51,801 tonnes of limestone flux.

Prospects: - Not worked recently.

Reserves are much smaller than those of deposits currently being worked.

SALMON (VC 410066) (CR7.12.2)

Two intersecting open cuts formerly mined for flux, are developed in yellowish calcite. Country rock on both footwall and hanging wall is medium-grained metadolerite. Chalcopyrite surrounded by rims of malachite and limonite is weakly disseminated throughout the 30 m wide reef and also in minor fracture of shear-zones. These two open cuts are over 200 m long, and about 20 m deep. A small vertical shaft in dolerite at least 7 m deep, is adjacent to one open cut. The surrounding host rock seems to be the source of the copper mineralization. The calcite may have been mobilized from calcareous country rocks.

Note: 500 m to the NW of SALMON are two massive hematite reefs, the larger trending due north for over 1 km, and the smaller, with quartz, trending NW. Relationship of Salmon to this mineralization is unknown. The reefs are probably associated with faulting.

WILGAR (VC 320152)

Two large pits up to 50 m wide and 25 m deep contain massive, coarsely crystalline calcite. The easternmost pit contains calcite with sporadic chalcopyrite and malachite nodules, and some tremolite. Rare fragments of pyritic quartzite are also present. Altered dolerite occurs along the northeast flank of the easternmost pit, and amphibolite-calcite breccia in the western pit.

# APPENDIX 2

## GEOCHEMISTRY

Numerous geochemical programs have been undertaken by mining companies in the Marraba 1:100 000 Sheet area. Most of this work has been stream sediment geochemistry; CRA, however, determined some average abundances of various elements in certain rock types, and it is this approach which BMR hope to continue in future geochemical programmes in the area.

Section A of this Appendix deals with results obtained from some whole rock geochemical programs undertaken in 1969 by BMR. Section B contains comments on geochemical prospecting techniques, results of mining company programs in the area, and outlines some pilot stream sediment sampling done by BMR in 1969.

### SECTION A - WHOLE ROCK GEOCHEMISTRY

1. Limestones
2. Iron and manganese deposits
3. Copper in basic rocks
4. Basalt analyses
5. Carbon and trace element contents of slate
6. Major element slate analyses.

In some cases the analytical results are listed without comment; some preliminary interpretation is given for certain groupings.

### 1. LIMESTONES

Intrusive carbonate rocks are widespread in the Corella Formation, and to a lesser extent in other formations. In hand specimen they consist of coarsely crystalline calcite and/or dolomite, and form dykes and lenses in amphibolite, basalt, porphyry, limestone, and calcsilicate rocks. Sulphide mineralization is common in some of the limestones.

The geochemical program sought to

a. determine calcite/dolomite proportions
b. determine carbonatite affinities, if any
c. comparison of intrusive and sedimentary limestones.

In addition to trace element geochemistry, major element analyses were also carried out. The key to the specimens is listed in Table A.

#### Results and Discussion

The major element analyses were carried out in the BMR. The results are presented in Table B.

Minor element analyses were performed by BMR (Smith and Slezak, 1971), and AMDL, and their results are listed in Tables C and D, respectively.

The major element analyses show that impure sedimentary limestones (340, 341, 344, 348) are all calcitic, or only slightly dolomitic. Non-sedimentary carbonate deposits appear to fall into two groups: carbonate (with copper minerals) in small fissure veins related to dolerite, is brown and highly magnesian (samples 342, 343); the other group is calcitic, and forms very large coarse-grained bodies, with scattered sulphide (samples 350, 351, 352), such as Lime Creek, Mt Frosty, and Dingo. One notable exception is sample 338 - this is a vein of carbonate analysing 20.2 percent MgO (nearly pure dolomite).

Relatively high values of MnO in samples 347 and 349 are probably due to thin Mn-stained cracks. All samples showed stain-reactions for dolomite (Evamy, 1963) consistent with the chemical analyses.

Trace element abundances of the elements Ba, Nb, Sr, La, and Y are useful indicators of carbonatite affinities. Table E lists the average abundances of these elements in the sedimentary and secondary limestones from the Marraba Sheet area, and compares them with average abundances in carbonatites (see tables in Gellatly, 1969). Results show that none of the intrusive, secondary carbonates are likely to be carbonatites. The sedimentary limestones from the Marraba area appear to be enriched in barium relative to average abundances elsewhere.

## 2. IRON AND MANGANESE DEPOSITS

Manganese-iron nodules and iron formation were analysed for Fe, Mn, Co, Ni, Pb, and Cu. The aim of the work was to obtain some Fe percentages for banded iron formation, Mn percentages for certain large deposits, and Cu, Co, Ni, and Pb values to determine whether the Fe-Mn samples are of submarine or terrestrial origin. Results are shown in Table F.

### Discussion of Results

The manganese nodules etc show high concentrations of the trace elements relative to average shale/carbonate rocks, but low concentrations relative to recently dredged deep-sea manganese nodules. The development and enrichment of the manganese ores have probably been effected by meteoric waters circulating along shear-zones etc.

Sample 328 shows anomalous copper values of 1650 ppm. It was collected 8.4 km southeast of the Overhang, and about 600 m east of the turnoff to Top Camp diggings, where the road cuts through a small rise of manganese-veined quartzitic breccia; further work in this area is suggested. Analyses of the banded iron formation indicate that, although some samples are of reasonable grade (48 percent Fe), overall grade and size of the deposits are uneconomic.

Table A : Specimen Key, Carbonate Geochemistry

Marraba Sheet Area

| Field Number | Reg'd No. | Locality (Co-ordinates)Y | Description |
|---|---|---|---|
| CR7.6.1 | 70200337* | 1.8 km NE Cloncurry | Massive c.g. pink limestone |
| CR7.12.11 | 338 | VC 402082 | Massive c.g. grey-buff limestone |
| L5.12.18 | 339 | VB084873 | Massive limestone |
| C13.34.35b | 340* | VB475926 | Laminated sedimentary limesto |
| C12.77.50g | 341 | UB975999 | " " " |
| CR7.16.46g | 342 | VC318086 | Massive limestone with Cu |
| L7.41.2 | 343 | VB034803 | " " " " |
| CR6.04.19 | 344 | VC019146 | Scapolite-diopside limestone |
| L6.57.1C | 345 | VB271793 | Fine-grained massive limeston |
| L1.66.12b | 346 | VC2670 | Massive limestone |
| L6.60.48 | 347 | VB223834 | Massive limestone |
| L6.72.6 | 348 | UB987808 | Impure arenaceous limestone |
| CR6.04.14d | 349 | VC024153 | Massive limestone |
| K11.38.44 | 350** | | Mt Frosty: massive calcite-pyrite |
| CR8.72.2b | 351 | VC406078 | Cupriferous limestone-Dingo |
| L5.30.25 | 352 | UC978182 | Lime Creek: massive pyrrhotitic limestone. |

* Cloncurry 1:100 000 Sheet
** Mary Kathleen 1:100 000 Sheet
Y Refers to 1 000 metre grid

## Table B: Chemical Analysis of Limestones from Marraba 1:100 000 Sheet Area, N.W. Queensland

by

J.W. Sheraton

Sixteen samples of limestones from the Marraba 1:100 000 Sheet area, N.W. Queensland, were submitted by G.M. Derrick for major element analysis. The analyses were carried out by X-ray fluorescence, using material ignited at 900°C, except for samples 0350 and 0352, which were ignited at 1000°C. The results are quoted on an unignited basis.

| Sample No. ** | 0337 | 0338 | 0339 | 0340 | 0341 | 0342 |
|---|---|---|---|---|---|---|
| $SiO_2$ | 1.0 | 5.6 | 0.0 | 17.6 | 17.0 | 4.6 |
| $TiO_2$ | 0.01 | 0.01 | 0.02 | 0.09 | 0.13 | 0.01 |
| $Al_2O_3$ | 0.15 | 0.03 | 0.08 | 1.68 | 3.87 | 0.07 |
| $+Fe_2O_3$ | 0.62 | 1.49 | 0.68 | 1.29 | 1.16 | 3.98 |
| MnO | 0.36 | 0.37 | 0.30 | 0.12 | 0.27 | 0.44 |
| MgO | 1.5 | 20.2 | 1.1 | 6.0 | 3.5 | 11.2 |
| CaO | 53.9 | 29.3 | 56.4 | 37.0 | 44.8 | 22.5 |
| $Na_2O$ | 0.1 | 0.1 | 0.1 | 0.4 | 0.0 | 0.1 |
| $K_2O$ | 0.01 | 0.01 | 0.01 | 0.71 | 0.37 | 0.00 |
| $P_2O_5$ | 0.06 | 0.04 | 0.06 | 0.25 | 0.35 | 0.04 |
| Loss on ignition | 42.7 | 43.8 | 42.6 | 34.5 | 27.8 | 44.2 |
| Total | 100.4 | 101.0 | 101.4 | 99.6 | 99.3 | 87.1* |

| Sample No. ** | 343 | 344 | 345 | 346 | 347 | 348 |
|---|---|---|---|---|---|---|
| $SiO_2$ | 12.0 | 18.9 | 2.4 | 0.6 | 5.5 | 29.5 |
| $TiO_2$ | 0.03 | 0.33 | 0.04 | 0.01 | 0.04 | 0.12 |
| $Al_2O_3$ | 0.24 | 2.70 | 0.47 | 0.07 | 0.34 | 3.47 |
| $+Fe_2O_3$ | 7.67 | 1.74 | 1.15 | 0.63 | 3.71 | 1.71 |
| MnO | 0.52 | 0.17 | 0.25 | 0.41 | 1.30 | 0.31 |
| MgO | 10.3 | 1.9 | 2.2 | 1.3 | 16.9 | 1.2 |
| CaO | 30.6 | 41.8 | 53.3 | 55.4 | 30.8 | 34.8 |
| $Na_2O$ | 0.1 | 0.4 | 0.1 | 0.2 | 0.1 | 0.4 |
| $K_2O$ | 0.01 | 0.51 | 0.04 | 0.01 | 0.01 | 1.57 |
| $P_2O_5$ | 0.05 | 0.12 | 0.17 | 0.07 | 0.04 | 0.76 |
| Loss on ignition | 35.4 | 30.8 | 40.8 | 41.8 | 42.3 | 25.9 |
| Total | 96.9* | 99.4 | 100.9 | 100.5 | 101.0 | 99.7 |

| Sample No.** | 349 | 350 | 351 | 352 |
|---|---|---|---|---|
| $SiO_2$ | 4.9 | 0.1 | 0.3 | 0.0 |
| $TiO_2$ | 0.02 | 0.01 | 0.01 | 0.00 |
| $Al_2O_3$ | 0.06 | 0.02 | 0.07 | 0.01 |
| $+Fe_2O_3$ | 0.78 | 29.3 | 1.16 | 27.4 |
| MnO | 4.03 | 0.10 | 0.21 | 0.11 |
| CaO | 49.5 | 31.9 | 54.4 | 38.1 |
| $Na_2O$ | 0.1 | 0.1 | 0.1 | 0.00 |
| $K_2O$ | 0.07 | 0.01 | 0.01 | 0.00 |
| $P_2O_5$ | 0.07 | 0.04 | 0.06 | 0.05 |
| Loss on ignition | 39.3 | 24.1 | 42.7 | 12.2 |
| Total | 100.0 | 86.5= | 100.2 | 79.7= |

** BMR registered number sample numbers eg 70200343
+ Total iron as $Fe_2O_3$
* Samples contain more than 1% of copper (determined by optical emission spectroscopy by T. Slezak).
= Samples contain abundant sulphide.

## Table C: Analyses of Limestones from Marraba 1:100 000 Sheet Area, N.W. Queensland

by

S.E. Smith and T.I. Slezak

Sixteen samples of limestones from the Marraba 1:100 000 Sheet area, N.W. Queensland, submitted by G.M. Derrick, were analysed by optical emission spectorscopy on the Hilger and Watts 3 metre Polychromator for Ba, Co, Cu, Fe, La, Mg, Mn, Ni, Sc, Sr, Ti, V, Y and Zr. The samples were ignited at 1000°C for 4 hours.

The analytical method used was adapted from Ahrens and Taylor ("Spectrochemical Analysis", 1961, p.189, Addison - Wesley Publishing Company). One part of sample was mixed with two parts of graphite (National Carbon Company Type L4160, Grade SP-2). The mix was loaded into a preformed graphite electrode (National Carbon Company Type L4206), and arced as the anode at a constant 8 amps D.C. for 130 seconds. Both internal standard and rock standard control were used.

| Sample No. | Ba (ppm) | Co (ppm) | Cu (ppm) | Fe (%) | La (ppm) | Mg (%) | Mn (%) | Ni (ppm) |
|---|---|---|---|---|---|---|---|---|
| 337* | 57 | 18 | 11 | 0.6 | 143 | 0.7 | +0.21 | 18 |
| 338 | -50 | 6 | 11 | 1.1 | -70 | +3.5 | +0.21 | 7 |
| 339 | -50 | 11 | 9 | 0.5 | 91 | 0.2 | +0.21 | 10 |
| 340 | 2162 | 6 | 8 | 0.9 | -70 | 3.4 | 0.13 | 8 |
| 341 | 87 | 7 | 11 | 0.9 | 80 | 3.0 | +0.21 | 10 |
| 342 | -50 | 46 | +250 | 2.5 | -70 | +3.5 | +0.21 | 8 |
| 343 | -50 | +175 | +250 | 4.5 | 71 | +3.5 | +0.21 | 90 |
| 344 | -50 | 48 | 104 | 1.5 | -70 | 1.1 | 0.14 | 20 |
| 345 | -50 | 15 | 9 | 1.0 | 112 | 1.4 | 0.18 | 13 |
| 346 | -50 | 8 | 9 | 0.6 | 81 | 0.2 | +0.21 | 10 |
| 347 | -50 | 7 | 16 | 2.8 | -70 | +3.5 | +0.21 | 5 |
| 348 | 560 | 8 | 19 | 1.4 | -70 | 0.4 | +0.21 | 9 |
| 349 | 220 | 12 | 35 | 0.6 | 105 | 0.4 | +0.21 | 11 |
| 350 | -50 | +175 | +250 | 8.8 | 89 | -0.2 | 0.07 | 375 |
| 351 | -50 | 23 | +250 | 1.0 | 109 | 0.2 | 0.19 | 17 |
| 352 | -50 | +175 | +250 | 9.0 | 119 | 0.8 | 0.09 | +900 |

*BMR registered numbers e.g. 70200337

Table C Continued

| Sample No. | Sc (ppm) | Sr (ppm) | Ti (%) | V (ppm) | Y (ppm) | Zr (ppm) | Loss on ignition (%) |
|---|---|---|---|---|---|---|---|
| 037 | 92 | 530 | -0.04 | 43 | 143 | -100 | 42.7 |
| 038 | 36 | 28 | -0.04 | 14 | 62 | -100 | 43.8 |
| 039 | 24 | 190 | -0.04 | 28 | 43 | -100 | 42.6 |
| 040 | 7 | 510 | 0.07 | 18 | 9 | -100 | 34.5 |
| 041 | 11 | 70 | 0.11 | 33 | 17 | -100 | 27.5 |
| 042 | 18 | -20 | -0.04 | 84 | 13 | -100 | 44.2 |
| 043 | 16 | 26 | 0.04 | 25 | 97 | -100 | 35.4 |
| 044 | 43 | 83 | 0.27 | 21 | 37 | -100 | 30.8 |
| 045 | 24 | 270 | 0.07 | 38 | 36 | -100 | 40.1 |
| 046 | 70 | 280 | -0.04 | 26 | 99 | -100 | 41.8 |
| 047 | 7 | 36 | 0.04 | 16 | 18 | -100 | 42.3 |
| 048 | 10 | 110 | 0.09 | 19 | 26 | 237 | 25.9 |
| 049 | 23 | 390 | -0.04 | 56 | 87 | -100 | 38.2 |
| 050 | 17 | 88 | -0.04 | 21 | 54 | -100 | 6.6 |
| 051 | 26 | 185 | -0.04 | 29 | 103 | -100 | 42.7 |
| 052 | 12 | 150 | -0.04 | 18 | 95 | -100 | 4.7 |

Table D: Semi-quantitative Spectrographic Analysis

Report AN 3065/70

Limestones from the Cloncurry-Mary Kathleen Area

(Results in ppm; detection limits in brackets)
X = not detected

| Sample No. | Be (1) | Nb (10) | Co (5) | Ni (5) | Cr* (20) | Y (10) | La (100) | Ba (50) | Sr (10) |
|---|---|---|---|---|---|---|---|---|---|
| 337** | X | X | 5 | 10 | 100 | X | X | X | X |
| 338 | " | " | 5 | 10 | 100 | 200 | " | 50 | 40 |
| 339 | " | " | 5 | 10 | 300 | 40 | " | X | 100 |
| 340 | " | " | 5 | 10 | 200 | 60 | " | X | 150 |
| 341 | 1 | " | 5 | 5 | 100 | 20 | " | 80 | 80 |
| 342 | X | " | 30 | 5 | 100 | 40 | " | 50 | 40 |
| 343 | 1 | " | 100 | 5 | 100 | 200 | " | 50 | 60 |
| 344 | X | " | 30 | X | 150 | 40 | " | 50 | 80 |
| 345 | " | " | 5 | " | 100 | 20 | " | X | 100 |
| 346 | " | " | 5 | " | 100 | 60 | " | " | 100 |
| 347 | " | " | 5 | 5 | 150 | 20 | " | " | 60 |
| 348 | 1 | " | 10 | 5 | 150 | 20 | " | 500 | 100 |
| 349 | X | " | 5 | X | 100 | 100 | " | 250 | 300 |
| 350 | " | " | 300 | 10 | 100 | 80 | " | X | 80 |
| 351 | " | " | 5 | 5 | 100 | 80 | " | X | 80 |
| 352 | " | " | 200 | 10 | X | 80 | " | 50 | 250 |

Analyst R.R. Robinson A.M.D.L. Adelaide

*Chrome steel grinding may have been used in sample preparation

** BMR registered number e.g. 70200337

Table E: Comparison of Trace Element Abundances in Sedimentary Limestone, Secondary Limestone veins, and Carbonatites

(All averages in ppm; X = not detected; averages other than Marraba results taken from Gellatly, 1969).

| | Ba | Nb | Sr | La | Y |
|---|---|---|---|---|---|
| Sedimentary limestones (this work) (*340, 341, 344, 348) | 690 | X | 193 | 46 | 22 |
| Sedimentary limestones (general) | 106 (0–350) | X | 474 (0–1600) | ?10 mainly X | ?15 mainly X |
| Intrusive Carbonates (this work) (*337, 338, 339, 342, 343, 345, 346, 347, 349, 350, 351, 352) | 53 | X | 182 | 85 | 70 |
| Carbonatites (general) | 1127 (0 to 5730) | 200 (0 to 1198) | 3200 (0 to 7750+) | 249 (0 to 854) | 94 (0 to 431) |

*BMR registered numbers e.g. 70200340

Table F: Analyses for Fe, Mn, Co, Cu, Ni, Pb in iron-manganese nodules and sediments, Marraba Sheet area, with comparative data

Analyses by A.M.D.L., Adelaide

| Field Number | Registered No.* | Fe % | Mn % | Co ppm | Cu ppm | Ni ppm | Pb ppm | Description | Location** |
|---|---|---|---|---|---|---|---|---|---|
| L 5.26.32 | 325 | 10.2 | 41.0 | 470 | 25 | 100 | 30 | Massive Mn with limonite | VB 357872 |
| C 12.68.14 | 326 | 9.4 | 31.5 | 200 | 10 | 60 | 30 | Massive Mn | VC 318048 |
| L 1.63.14 | 327 | 1.1 | 26.5 | 70 | 330 | 30 | 25 | Massive Mn with quartz | VC 204032 |
| Du 1.81.33c | 328 | 0.4 | 30.0 | 530 | 1650 | 75 | 25 | Nodular Mn with quartzite | 8.4 km SE of Overhang |
| CR 6.02.39b | 329 | 2.6 | 55.0 | 160 | 10 | 160 | 35 | Massive Mn, nodular | UC 999 122 |
| Du 1.81.33a | 330 | 0.8 | 9.5 | 220 | 270 | 15 | 20 | Botryoidal Mn with quartzite | 8.4 km SE of Overhang |
| L 3.52.18 | 331 | 1.0 | 33.9 | 200 | 80 | 60 | 30 | Nodular Mn | VB 329937 |
| CR 5.22.6 | 332 | 7.6 | 3.5 | 20 | 55 | 15 | 20 | Mn with garnet (metasediment) | VC 138172 |
| L 2.94.41c | 333 | 37.0 | 0.27 | 25 | 10 | 15 | 65 | Banded iron formation | VB 347972 |
| L 2.94.41a | 334 | 48.5 | 0.11 | 40 | 5 | 10 | 25 | Banded iron formation | VB 347972 |
| Du 1.81.6c | 335 | 15.0 | 0.12 | 20 | 5 | 15 | 20 | Banded iron formation | 2 km SE of Overhang |
| CR 8.76.21 | 336 | 3.9 | 11.0 | 50 | 5 | 25 | 20 | Mn-bearing marl | VC 319049 |
| Overhang (Carter et al 1961) | - |  | 43.6 | 400 |  | 200 |  | Typical high-grade ore | VB 365792 |
| Average Shale[1] |  | 4.72 | 0.085 | 19 | 45 | 68 | 20 |  |  |
| Average Carbonate[1] |  | 0.38 | 0.11 | 0.1 | 4 | 20 | 9 |  |  |
| Average pelagic clay[2] | - | 5.06 | 0.48 | 100 | 300 | 200 | 60 |  |  |
| Mn nodules[3] | - | 11.6 | 21.6 | 3000 | 2000 | 6200 | 1000 |  |  |
| Mn nodules[4] | - | 11.7 | 19.2 | 2800 | 4000 | 5800 | 1000 |  |  |
| Mn nodules[5] | - | 10.8 | 12.6 | 800 | 2100 | 4500 | 700 |  |  |

1 Turekian & Wedepohl (1961)
2 Cronan (1969)
3 Ahrens et al (1967)
4 Manheim (1965)
5 Frazer & Ostwald (1970)
** 1000 metre grid
* BMR registered number e.g., R 70200325

## Table G: Analysis of Chip Samples from Marraba Sheet Area, Queensland

by

A.D. Haldane

The following results were obtained for the determination of copper in twenty three samples of basic rock from the Marraba Sheet area. The samples were submitted by G. Derrick.

Following digestion with 5N HCl, Cu was determined by atomic absorption spectrophotometry.

| Sample | Cu ppm | Sample | Cu ppm |
|---|---|---|---|
| *69070052 | 45 | 69070063 | 180 |
| 69070053 | 50 | 69070064 | 90 |
| 69070054 | 55 | 69070065 | 95 |
| 69070055 | 95 | 69070066 | 40 |
| 69070056 | 60 | 69070067 | 80 |
| 69070057 | 60 | 69070068 | 315 |
| 69070058 | 26 | 69070069 | 145 |
| 69070059 | 50 | 69070070 | 35 |
| 69070060 | 145 | 69070071 | 55 |
| 69070061 | 1320 | 69070072 | 50 |
| 69070062 | 670 | 69070073 | 52 |

Average for basic rocks 87 ppm (Turekian & Wedepohl, 1961)

### Sample Key

| | | | |
|---|---|---|---|
| 52 to 58 | Vicinity of L7.56.4, | location | VB 333798 |
| 59 to 62 | " " L7.56.30 | " | VB 338786 |
| 63 to 68 | " " L8.80.43 | " | VC 253041 |
| 69 to 74 | " " L7.54.17 | " | VB 260782 |

*BMR registered numbers

Table H: Chemical Analyses of Metabasalts of the Marraba Volcanics

(excluding ignition losses)

($Fe_2O_3$ includes total iron)

Analyses by A.M.D.L., Adelaide

| Sample Nos. | 305 | 307 | 308 | 309 | 310 | 311 | 312 |
|---|---|---|---|---|---|---|---|
| $SiO_2$ | 53.37 | 48.70 | 52.11 | 52.14 | 48.21 | 48.16 | 49.77 |
| $TiO_2$ | 1.39 | 2.21 | 0.98 | 0.91 | 3.09 | 2.61 | 0.64 |
| $Al_2O_3$ | 14.34 | 13.25 | 14.44 | 14.26 | 12.02 | 13.01 | 12.64 |
| $Fe_2O_3$ | 12.56 | 17.22 | 10.99 | 10.55 | 19.92 | 18.09 | 10.93 |
| MnO | 0.28 | 0.15 | 0.33 | 0.25 | 0.36 | 0.24 | 0.15 |
| MgO | 5.06 | 3.21 | 6.60 | 6.76 | 4.64 | 5.46 | 3.45 |
| CaO | 4.69 | 5.20 | 7.94 | 7.21 | 7.63 | 8.95 | 15.55 |
| $Na_2O$ | 2.98 | 2.73 | 1.67 | 2.35 | 2.07 | 1.99 | 0.29 |
| $K_2O$ | 3.02 | 3.36 | 2.45 | 2.24 | 1.32 | 0.87 | 0.15 |
| $P_2O_5$ | 0.19 | 0.27 | 0.15 | 0.15 | 0.34 | 0.39 | 0.13 |
| Total | 97.88 | 96.30 | 97.16 | 96.82 | 99.59 | 99.77 | 93.75 |

*BMR registered numbers e.g. 70200305

## 3. COPPER IN BASIC ROCKS

Samples of basic rock from the vicinity of small copper mines or showings were collected by P.W. Crohn in 1969. All samples are from the Marraba Sheet area, and include extrusive metabasalt, intrusive dolerite, and some amphibolite. They were assayed for copper, and the results are given in Table G.

Sample areas L7.56.4 and L7.56.30 are located about small maiden copper showings in the 'Wakeful Basalt Member' of the Mitakoodi Quartzite. Area L7.54.17 is in the vicinity of Chinaman, in the Duck Creek area, and area CR8.80.43 is located about a small copper occurrence, again in the 'Wakeful Basalt Member' near Butcher Bore. Insufficient samples have been analysed to show whether Cu content of basic rock decreases or increases towards mineralized zones.

## 4. BASALT ANALYSES

A number of samples from the Marraba Volcanics have been analysed for major and minor trace elements, as part of a study embracing basalt units between Cloncurry and Mount Isa. These analyses are reproduced in Table H, and will be commented on in a Bulletin dealing with basic rocks in the area.

## 5. CARBON AND TRACE ELEMENT ASSAYS OF SLATES OF THE MARIMO SLATE AND CORELLA FORMATION

Twenty elements were determined in 20 samples from the Marimo Slate, and in 6 samples from the Corella Formation; a further 4 samples from GSQ were analysed for carbon. The results are listed in Table I.

### Discussion

The carbon content (present as graphite) of the slates is high (up to 16.7 percent). Most of the important metallic elements (Cu, Pb, Zn, Co, Ni, etc) are present in below-average concentrations, except in samples such as 287, which contains veins and coatings of copper minerals, mainly chrysocolla, indicating that processes which conentrate copper also concentrate cobalt and nickel in particular (+1 000 and 1 000 ppm respectively).

Barium (average 800 ppm) is above average in the black slates; this concentration could reflect baryte in the shales, possibly derived mechanically from the baryte-bearing 'Overhang Jaspilite' to the west of the Marimo Slate, or as baryte seams deposited syngenetically.

Rubidium is most likely present in trace amounts in K feldspar, a proposition supported by the broad positive correlation between Rb and $K_2O$ shown in figure O.

Gallium and boron were determined in order to compare with gallium-boron plots shown by Keith and Degens (1959, Fig. 1, p. 45). These plots, based on analyses of Pennsylvanian (Carboniferous) shales, show a separation of samples into marine (relatively high boron) and freshwater (relatively low boron) types. A plot of the Marimo Slate analyses shows that all samples (with the exception of one) fall well within the freshwater range. These results should be treated with reservation because differences between Carpentarian and Pennsylvanian sedimentary environments are probably significant; e.g. Landergren (1945) hypothesizes that each marine cycle of sedimentation adds an increment of boron to the sedimentary environment, in which case Precambrian marine environments could be very much lower in boron (and gallium) than a Pennsylvanian marine environment.

## 6. MAJOR ELEMENT SLATE ANALYSIS

Twenty samples of Marimo Slate and six slates from the Corella Formation were analysed. Results are listed in Table J. A minor point is that sample 300 is a graphitic magnesian limestone, rather than a slate. Evaluation of these analyses will be made in future reports.

# SECTION B: GEOCHEMICAL PROSPECTING AND TECHNIQUES

## Introduction

Geochemical prospecting relies on chemical and mechanical dispersion of the elements in orebodies over a large area where the concentration of those elements is higher than in a similar environment not near an orebody. This increase in concentration is supposedly easier to locate than the orebody it comes from because of (i) its larger area, (ii) the possibility of employing a systematic search procedure and (iii) the speed with which such a survey can be carried out.

The purpose of this section is to examine whether such areas of dispersal do exist, and if so how reliable they are for locating orebodies. The method originated in northern Europe in the 1930's and considerable doubt still exists as to its applicability to tropical Australia. Soil, stream sediment, or vegetation can be sampled.

## History of the Use of Geochemical Prospecting in Northwest Queensland (See fig. 104 and Table 19)

BMR tested the technique in 1952, applying soil sampling to the Northern Leases of Mt Isa Mines. They were able to show that apart from some lateral downslope displacement the high lead values were very good indicators of lead mineralization in the underlying rock (Debnam, 1953).

Table I: Carbon Analyses and Trace Elements, in Slates and Siltstones of Marimo Slate and Corella Formation

(All analyses quantitiative; Trace elements Co to Zr by direct reading optical spectrograph, BMR: S to Rb, AMDL; Ga & B, semi-quantitative emission spectroscopy, AMDL)

| | | | ppm | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number | | C% | Co | Cr | Cu | Pb | Zn | Ba | La | Ni | Se | Sr | V | Y | Zr | S | $CO_2$ | Na | Rb | Ga | B |
| 279* | | .80 | 10 | 100 | 17 | 5 | 5 | 1350 | 100 | 12 | 13 | -30 | 370 | 31 | 150 | 400 | 500 | 900 | 150 | 30 | 25 |
| 280 | | 1.92 | 8 | 100 | 22 | 10 | 5 | 380 | 125 | 13 | 18 | 73 | 100 | 34 | 230 | 2700 | 500 | 2800 | 140 | 50 | 25 |
| 281 | | .24 | -8 | 64 | 10 | 15 | 5 | 340 | 105 | 10 | 13 | 36 | 86 | 40 | 280 | 2500 | 500 | 900 | 130 | 30 | 50 |
| 282 | | 2.1 | 10 | 24 | 21 | 10 | 25 | 310 | 80 | 14 | 11 | -30 | 48 | 35 | 120 | 350 | 500 | 300 | 40 | 20 | 5 |
| 283 | | 5.3 | 9 | 50 | 22 | 15 | 5 | 820 | 105 | 14 | 12 | -30 | 44 | 28 | 150 | 6100 | 500 | 900 | 10 | 20 | 25 |
| 284 | | 4.1 | 13 | 56 | 42 | 5 | 10 | 420 | 115 | 33 | 17 | 90 | 110 | 54 | 230 | 1400 | 500 | 900 | 13 | 30 | 10 |
| 285 | | .36 | 9 | 90 | 25 | -5 | 5 | 830 | 75 | 13 | 11 | -30 | 62 | 28 | 100 | 450 | 500 | 400 | 80 | 20 | 10 |
| 286 | | 1.08 | 15 | 100 | +500 | -5 | 5 | 710 | 110 | 18 | 15 | -30 | 200 | 50 | 200 | 1100 | 3500 | 1100 | 150 | 50 | 20 |
| 287 | | 3.9 | +1000 | 54 | +500 | 20 | 5 | 730 | 200 | 1000 | 25 | 270 | 300 | 120 | 280 | 1250 | 3000 | 18400 | 30 | 10 | 100 |
| 288 | MARIMO SLATE | 0.18 | 11 | 66 | 60 | 5 | 5 | 840 | 75 | 14 | 14 | 180 | 125 | 54 | 220 | 550 | 500 | 1200 | 70 | 40 | 15 |
| 289 | | 1.63 | 8 | 85 | 29 | 5 | 5 | 2250 | 110 | 11 | 14 | 430 | 90 | 37 | 180 | 1650 | 1000 | 1300 | 100 | 50 | 30 |
| 290 | | 3.2 | 9 | 60 | 13 | -5 | 5 | 1700 | 110 | 11 | 27 | 120 | 110 | 41 | 250 | 7300 | 500 | 700 | 270 | 30 | 30 |
| 291 | | 2.6 | 15 | 75 | 15 | 5 | 10 | 940 | 110 | 23 | 23 | -30 | 240 | 35 | 170 | 1150 | 500 | 900 | 170 | 10 | 15 |
| 292 | | 2.35 | 15 | 73 | 30 | 15 | 5 | 330 | 150 | 16 | 16 | 210 | 210 | 35 | 105 | 450 | 17.1% | 1600 | 80 | 20 | 20 |
| 293 | | 3.75 | 200 | 53 | 47 | 5 | 10 | 700 | 120 | 41 | 15 | 38 | 155 | 40 | 230 | 1200 | 500 | 700 | 140 | 15 | 30 |
| 294 | | 1.18 | 150 | 72 | +500 | 5 | 5 | 740 | 170 | 65 | 19 | 38 | 110 | 105 | 130 | 1950 | 7% | 300 | 90 | 5 | 10 |
| 295 | | 16.7 | 11 | 46 | 130 | 25 | -5 | 500 | 180 | 12 | 14 | 75 | 130 | 50 | 280 | 4900 | 500 | 500 | 50 | 20 | 5 |
| 296 | | 3.75 | 9 | 70 | 46 | 10 | 10 | 800 | 110 | 16 | 13 | 320 | 185 | 44 | 160 | 4500 | 500 | 900 | 100 | 20 | 5 |
| 297 | | 2.05 | 10 | 90 | 330 | -5 | 5 | 820 | 90 | 11 | 13 | 58 | 180 | 31 | 155 | 1050 | 2500 | 1300 | 190 | 40 | 25 |
| 298 | | 2.6 | 8 | 33 | 14 | 5 | 5 | 295 | 90 | 13 | 12 | -30 | 56 | 30 | 100 | 350 | 500 | 200 | 90 | 30 | 10 |

Table I Continued

| Number | C% | Co | Cr | Cu | Pb | Zn | Ba | La | Ni | Se | Sr | V | Y | Zr | S | CO2 | Na | Rb | Ga | B |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ppm | | | | | | | | | | | | | | | | | | |
| 299 | 3.0 | -8 | 24 | 31 | 5 | 5 | 1200 | -60 | 11 | 7 | 35 | 56 | 18 | -100 | 2500 | 500 | 600 | 120 | 10 | 3 |
| 300 | 7.65 | 8 | 33 | 20 | 15 | 5 | 400 | 68 | 11 | 11 | 80 | 42 | 23 | 170 | 200 | 21.2% | 400 | 50 | 5 | n.d. |
| 301 | 6.45 | -8 | 54 | 18 | 5 | 5 | 1200 | 65 | 11 | 11 | -30 | 78 | 21 | 170 | 1350 | 500 | 900 | 220 | 30 | 30 |
| 302 | 9.4 | -8 | 50 | 10 | -5 | 5 | 640 | 84 | 9 | 12 | -30 | 80 | 28 | 230 | 400 | -500 | 2100 | 190 | 40 | 10 |
| 303 | 4.95 | -8 | 77 | 33 | 15 | 15 | 2400 | 84 | 10 | 15 | 210 | 110 | 26 | 170 | 700 | -500 | 3800 | 180 | 60 | 30 |
| 304 | 8.65 | 10 | 77 | 31 | 5 | -5 | 1600 | 82 | 13 | 16 | 180 | 150 | 26 | 170 | 900 | 500 | 2100 | 170 | 40 | 30 |
| 4714 | 0.5 | Geological Survey of Queensland registered rock numbers | | | | | | | | | | | | | | | | | | |
| 4716 | 2.9 | | | | | | | | | | | | | | | | | | | |
| 4725 | 8.9 | | | | | | | | | | | | | | | | | | | |
| 4747 | 2.0 | | | | | | | | | | | | | | | | | | | |
| Average Pelagic Clay | | 100 | 102 | 300 | 60 | | | | 200 | | | 215 | | | | | | | | |
| Average Shale[1] | | 19 | 90 | 45 | 20 | 95 | 580 | 92 | 68 | 0.6 | 300 | 130 | 26 | 160 | 2400 | | 9600 | 140 | 19 | 100 |

CORELLA FORMATION

1. Turekian & Wedepohl (1961)
2. Cronan (1969?
* BMR registered samples 70200279

Samples 279 - 298 = Marimo Slate
Samples 299 - 304 = Corella Formation

Table J: Chemical Analyses of Slates and Siltstones from the Marimo Slate and the Corella Formation

Analyses by A.M.D.L., Adelaide

| | Marimo Slate | | | | | |
|---|---|---|---|---|---|---|
| Sample Nos.* | 279 | 280 | 281 | 282 | 283 | 284 |
| $SiO_2$ | 76.11% | 69.29 | 81.20 | 83.06 | 75.06 | 71.59 |
| $TiO_2$ | 0.57 | 0.74 | 0.75 | 0.21 | 0.46 | 0.56 |
| $Al_2O_3$ | 14.27 | 17.77 | 10.53 | 7.27 | 9.00 | 12.30 |
| $Fe_2O_3$ | 0.25 | 1.46 | 0.195 | 2.83 | 0.939 | 3.72 |
| MnO | 0.029 | 0.00 | 0.00 | 0.010 | 0.00 | 0.00 |
| MgO | 0.778 | 0.378 | 0.488 | 0.77 | 0.092 | 0.919 |
| CaO | 0.078 | 0.019 | 0.029 | 0.029 | 0.046 | 0.119 |
| $Na_2O$ | 0.19 | 0.47 | 0.195 | 0.19 | 0.18 | 0.09 |
| $K_2O$ | 4.61 | 3.96 | 3.21 | 1.53 | 6.68 | 2.56 |
| $P_2O_5$ | 0.049 | 0.057 | 0.088 | 0.067 | 0.101 | 0.27 |
| Total | 96.93 | 94.14 | 96.69 | 95.97 | 92.55 | 92.13 |
| Ignition Loss | 2.79 | 5.60 | 2.39 | 4.25 | 7.95 | 8.13 |
| Total | 99.72 | 99.74 | 99.08 | 100.22 | 100.50 | 100.26 |

*BMR registered numbers e.g. 70200279

Table J Continued

| | Marimo Slate | | | | | | |
|---|---|---|---|---|---|---|---|
| Sample Nos. | 285 | 286 | 287+ | 288 | 289 | 290 | 291 |
| $SiO_2$ | 87.08 | 72.84 | 58.63 | 78.44 | 74.63 | 66.53 | 72.26 |
| $TiO_2$ | 0.276 | 0.59 | 0.48 | 0.49 | 0.69 | 0.67 | 0.57 |
| $Al_2O_3$ | 7.41 | 13.99 | 12.76 | 13.28 | 14.12 | 15.83 | 13.62 |
| $Fe_2O_3$ | 0.33 | 0.53 | 1.11 | 0.30 | 0.92 | 1.99 | 2.03 |
| MnO | 0.059 | 0.00 | 0.009 | 0.00 | 0.00 | 0.009 | 0.00 |
| MgO | 0.69 | 0.67 | 0.615 | 0.78 | 0.67 | 0.924 | 0.86 |
| CaO | 0.098 | 0.029 | 0.42 | 0.117 | 0.048 | 0.037 | 0.095 |
| $Na_2O$ | 0.098 | 0.19 | 2.46 | 0.19 | 0.19 | 0.18 | 0.19 |
| $K_2O$ | 2.46 | 4.50 | 1.16 | 3.58 | 4.26 | 5.37 | 4.49 |
| $P_2O_5$ | 0.079 | 0.067 | 0.23 | 0.165 | 0.29 | 0.15 | 0.057 |
| Total | 98.58 | 93.41 | 77.87 | 97.34 | 95.82 | 91.69 | 94.17 |
| Ignition Loss | 1.65 | 3.88 | 12.13 | 2.75 | 4.25 | 7.59 | 4.81 |
| Total | 100.23 | 97.29 | 90.00 | 100.09 | 100.07 | 99.28 | 98.98 |

+These samples contain more than 3% Cu.

Table J Continued

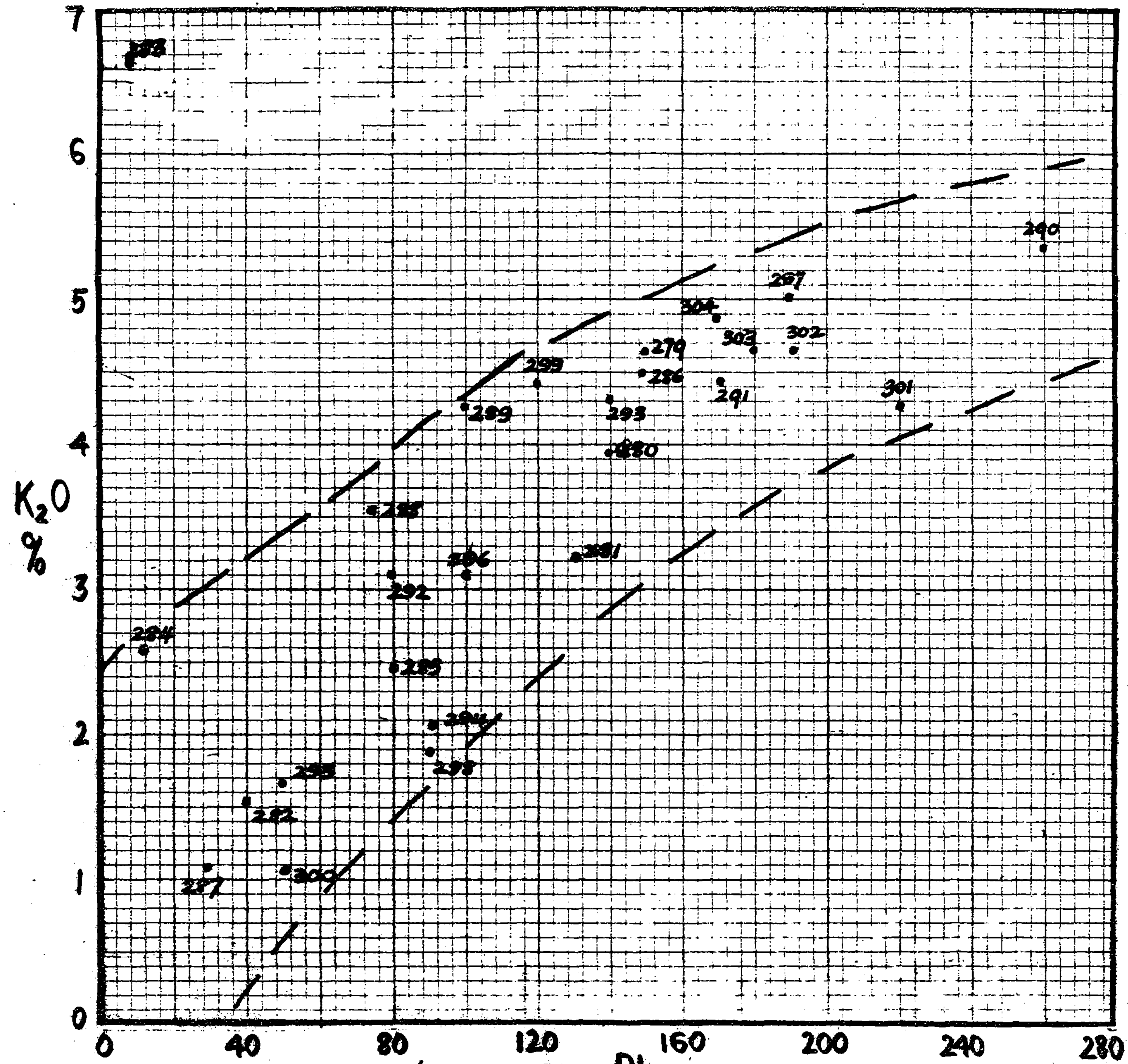
| | Marimo Slate | | | | | | |
|---|---|---|---|---|---|---|---|
| Sample Nos. | 292 | 293 | 294+ | 295 | 296 | 297 | 298 |
| $SiO_2$ | 43.00 | 55.38 | 50.05 | 63.60 | 65.55 | 70.91 | 84.7 |
| $TiO_2$ | 0.38 | 0.59 | 0.21 | 0.61 | 0.42 | 0.62 | 0.25 |
| $Al_2O_3$ | 8.93 | 16.91 | 8.95 | 7.27 | 12.25 | 15.28 | 8.04 |
| $Fe_2O_3$ | 0.69 | 11.83 | 0.71 | 5.01 | 8.16 | 0.57 | 0.47 |
| MnO | 0.00 | 0.009 | 0.026 | 0.00 | 0.009 | 0.00 | 0.00 |
| MgO | 8.34 | 1.20 | 0.43 | 0.40 | 0.74 | 0.86 | 0.38 |
| CaO | 13.46 | 0.25 | 0.043 | 0.079 | 0.35 | 0.038 | 0.029 |
| $Na_2O$ | 0.156 | 0.18 | 0.00 | 0.16 | 0.18 | 0.28 | 0.096 |
| $K_2O$ | 3.16 | 4.33 | 2.01 | 1.68 | 3.10 | 5.00 | 1.92 |
| $P_2O_5$ | 0.055 | 0.52 | 0.14 | 0.19 | 0.85 | 0.096 | 0.067 |
| Total | 78.17 | 91.20 | 62.57 | 79.00 | 91.61 | 93.66 | 95.95 |
| Ignition Loss | 22.12 | 8.01 | 13.37 | 20.95 | 7.78 | 4.26 | 4.38 |
| Total | 100.29 | 99.21 | 75.93 | 99.95 | 99.39 | 97.92 | 100.33 |

+These samples contain more than 3% Cu.

Table J Continued

| Corella Formation Slates (Blc2s) | | | | | | |
|---|---|---|---|---|---|---|
| Sample Nos. | 299 | 300 | 301 | 302 | 303 | 304 |
| $SiO_2$ | 82.38 | 37.36 | 70.86 | 66.28 | 68.15 | 60.79 |
| $TiO_2$ | 0.25 | 0.35 | 0.51 | 0.54 | 0.67 | 0.81 |
| $Al_2O_3$ | 6.29 | 3.67 | 13.71 | 15.04 | 16.86 | 16.43 |
| $Fe_2O_3$ | 1.51 | 0.19 | 0.39 | 0.70 | 0.69 | 1.48 |
| MnO | 0.010 | 0.00 | 0.00 | 0.00 | 0.028 | 0.009 |
| MgO | 0.096 | 5.99 | 0.46 | 0.62 | 0.46 | 0.70 |
| CaO | 0.038 | 19.52 | 0.027 | 0.018 | 0.056 | 0.07 |
| $Na_2O$ | 0.192 | 0.14 | 0.36 | 0.35 | 0.65 | 0.35 |
| $K_2O$ | 4.41 | 1.09 | 4.27 | 4.63 | 4.65 | 4.88 |
| $P_2O_5$ | 0.16 | 0.09 | 0.046 | 0.07 | 0.12 | 0.10 |
| Total | 95.34 | 68.4 | 90.62 | 88.25 | 92.33 | 85.68 |
| Ignition Loss | 4.08 | 31.17 | 8.84 | 12.12 | 7.39 | 11.90 |
| Total | 99.42 | 99.57 | 99.46 | 100.37 | 99.72 | 97.58 |

Fig 0 Graph showing broad correlation of K with Rb in slates of Marimo Slate + Corella Formation




To accompany Record 1971/56.

The method was extensively used in areas of slate by TAMCO, Mt Isa Mines, Enterprise Explorations and Rio Tinto Southern Pty, in the following 10 years.

Although the exploratory surveys were done on lead prospects the method was easily converted to copper and zinc surveys because the analyses were colorimetric, using dithizone, which is suitable for determining each element at different pH. It has proved successful for lead and to a lesser extent for copper. The exploration of zinc anomalies delineated by TAMCO failed to find any associated zinc mineralization.

Rio Tinto Southern appear to have been the first to apply stream sediment sampling in the area as a result of a recommendation by Atkinson (1962) that this method is quicker and should precede soil sampling and detailed geological mapping. Mechanical transportation can produce more extensive dispersion trains, but the location of the exact origin of the anomaly is often doubtful; hence the need for follow up surveys.

Extensive stream sediment surveys were carried out by Kennecott and Conzinc Riotinto Australia (CRA) from 1965 onwards. In the preliminary surveys the samples were collected at a density of about one per $km^2$. Each company covered about 1 500 $km^2$ of the Marraba Sheet area. Kennecott delineated 49 copper anomalies, 42 lead anomalies, 61 zinc anomalies, 59 cobalt anomalies, and 39 nickel anomalies. Each was investigated on the ground. Areas of poor drainage development had been soil-sampled. The geological evaluation indicated no new deposits (Kennecott, 1968b). CRA delineated prospective areas from their first survey and carried out a more intensive stream sediment sampling program at a density of about 4 samples per $km^2$. Twenty-seven areas were sampled at a density of about 32 samples per $km^2$, and finally 3 were selected for further work (Muceniekas, 1967, 1968; Scott, 1969a). As a result of plane table mapping and chip sampling of the Spring Creek North area 15 km south of the Mary Kathleen open cut, a copper deposit was outlined containing 6 600 tonnes per vertical metre of 1 percent copper ore, in a calcite-filled shear in banded calc-silicate rocks. A diamond drill hole was drilled at 50° depression to the east, to a length of 122 m. The drilling confirmed the surface chip sample results, but the copper values at depth were about two thirds as high as the surface values. The host rocks contain from 0.01 to 0.05 percent copper.

Noranda, Placer, and Ausminda carried out a similar program on Authority to Prospect 222(M), with follow-up soil sampling in selected areas.

Anomalies have been attributed to several sources. An examination of 100 copper anomalies by Kennecott in the Marraba Sheet area showed that the majority (66) are associated with quartz veins, pegmatites, and minor shear-zones, 9 are associated with calcite pods, 15 are associated with rocks such as slate and dolerite having high background copper contents, 4 are due to disseminated copper mineralization in calcsilicate rocks, and 6 are due to old workings. A further 5 may have been due to instrumental error. These results indicate that the method is capable of detecting small bodies of copper mineralization. It also emphasizes the need to consider the bedrock geology as dolerite and slate generally have high backgrounds (in excess of 100 ppm).

One problem which may arise from the sensitivity of the method is that the dispersion train from a pre-existing mine may contaminate a stream's sediment to such an extent that the trains from neighbouring unknown deposits may be masked. An apparent correlation between the production from a mine and the size of its stream sediment dispersion pattern was pointed out by geologists from Australian Selection, for areas near Soldiers Cap, on the adjoining Cloncurry 1:100 000 Sheet area.

A different effect is noted in the Marraba siding area, where there are numerous moderately large copper mines (10-100 tonnes copper production), and also basalt and dolerite country rock, both of which have been shown to have high copper backgrounds (35-1 320 ppm). Stream sediment values are low (averaging 20 ppm), which may be due to deeper weathering during Mesozoic time, thicker soil, especially transported soil from the Mitakoodi Quartzite, which has a very low copper background, or leaching over the period of 50 years since the mines were operating. This would indicate that stream sediment prospecting will be of little use in locating ore bodies buried by transported alluvium. Soil sampling is of no use either in this case unless the samples are taken by drilling to bedrock, as has been done by Placer Exploration (Lewis, 1968). The area examined by CRA contained only one large area of alluvium so their results can be considered fairly reliable indicators of the ore potential of the area. They considered that of the 10 elements they analysed for, only copper and uranium were significant, and that scintillometers would have detected major uranium deposits. They also conclude that there are no large copper orebodies in the area examined (Muceniekas, 1968).

Several areas covered by these early surveys have been resampled by other companies at greater density-e.g. Western Nuclear. A comparison of the geochemical programs of Kennecott and Western Nuclear follows:

The geochemical stream sampling program of Kennecott involved sampling at a density of about 1 sample per $km^2$. The data was then presented as a single 50 ppm copper contour on 1:253 440 scale maps with very little topographic control (20 minute geographic co-ordinates, the ATP boundaries and some mines). Anomalous values were determined statistically on the basis of the whole area, without regard to rock type. (Fitch, 1967; Fitch et al, 1967; Kennecott Exploration (Aust.) Pty Ltd, 1967a, b and 1968a, b, c).

Table K: Analytical Results of Stream Sediment Survey, West of Overhang, Marraba Sheet area

(Results semi-quantitative; values in ppm)

Analyses by A.M.D.L., Adelaide

| Sample | Cu | Pb | Zn | Sn | Au | Co | Ni | Cr | V | W | Mo | Mn | Ta | Be | Pd |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Stream sediments, Marraba (average) | 30 to 100 | 10 | 50 to 100 | 1-2 | 0 to 3 | 50 to 100 | 30 to 60 | 150 to 300 | 100 to 300 | 0 to 50 | 0 to 3 | 2000 | 0 to 100 | 2 | 0 to 10 |
| Average for basic rocks[1] | 140 | 12 | 130 | 6 | .0035 | 45 | 160 | 300 | 200 | 2 | 1.4 | 2200 | - | 1.5 | - |
| Average for basic rocks[2] | 87 | 6 | 105 | 1.5 | .004 | 48 | 130 | 170 | 250 | 0.7 | 1.5 | 1500 | 1.1 | 1 | 0.02 |

1. Hawkes & Webb (1962)
2. Turekian & Wedepohl (1961)

The Western Nuclear investigation involved a stream sediment sampling density of about 25 samples per $km^2$, and a regional soil sampling density of about 50 per $km^2$. The results are presented on 1:20 000 (approx.) geological maps with a detailed topographic base (Laanela, 1971a, b). The anomalies were evaluated with relation to rock type, and data was presented as three contours at 40, 80 and 120 ppm Cu. Certain areas have been retained under mining leases for further detailed work.

In an area immediately east of Mary Kathleen it is obvious that the more detailed sampling of Western Nuclear delineates prospective copper-producing areas with more precision but in general the anomalous areas are within the limits of the anomalous areas defined by Kennecott.

Current Research

In 1969 BMR collected two sets of samples from streams draining the Mitakoodi Quartzite in areas cut by dolerite and with known copper vein mineralization that had not been previously worked. The copper mineralization was confined to the 'Wakeful Basalt Member' of the Mitakoodi Quartzite, in association with dolerite; mineralization consisted of very small, high-grade pods of quartz-chalcocite-malachite. Results from only one of the two areas chosen are available.

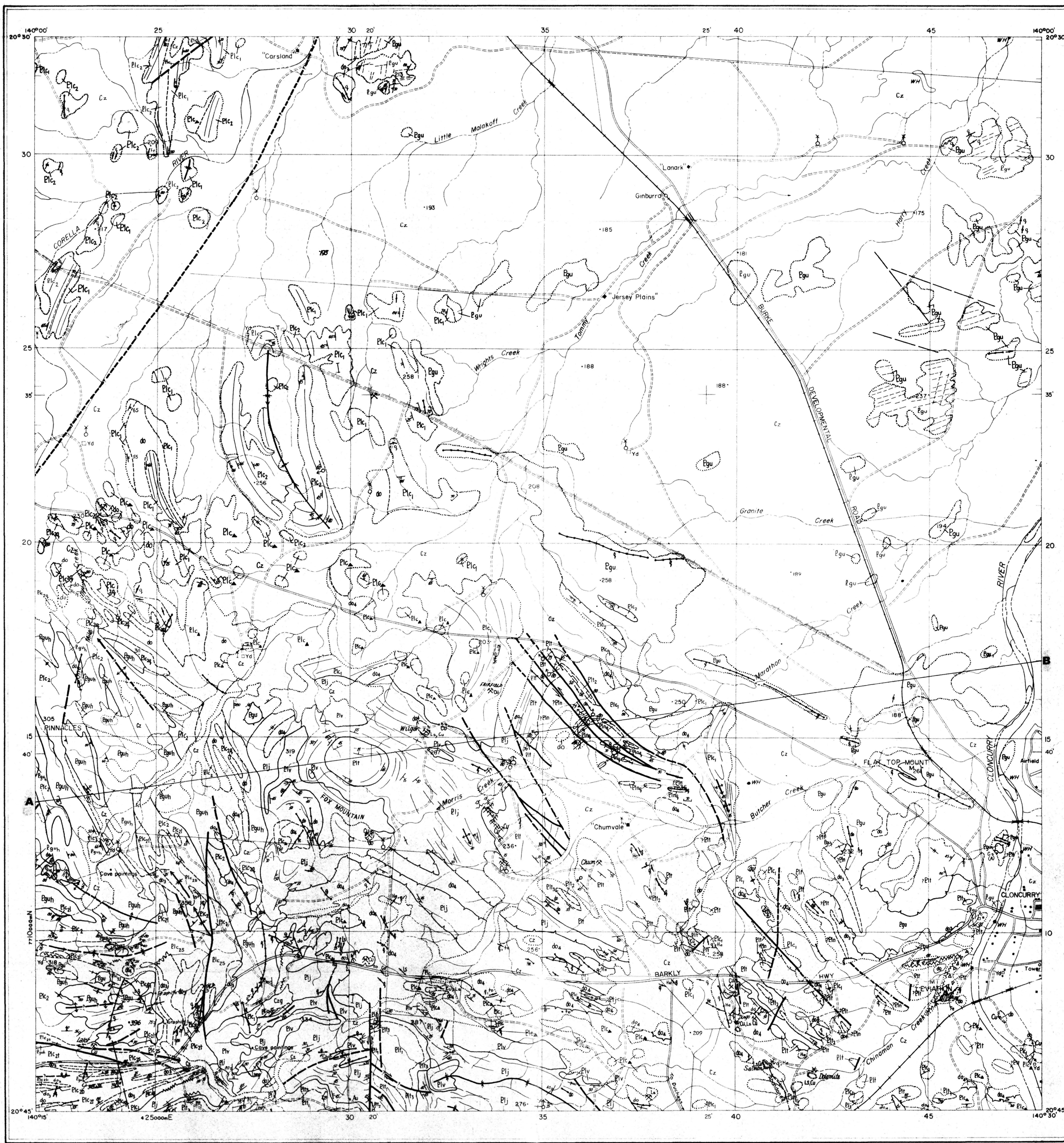
The object of the survey was to determine sample density required to geochemically define these areas of known mineralization. In one area, west of Overhang, 67 samples were collected from streams draining 10 square miles. Average sample density was 7 per square mile, but ranged from 12 to 4, depending on proximity of mineralization. The -80 mesh fraction was analysed by emission spectroscopy for Cu, Pb, Zn, Sn, Au, Co, Ni, Cr, V, W, Mo, Mn, Ta, Be, and Pd.

The results (shown in Table K) failed to indicate an anomaly in the area of known mineralization. This maybe due to two factors: (1) insufficiently high sample density, and/or (2) small size of the mineralized bodies - too small to provide a dispersion halo (i.e., insufficient copper in the stream sediment). A soil sampling program may have achieved better results.

An anomalous distribution of copper unrelated to the basalt unit appears to be related to dolerite dykes in quartzite.

Other projects are being carried out by W. Cooper, of the University of Queensland, and Professor Monica Cole, of Bedford College, London. Cooper is examining the effect of background on stream sampling to the south of the Marraba Sheet area, and Cole is conducting a pilot biogeochemical survey to the north of the area.

# 6956-I




MARRABA 1:100,000

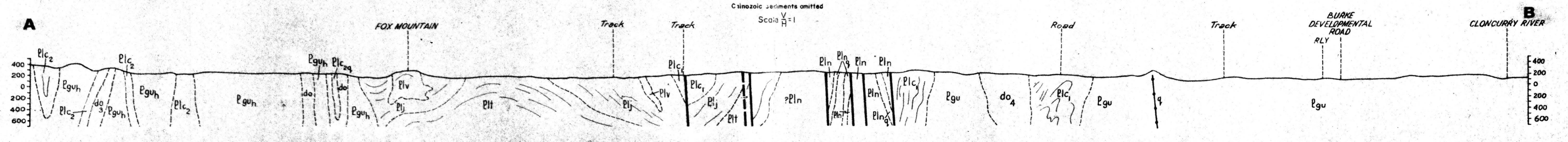
| IV | I |
|---|---|
| III | II |

1:50,000

SECTION

Cainozoic sediments omitted

Scale V/H = 1



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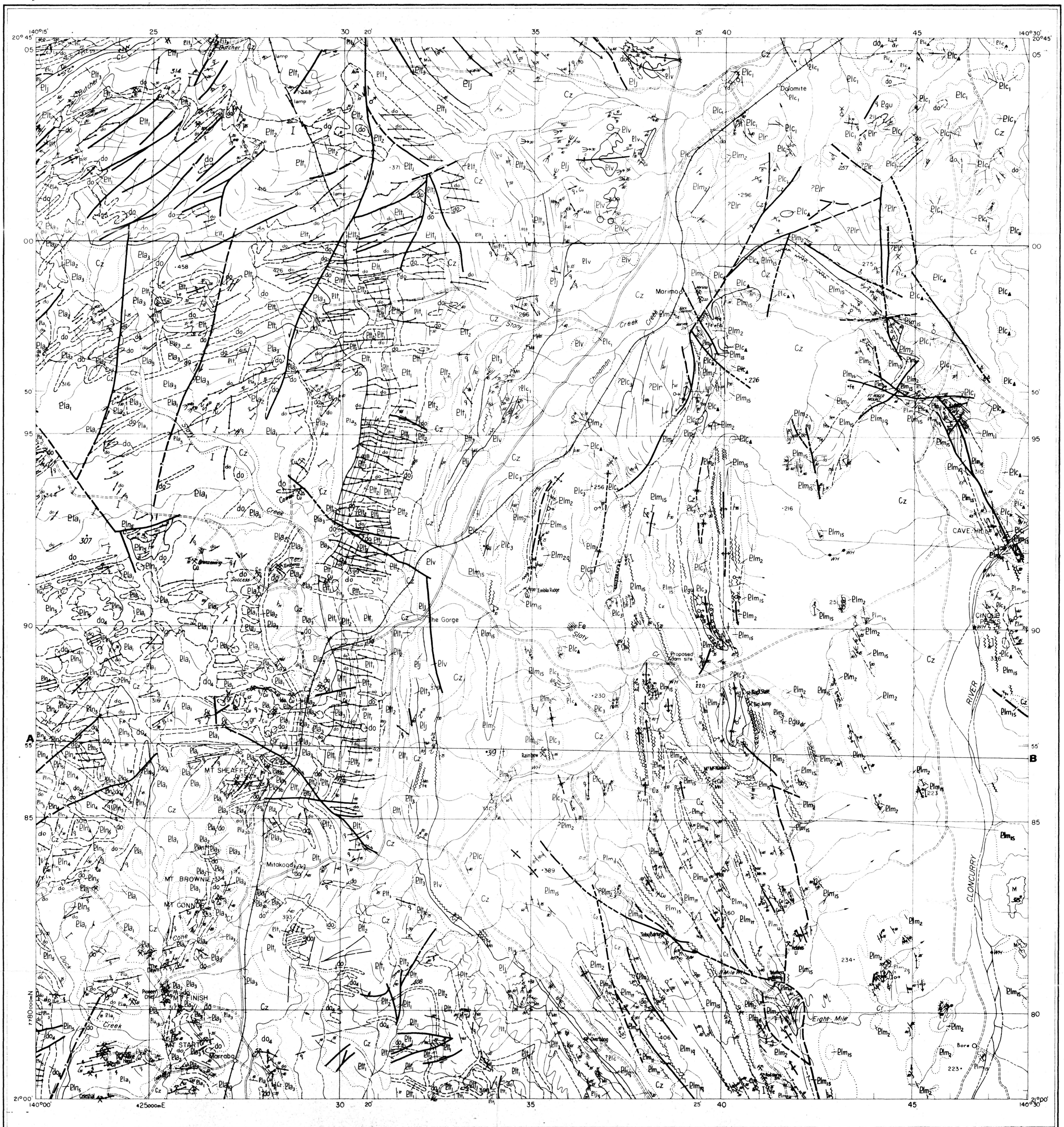



MARRABA 1:100,000

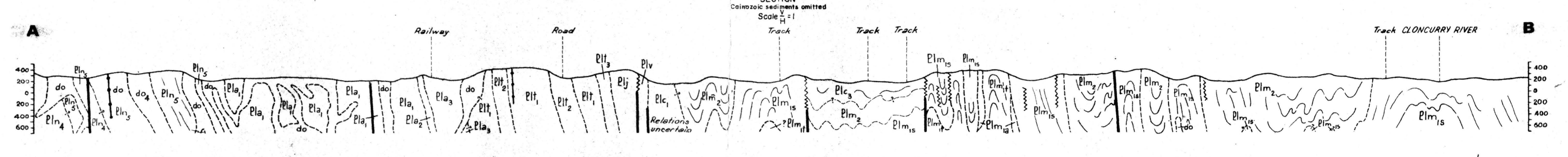
| | |
|---|---|
| IV | I |
| III | II |

1:50,000

SECTION

Cainozoic sediments omitted

Scale H/V = 1



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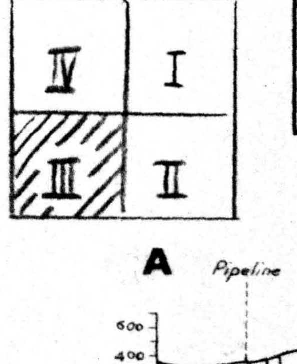
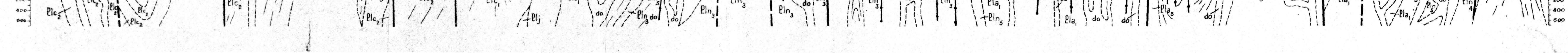
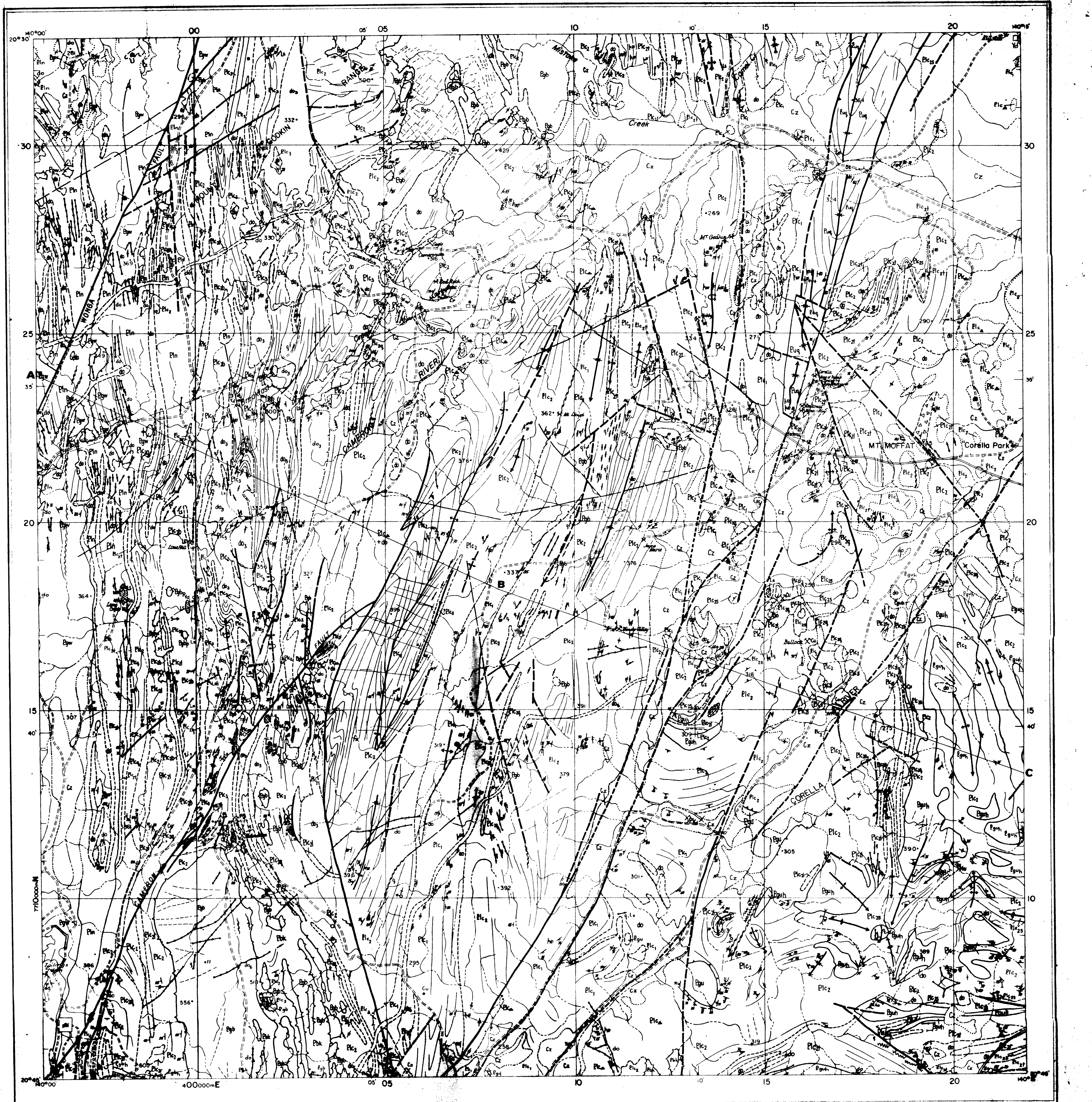


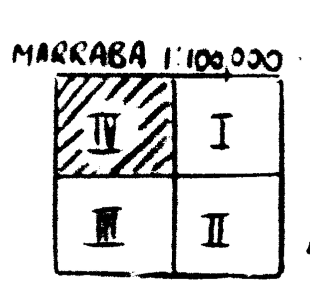

1:50,000

SECTION
Cainozoic sediments omitted
Scale H/V = 1



6956-IV

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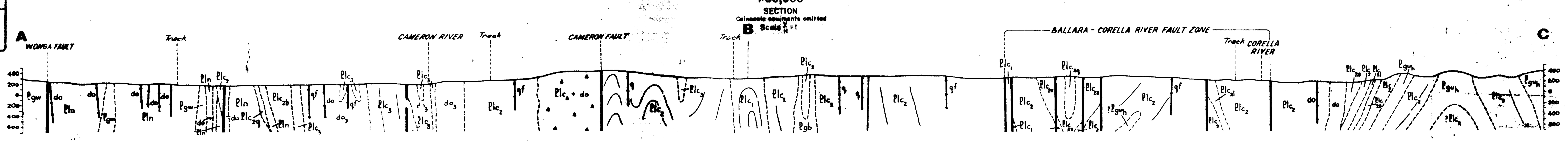
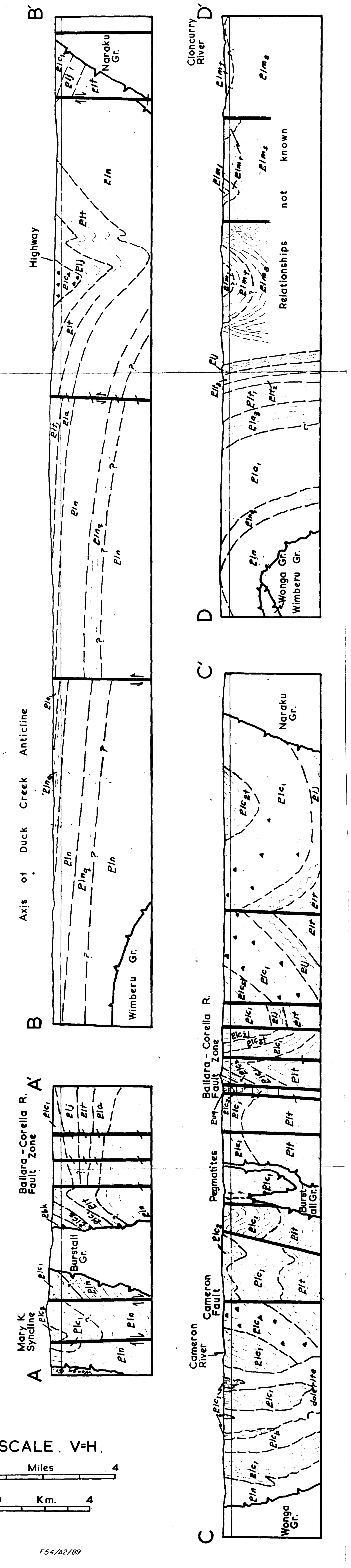


# MAP 5
# STRUCTURAL MAP, MARRABA 1:100,000 SHEET AREA.


## LEGEND

- Geological Boundary
- Anticline & Plunge
- Syncline, Overturned
- Plunge of Minor Anticline
- Fault
- Stream Dam
- Road
- Railway Line, Siding

| | |
|---|---|
| Puq | Quamby Conglomerate |
| Plm_l | Marimo Slate, limestone member |
| Plm_t | .. .. siltstone .. |
| Plm_s | .. .. slate |
| Plm_q | .. .. quartzite |
| Plc_3 | Corella Formation upper sediments |
| Plc_2t | .. .. middle siltstone |
| Plc_2s | .. .. .. slate |
| Plc_2q | Corella Formation middle quartzite |
| Plc_2l | .. .. .. limestone |
| Plc_1 | .. .. lower limestone |
| Plc▲ | .. .. breccia |
| Plj | Overhang Jaspilite |
| Plt_3 | Mitakoodi Quartzite upper siltstone |
| Plt_2 | .. .. middle basalt |
| Plt_1 | Mitakoodi Quartzite, lower quartzite |
| Pla_3 | Marraba Volcanics, upper sediments |
| Pla_2 | .. .. middle .. |
| Pla_1 | .. .. lower basalts |
| Plnq | Argylla Formation quartzite |
| Pln | undifferentiated lava |
| Pguh | Hypabyssal Naraku Equivalent |
| Pbk | Kuta Gabbro |

SCALE. V=H.

Miles 0 – 4

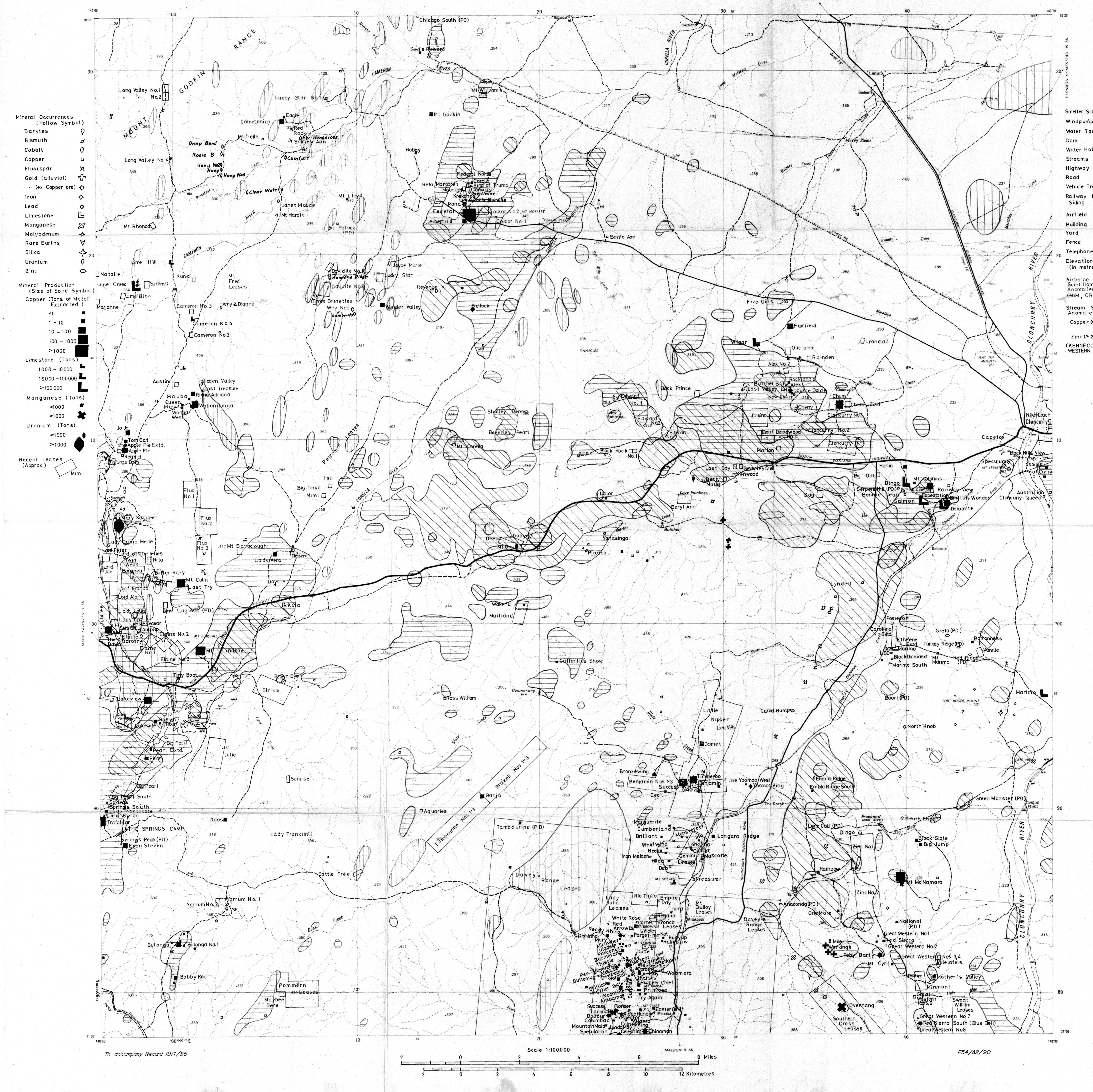
Km. 0 – 4

F54/A2/89

To accompany Record 1971/56

# MAP 6

## MARRABA 1:100 000 MINERAL OCCURRENCE MAP.



# MARRABA
QUEENSLAND

1:100,000 GEOLOGICAL MAP

SHEET 6956

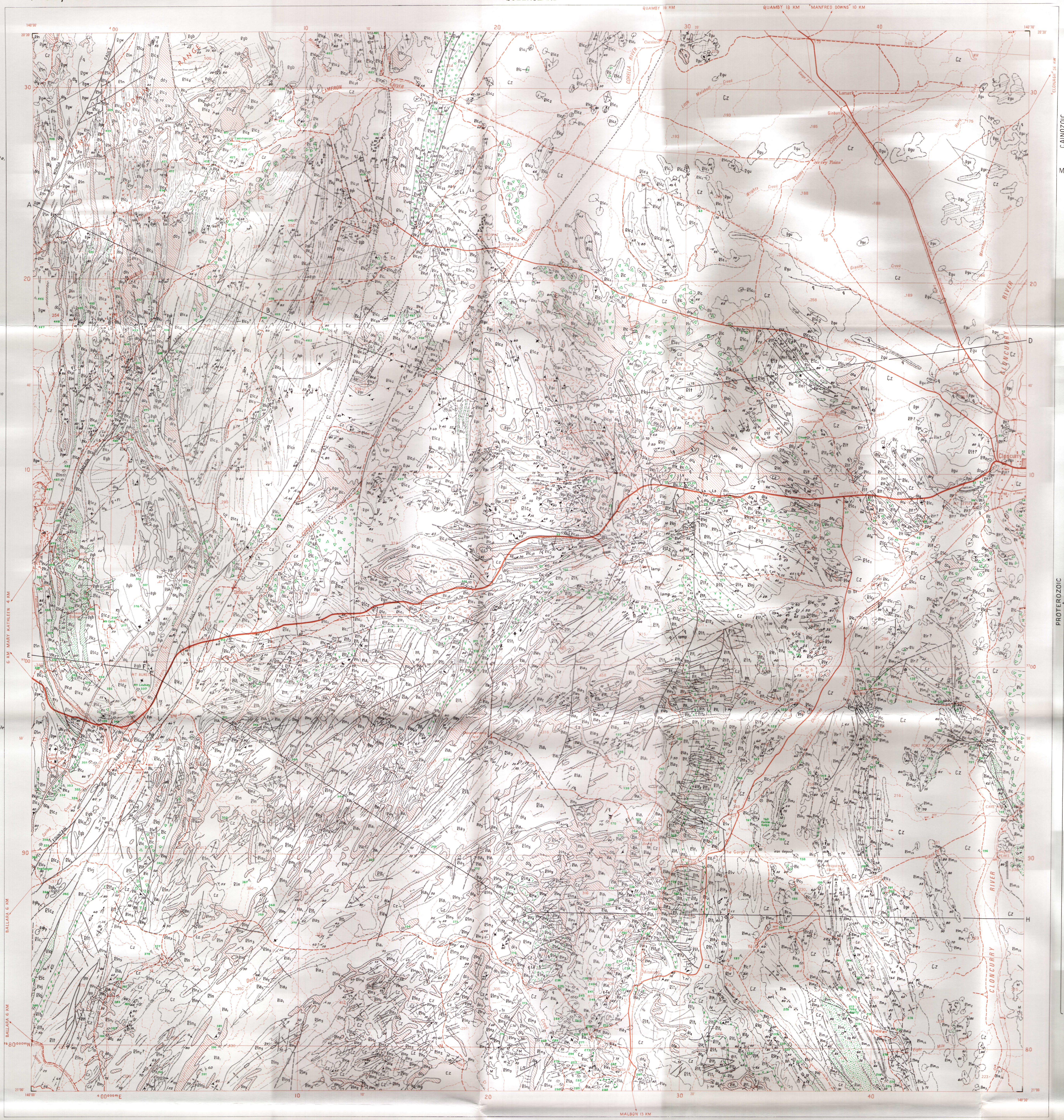
## Mining and Lease Index

Numbers refer to location on map. Where space insufficient, groups are represented by a single number, eg. 123

Distribution of numbers within map quadrants

## Reference

Geological boundary
Unconformity (teeth towards younger formation)
Anticline, showing plunge
Syncline, showing plunge
Overturned anticline
Overturned syncline
Anticline, fold axis horizontal
Fault, showing relative horizontal movement
Normal fault
Inclined fault



## Reference

CAINOZOIC

| Symbol | Description |
|---|---|
| Cz | Soil, sand, alluvium |
| Czg | Cobble and boulder gravels |

MESOZOIC

| Symbol | Description |
|---|---|
| M | Conglomerate, sandstone, siltstone, porcellanite, chert, laterite |
| do | Dolerite, metadolerite, of various ages |
| dr | Monzodiorite of various ages |

ADELAIDEAN ?

| Unit | Symbol | Description |
|---|---|---|
| Quamby Conglomerate | Puq | Conglomerate, sandstone, greywacke |

PROTEROZOIC — LOWER PROTEROZOIC OR CARPENTARIAN

| Unit | Symbol | Description |
|---|---|---|
| *Lakeview Dolerite Dyke | $do_6$ | Coarse to medium pyroxene dolerite |
| *Burstall Granite | Pgb | Medium to coarse granite, microgranite, aplite |
| | $Pgb_p$ | Tourmaline pegmatite |
| | | Fine microgranite with garnet and albite |
| Naraku Granite | Pgu | Medium to coarse leucogranite |
| *Tommy Creek Microgranite | | Leucocratic microgranite and porphyritic rhyolite |
| | gr | Granite |
| | $do_4$ | Coarse to medium dolerite |
| *Lunch Creek Gabbro | Pbk | Olivine-pyroxene gabbro, biotite diorite, hybrid diorite and tonalite |
| Roxmere Quartzite | Plr | Feldspathic quartzite, calcareous sandstone, minor siltstone and conglomerate |
| Marimo Slate | Plm | Undivided: siltstone, slate, marl, limestone, calcareous sandstone |
| | $Plm_2$ | Undivided: ferruginous siltstone, fine sandstone, minor marl and conglomerate |
| *Mick Creek Sandstone Member | | Fine to coarse sandstone, quartzite |
| | | Fine to medium quartzite |
| | | Specularitic quartzite conglomerate, breccia |
| | $Plm_1$ | Undivided: siltstone, grey and brown shale |
| *Toby Barty Sandstone Member | | Fine sandstone, quartzite |
| | | Fine to medium feldspathic quartzite |
| | $Plm_{1s}$ | Grey slate, black carbonaceous slate |
| | $Plm_{1a}$ | Siltstone, marl, limestone |
| | $Plm_{1l}$ | Limestone, marl, calcareous siltstone |
| | $Plm_{1t}$ | Phyllite, mica schist, siltstone |
| | $do_3$ | Metadolerite, amphibolite |
| Corella Formation | Plc | Undivided: calcareous granofels, limestone, schist, quartzite |
| | | Calcareous breccia, limestone, hematite pods |
| | $Plc_t$ | Schist, phyllite, phyllonite |
| | $Plc_3$ | Undivided: calcareous and calc-silicate granofels, limestone, marl, minor para-amphibolite |
| | | Quartzite |
| | $Plc_2$ | Undivided: calcareous sandstone, slate, schist, marl |
| | $Plc_{2s}$ | Slate with andalusite, kyanite, garnet, graphite |
| | $Plc_{2l}$ | Limestone, calcareous granofels with diopside, vesuvianite and garnet |
| | $Plc_{2t}$ | Phyllite, schist, basic tuff, acid agglomerate |
| | | Metabasalt, basaltic pillow lava, amphibolite |
| | | Quartzite |
| | | Metaconglomerate |
| | | Garnetite, garnet-diopside skarn |
| | $Plc_1$ | Undivided: calcareous and calc-silicate granofels, limestone, marl |
| | | Quartzite |
| *Chumvale Breccia | Plv | Quartzite breccia with jaspilite remnants |
| *Overhang Jaspilite | Ploj | Jaspilite, limestone, shale, marl |
| | | Quartzite, quartzite breccia |
| Mitakoodi Quartzite | Plt | Undivided: quartzite, feldspathic quartzite, siltstone, basalt, schist, minor limestone |
| | $Plt_3$ | Buff silt and shale |
| *Wakeful Basalt Member | $Plt_2$ | Metabasalt, minor siltstone |
| | $Plt_1$ | Feldspathic quartzite, minor siltstone |
| Marraba Volcanics | $Pla_3$ | Slate, siltstone, sandstone, limestone, marl |
| Timberoo Member | | Metabasalt |
| Mount Start Member | $Pla_2$ | Fine calcareous sandstone, limestone, chert |
| | $Pla_1$ | Metabasalt, dolerite, minor arkose |
| Cone Creek Volcanic Member | | Agglomerate and pillow lava |
| | $do_2$ | Metadolerite, amphibolite, basic schist |
| Wonga Granite | Pgw | Coarse foliated granite, minor fine granite and aplite; age not yet determined but possibly coeval with Burstall Granite |

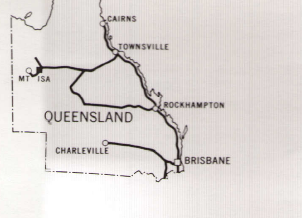
LOWER PROTEROZOIC ?

| Unit | Symbol | Description |
|---|---|---|
| Argylla Formation | Pln | Undivided: porphyritic rhyolite, rhyodacite, dacite; quartzite |
| | | Quartzite |
| | | Metabasalt |
| | $Pln_5$ | Medium to coarse feldspathic quartzite |
| | $Pln_4$ | Quartz-rich porphyry, porphyritic rhyolite, rhyodacite |
| | $Pln_3$ | Quartz-poor porphyry, porphyritic dacite and andesite |
| | $Pln_2$ | Feldspathic quartzite, siltstone, chert, tuffaceous and epidote-rich sandstone |
| | $Pln_1$ | Sericite quartzite |

* Name not yet approved

Compiled by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development. Issued under the authority of the Hon. R.W. Swartz, M.B.E., E.D., Minister for National Development. Base map compiled by the Division of National Mapping from aerial photography at 1:80,000 scale. Transverse Mercator Projection. Horizontal Datum: Australian Geodetic Datum 1966

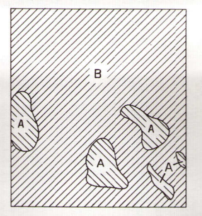
Geology 1952-1959 by E.K. Carter, E.M. Bennett, R.A. Searl, J.F. Ivanac, K.A. Townley, K.R. Walker, R.B. Fraser, W.M.B. Roberts, C.E. Prichard (BMR); J.H. Brooks, B.W. Hawkins (GSQ)
Detailed mapping and complete geological revision 1969-1970 by G.M. Derrick, R.M. Hill, J.E. Mitchell, A.Y. Glikson (BMR); I.H. Wilson (GSQ)
Compiled 1970-1971 by G.M. Derrick, G. Millist, M. Little
Cartography by Geological Branch BMR
Drawn by M. Little




Scale 1:100,000

KILOMETRES 4 3 2 1 0 2 4 6 8 10
MILES 2 1 0 2 4 6

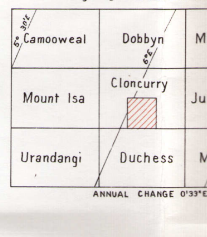
RELIABILITY DIAGRAM




Geology A Detailed mapping
B Detailed reconnaissance: numerous traverses, and air-photo interpretation

RELIABILITY TO 1:250,000 SERIES

Showing Magnetic Declination 1970



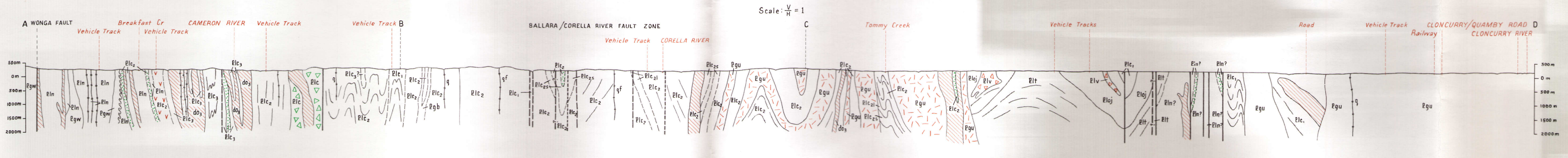
| | | |
|---|---|---|
| Camooweal | Dobbyn | Millungera |
| Mount Isa | Cloncurry | Julia Creek |
| Urandangi | Duchess | McKinlay |

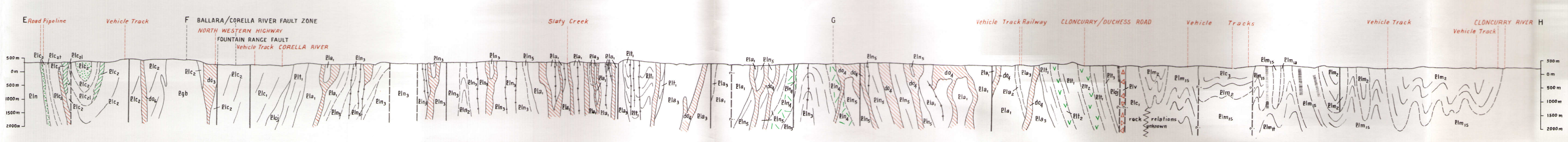
ANNUAL CHANGE 0°33'E

## Sections

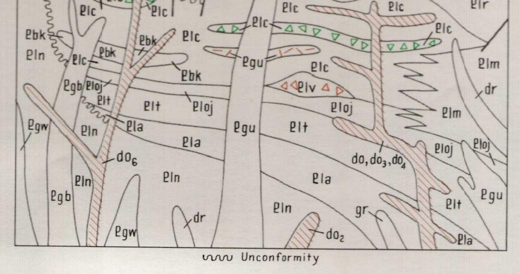
Cainozoic sediments omitted

Scale: $\frac{V}{H} = 1$




DIAGRAMMATIC RELATIONSHIP OF ROCK UNITS




PRELIMINARY EDITION, 1972
SUBJECT TO AMENDMENT



MARRABA
SHEET 6956

MERCURY-WALCH

*Marraba 1:100,000 Sheet area.*

## REFERENCE

**MESOZOIC CAINOZOIC**

| Symbol | Description |
|---|---|
| Cz | Soil, sand, alluvium |
| Czg | Cobble and boulder gravels |
| M | Laterite, altered sandstone, chert |

**PROTEROZOIC**

**? UPPER PROTEROZOIC OR ADELAIDEAN**

| Unit | Symbol | Description |
|---|---|---|
| Quamby Conglomerate | Puq | Conglomerate, sandstone, greywacke |

**LOWER PROTEROZOIC OR CARPENTARIAN**

| Unit | Symbol | Description |
|---|---|---|
| Roxmere Quartzite | Plr | Feldspathic quartzite, minor siltstone, calcareous sandstone |
| Marimo Slate | $Plm_2$ | Ferruginous siltstone, f.g. sandstone, minor marl, conglomerate. |
| Mick Creek Sandstone Member | $Plm_{1d}$ | F.g. to m.g. quartzite |
| | $Plm_{1s}$ | Grey slate and black carbonaceous slate |
| | $Plm_{1a}$ | Siltstone, marl, limestone, attenuated siltstone |
| | $Plm_{1l}$ | Limestone, marl |
| | $Plm_{1t}$ | Phyllite, mica schist, interbedded siltstone |
| Toby Barty Sandstone Member | $Plm_{1q}$ | F.g. to m.g. feldspathic quartzite |
| Corella Formation | Plc | Undiff: calcareous granofels, marl, limestone, schist, sandstone |
| | | Breccia: |
| | Plc 3 | Calc-silicate granofels, limestone, marl |
| | q | quartzite. |
| | Plc 2 | Undiff: calcareous quartzite, slate, schist, marl |
| | s | Slate, with andalusite, kyanite, garnet, graphite |
| | l | Limestone, with garnet, vesuvianite, diopside, plagioclase |
| | t | Phyllite, schist, basic tuff |
| | b | Metabasalt, pillow basalt, amphibolite |
| | q | Quartzite |
| | ◦◦◦ | Conglomerate |
| | r | Garnetite. |
| | Plc 1 | Calc-silicate granofels, limestone, marl |
| | q | Quartzite. |
| Chumvale Breccia | Plv | Quartzite breccia with jaspilite remnants |
| Overhang Jaspilite | Plj | Jaspilite, limestone, shale, marl |
| | q | Quartzite, vuggy quartzite. |
| Mitakoodi Quartzite | Plt | Undiff: quartzite, siltstone, basalt, schist, minor limestone |
| | $Plt_3$ | Buff silt and shale |
| Wakeful Basalt Member | $Plt_2$ | Massive and amygdaloidal metabasalt, minor siltstone. |
| | $Plt_1$ | Feldspathic quartzite, minor siltstone |
| Marraba Volcanics — Timberoo Member | $Pla_3$ | Slate, siltstone, sandstone, limestone, marl |
| | 3b | metabasalt |
| Mt. Start Member | $Pla_2$ | Lamin. f.g. calcareous sandstone, limestone, chert |
| Duck Creek Volcanic Member | $Pla_1$ | Massive and amygdaloidal metabasalt, dolerite, minor arkose. |
| | 1g | Agglomerate |
| Argylla Formation | Pln | Undiff: porphyritic acid volcanics and quartzite. |
| | q | quartzite |
| | $Pln_5$ | M. to c.g. feldspathic quartzite |
| | $Pln_4$ | Quartz-rich porphyry, porphyritic rhyolite and rhyodacite |
| | $Pln_3$ | Quartz-poor porphyry, porphyritic dacite and andesite |
| | $Pln_2$ | Lamin. feldspathic quartzite and siltstone, tuffac. and epid. sandstone |
| | $Pln_1$ | Sericite quartzite |

### BASIC INTRUSIVE ROCKS

| Unit | Symbol | Description |
|---|---|---|
| | do | Undiff: dolerite, metadolerite, amphibolite |
| Lakeview Dolerite Dyke | $do_6$ | Dolerite, m.g. to f.g. |
| | $do_4$ | Dolerite, metadolerite |
| | $do_3$ | Metadolerite and amphibolite |
| | $do_1$ | Metadolerite, amphibolite, basic schist |
| | dr | Monzodiorite |
| Kuta Gabbro | Pbk | Layered olivine-pyroxene gabbro, pyroxene diorite, hybrid diorite and tonalite, agmatite |

### ACID INTRUSIVE ROCKS

| Unit | Symbol | Description |
|---|---|---|
| Burstall Granite | Pgb | Leucocratic med. to c.g. granite and aplite |
| | $Pgb_p$ | C.g. graphic pegmatite with tourmaline |
| | $Pgb_h$ | Very f.g. microgranite with garnet and albitite. |
| Pinnacles Microgranite | $Pgu_h$ | F.gr. leucocratic microgranite and porphyry |
| Naraku Granite | Pgu | M.g., even-grained, massive leucocratic granite |
| ?LOWER PROTEROZOIC — Wonga Granite | Pgw | C.g porphyritic gneissose granite, minor f.g. granite and aplite. |
| | gr | Undifferentiated granite |

## LEGEND - Marraba 1:100,000 Sheet

- Formation boundary
- Intrusive boundary (older / younger)
- Unconformity
- Member or minor boundary
- Rock - soil boundary

Most geological boundaries are accurate; boundaries are queried when approximate, inferred or concealed.

- Anticline, position accurate, with direction of plunge
- Anticline, " approximate, " " "
- Anticline, inferred
- Anticline, fold axis horizontal
- Syncline, position accurate, " " "
- Syncline, " approximate, " " "
- Syncline, " inferred.
- Overturned anticline
- Overturned syncline
- Plunge of minor anticline
- Plunge of minor syncline
- Plunge of drag fold.
- Plunge added to trend line
- Fault, position accurate, showing relative horizontal movement
- Fault, position approximate
- Fault, inferred
- Fault, concealed
- Fault, inferred and concealed
- Normal fault, teeth on downthrown side, with dip of fault plane. (70)
- Lineament
- Fault breccia
- Shear zone
- Zone of silicification, with iron and manganese. (Fe, Mn)
- Bedding, measured strike and dip (60)
- " " " " " , facing unknown. (65)
- Bedding, vertical
- " " , facing unknown
- " , overturned (80)
- Dip > 45° (air-photo interpretation)
- Trend line
- Facing of beds
- Facing of lava flow
- Joint, measured dip (75)
- " , vertical
- " , horizontal
- Joint pattern (air photo interpretation)
- Metamorphic foliation, dip measured (70)
- " " , vertical
- Cleavage, measured (52)
- " , vertical
- Lineation on cleavage (61, 85)
- " " bedding (75, 80)
- " " " , facing unknown (75, 80)
- " " metamorphic foliation (60, 85)
- Igneous banding, measured dip (72)
- " " vertical
- Current direction from cross-bedding

- Dyke or vein : do - dolerite, q - quartz, ap - aplite, py - quartz-feldspar porphyry, qf - quartzofeldspathic vein, QF - quartz-feldspar pegmatite, lamp - biotite lamprophyre, Ls - limestone, q-to - quartz tourmaline
- Bedded limestone

| Symbol | Meaning |
|---|---|
| • Mn | Minor mineral occurrence |
| Cu | Copper |
| Mn | Manganese |
| Ls | Limestone (calcite, marble) |
| Au | Gold |
| To | Tourmaline |
| He | Hematite |
| Fl | Fluorite |
| Fe | Iron |
| Ba | Barytes |
| Gs | Gemstones |
| A | Amethyst |
| As | Arsenic |
| Mo | Molybdenum |
| Im | Ilmenite |
| Chl | Chlorite |
| Tr | Tremolite |

- Prospect
- Mine, with name (Hobby)
- Mine, not working
- Open cut, quarry
- Costean
- Treatment plant, not operating
- Bore, power-equipped (o pe)
- Windmill
- Earth tank (E)
- Dam on stream
- Waterhole (WH)
- Rockhole (RH)
- Waterfall on stream (Falls)
- Lake
- Position doubtful (pd)
- Highway
- Road
- Vehicle track
- Railway line, with siding (Marimo)
- Airstrip
- Landing ground
- Homestead ("Corella Park")
- Yard (Yd)
- Fence
- Township
- Telephone line
- Astronomical station
- Trigonometric station
- Spot height in metres. (•446)

*Note: this sheet also refers to Mary Kathleen 1:100,000, but does not refer in every detail to the Mary Kathleen 1:50,000 compilation sheets e.g. in the latter all roads, tracks etc are marked at present by two continuous parallel lines.*