DEPARTMENT OF NATIONAL RESOURCES

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Record 1975/175

GEOLOGY OF THE MOUNT ISA 1:100 000 SHEET AREA, NORTHWEST QUEENSLAND

by

R.M. Hill*, I.H. Wilson** and
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SUMMARY

The Mount Isa 1:100 000 Sheet area of northwest Queensland is bounded by latitudes $20^\circ 30'$S and $21^\circ 00'$S and longitudes $139^\circ 00'$E and $139^\circ 30'$E. The city of Mount Isa lies near the eastern margin of the Sheet area.

The major rock units belong to the Carpentarian western succession of the Mount Isa Geosyncline. The oldest unit is the Yaringa Metamorphics, a structurally complex metasedimentary sequence intruded and probably uplifted by the 'Big Toby Granite'. Uplift of this Yaringa-Big Toby Granite block, as well as uplift of a crystalline basement block (Kalkadoon-Leichhardt block) to the east, resulted in rapid erosion from these areas and the deposition of conglomerate, greywacke, sandstone, and siltstone in the interjacent trough; these sediments are represented by the Mount Guide Quartzite. This period of sedimentation was followed by vast outpourings of continental tholeiitic basalt to form the Eastern Creek Volcanics. These volcanics are overlain by the mainly arenaceous Myally Beds east of the Mount Isa Fault and by the Judenan Beds west of the Mount Isa Fault.

Intrusion of the multi-phase Sybella Granite into these sediments and volcanics caused renewed uplift and erosion; one phase of the intrusion is possibly comagmatic with the 'Carters Bore Rhyolite'. Conglomerates and feldspathic quartzite of both the lower Mingera Beds to the west, and the 'Warrina Park Quartzite', at the base of the Mount Isa Group to the east, represents the products of renewed erosion, and were succeeded by shale, siltstone, and dolomite in the west, and by dolomitic and pyritic siltstone and shales and thin tuff beds of the Mount Isa Group in the east.

The Mount Isa Group and older rocks were considerably deformed after which the Adelaidean Pilpah Sandstone was deposited in the northwest of the Sheet area; this formation has been subjected to subsequent gentle basin-and-dome folding.

The whole area was uplifted and eroded before siltstone, shale, chert, and phosphorite of the Middle Cambrian Beetle Creek Formation and Inca Formation were deposited in the Georgina Basin. Denudation and minor deposition occurred during the Mesozoic and Cainozoic.

Three main phases of metamorphism are recognized in the area: the first took place during the intrusion of 'Big Toby Granite' and affected only the Yaringa Metamorphics; the second phase was a low-pressure/high-temperature metamorphism associated with the intrusion of the Sybella Granite; the third phase was a widespread regional greenschist metamorphism immediately after the deposition of the Mount Isa Group.

Silver-lead-zinc ore in the Urquhart Shale is mined at Mount Isa and similar ores are being developed for mining at Hilton; the mineralization is considered to be syngenetic. Overlying these deposits at Mount Isa are rich copper deposits in brecciated Urquhart Shale; the copper may be either syngenetic or epigenetic. A large number of uranium anomalies commonly associated with dolerite, have been discovered in the Eastern Creek Volcanics, but detailed investigations have failed to indicate any economic deposits. Beryl, mica, and tantalite-columbite have been mined in the 'Mica Creek Pegmatite', which also contains monazite, cassiterite, ilmenite, rutile, and bismuth minerals. Gold has been obtained from numerous small workings in the northwest of the Sheet area; earliest discoveries were alluvial but most subsequent production has come from north-trending quartz reefs in pelitic and arenaceous Mingera Beds within the May Downs Fault Zone.

INTRODUCTION

Location

The Mount Isa 1:100 000 Sheet area (6756) lies in northwest Queensland and is bounded by latitudes 20°30'S and 21°00'S, and longitudes 139°00'E and 139°30'E, (Fig. 1). It forms the southeastern portion of the Mount Isa 1:250 000 Sheet area SF/54-1. The city of Mount Isa, which is about 1880 km by road from Brisbane, is situated near the eastern edge of the Sheet area.

Object

This Record presents results of detailed reconnaissance geological mapping of the Mount Isa 1:100 000 Sheet area by members of the Bureau of Mineral Resources (BMR) and Geological Survey of Queensland (GSQ). Records on the geology of the three 1:100 000 Sheet areas to the east, Cloncurry (7056) (Glikson & Derrick, 1970), Marraba (6956) (Derrick et al., 1971) and Mary Kathleen (6856) (Derrick et al., 1974) have already been completed.

The aims of the survey were to:

1. present a map at 1:100 000 scale of the Precambrian geology
2. reassess the stratigraphy, structure, petrology, economic geology, and geological history of the region
3. undertake a geochemical study of various rocks units
4. prepare a detailed report of the geology.

Access

Access to and within the Sheet area is generally good. The sealed Barkly Highway traverses northwards from Mount Isa parallel to the eastern Sheet boundary, and a sealed beef raod leads southwards from Mount Isa, through the southeastern part of the Sheet area, to Dajarra.

Tracks from these sealed roads to station homesteads and water-bores form a close network throughout the rest of the area. These tracks follow boundary fences and the major watercources (Yaringa Creek, Mingera Creek, and the Templeton River), along which most of the water-bores in the area are located. In the eastern part of the Sheet area a network of minor tracks, mostly in poor repair, serve small-scale mining operations.

Population and industry

Mount Isa, the main population centre in the Sheet area, has a population of over 25 000 (1971 census). About 20 km north of the city, Mount Isa Mines Limited is building Hilton, a satellite township with a proposed initial population of 5000, in conjunction with the development of the Hilton Mine. May Downs is the only major station homestead in the Sheat area; a small property and homestead has been established west of Mount Isa on the road to May Downs. Ardmore station has an outstation building at Carters Bore.

Mount Isa Mines is Queensland's biggest single industrial enterprise and one of the largest in Australia. It employs over 5 000 people and has an annual payrole of over $26 m (1972). The rest of the working population in the area are engaged mainly in services related to the mining industry and the building and maintenance of the city; less than one percent of the population is involved in the pastoral industry.

Climate

The area has a semi-arid, monsoonal, tropical climate, with well-defined wet and dry seasons. Nearly all the rain is received between November and April with the greatest incidence during January and February. Occasionally, additional light rain falls in the early winter months. The area lies between the 38 and 50 cm isohyets of annual rainfall, which trend northwesterly; rainfall decreases to the southwest.

The annual average maximum temperature for the area is about 32°C and the annual average minimum temperature is about 17°C. The highest monthly average maximum is 38°C, in December, and the lowest monthly average minimum is 8°C, in July. Relative humidity is low, ranging from about 25 percent during winter to a maximum monthly average during the wet season of about 50 percent. More detailed accounts of the climate of the area are given by Slatyer & Christian (1954) and Carter, Brooks, & Walker (1961).

Vegetation and pasture

Detailed accounts of vegetation and pasture in the Sheet area are given by Perry & Christian (1954) and Perry & Lazarides (1964); a summary is given by Carter et al. (1961).

As this Sheet area contains a wide variation in topography, soil type, and drainage, a large number of plant communities are represented. The vegetation in the eastern part of the Sheet area is similar to that of the Mary Kathleen

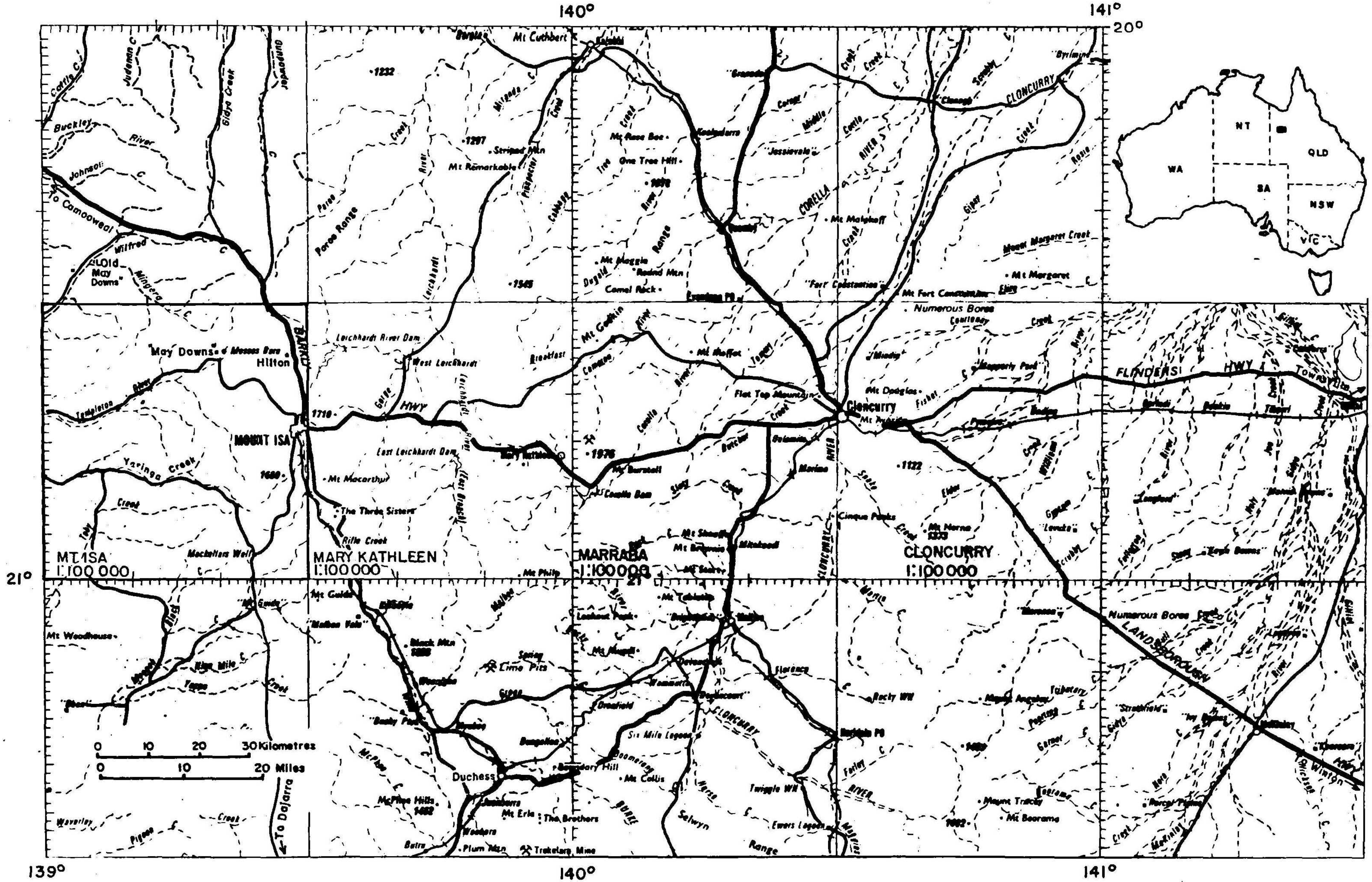

FIG. I

Fig. I Location map

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Sheet area (Derrick et al., 1974), to the east, and is characterized by snappy gum (*E. brevifolia*), stunted acacias, and various species of spinifex (*Triodia* spp); kurrajongs (*Brachychiton* spp.) grow as small isolated groups or individuals on rocky, strongly jointed outcrops of granite, dolerite, and quartzite. To the west, sandy well drained plains are covered with low eucalypts (*E. argillacea* and *E. terminalis*) and acacia scrub and pasture grasses such as Mitchell grass (*Astrebla* spp.) and Flinders grass (*Iseilema* spp.). Gidyea (*Acacia georginae* and *A. combagei*) forms small isolated patches of thick scrub, generally near the bottoms of gentle undulations in the plain, and in areas underlain by shale. Both Mitchell and Flinders grasses, and green herbaceous plants, grow on the restricted black-soil plains which have formed in areas of poor drainage, especially over basic rocks; these are good grazing areas.

Watercourses are lined by stately white-trunked river gums (*E. camaldulensis*) and to a lesser extent, by carbeen (*E. papuana*); paper barks (*Melaleuca* spp.) are common along water courses containing permanent or near-permanent surface water.

Water resources

Most of the creeks and rivers in the Sheet area contain surface water during and for a few weeks after the main wet season. A few large permanent and semipermanent waterholes are located along the Templeton River and in Mingera and Yaringa creeks. Several large shallow dams have been constructed recently in the western part of the area.

Underground water, pumped from bores along the main creek systems, has been essential to the pastoral industry. Most pumping is done by windmills, supplemented by diesel engines during the less windy months.

Mining operations at Mount Isa have necessitated the construction of large dams for tailings west and southwest of the city. The tailings are transported by pipeline as a slurry.

Previous literature

A comprehensive bibliography of geological work carried out in the Precambrian belt of northwest Queensland before 1960 is included in Carter et al. (1961). Reports dealing with the Mount Isa 1:100 000 Sheet area are also listed in the Bibliography of this record along with more recent relevant work.

Present investigation

This report presents the results of mapping by geologists from BMR and GSQ during 1970 and 1971. At the end of the 1970 field season part of the southeast corner of the Sheet area was mapped by G.M. Derrick, R.M. Hill, and J.E. Mitchell (BMR), and I.H. Wilson (GSQ), but the bulk of the mapping was done in 1971 (July to October) by I.H. Wilson and R.M. Hill with some contributions by G.M. Derrick and S. Henley (BMR). In describing the Mount Isa Group the authors have relied heavily on the work by Mount Isa Mines geologists, and some of the mapping by Wilson (1972) in an area west of Mount Isa has also been incorporated.

Closely spaced vehicle and foot traverses were used to cover the area. Geology was drawn on overlays to the aerial photographs, and was then compiled on photoscale bases by draughtsman, M. Little. Base camp was located near Clem Walton Park, just below the dam wall of Lake Corella.

Aerial photographs and maps

Airphoto coverage available in November 1971 is shown in Figure 2. Maps covering the area are listed below.

1. Mount Isa 1:250 000 topographic map, compiled in 1960 from 1947 aerial photographs by the Royal Australian Survey Corps; available from Division of National Mapping

2. Mount Isa 1:250 000 Sheet of Mining Lease Atlas, by Department of Mines Queensland

3. Mount Isa (Special) 1:50 000, showing mining leases, by Department of Mines, Queensland

4. Airphoto mosaics at 1:32 000 and 1:63 000 compiled from 1:24 000 photography (4 in Fig. 2); available from the Surveyor-General, Brisbane

5. Airphoto mosaic at 1:250 000 compiled in November 1950 from the 1947 1:50 000 photography (1 in Fig. 2); available from Division of National Mapping

6. Mount Isa 1:100 000 topographic map (6756), produced by the Division of National Mapping in 1972 from 1966 RC9 photography (2 in Fig. 2).

7. Photomosaic of the Mount Isa Sheet at 1:100 000 compiled in 1969 from RC9 photography (2 in Fig. 2); available from Division of National Mapping.

8. Mount Isa 4-mile (1:253 440) Geological Series map, SF/54-1, published in 1959 by BMR.

9. Mount Isa district geological map produced by Mount Isa Mines Limited-shows available information at October 1962; published in Geology of Australian Ore Deposits, 2nd Ed. (Bennett, 1965).

In 1972, SLAR imagery flown by Goodyear-Aerospace for the former Department of National Development covered most of the Mount Isa Sheet area at about 1:100 000 scale; it has been evaluated by Maffi (1974). ERTS-satellite imagery of the area became available early in 1973; an appraisal of its use in geological investigations has been made by Maffi et al. (1974).

The RC8 colour photographs at 1:25 000 were not available at the beginning of the survey and were used only for the northwestern part of the Sheet area. The eastern part of the Sheet area was mapped using the 1968 RC8 colour photograph (5 in Fig. 2) and Anaconda colour photos (6 in Fig. 2); the southern part of the Sheet area was mapped using black and white photographs flown for the Department of Lands, Queensland (4 in Fig. 2). The geological overlays from these photographs were compiled on topographic bases enlarged to photoscale from the 1:100 000 bases (6 above).

<u>Nomenclature</u>

Streckeisen's (1967) classification has been used in this Record for naming igneous rocks; Crook's (1960) for arenites; and Joplin's (1968) for metamorphic rocks. The term 'granofels', defined by Goldsmith (1959), is used instead of 'granulite' or 'hornfels' for a metamorphic rock with a granoblastic texture. All textural terms describing both igneous and metamorphic rocks are used in the sense defined by Joplin (1964, 1968). In describing the amount of a mineral present in a rock 'accessory' is used to mean less than 10 percent, and 'trace' less than one percent; 'minor' also indicates less than 10 percent. 'Essential' is used to describe any mineral whose presence is essential to the classification of rock.

Estimated modal analyses are visual estimates of the percentage of mineral constituents observed in a thin-section, compared with standard charts for estimating percentage composition of rocks and sediments (Composition, 1962). All specimen numbers prefixed by R are GSQ rock numbers; all other numbers are BMR registered numbers with the prefix 7120 deleted. 'Agd' is used in tables for average grain diameter, measured in millimeters.

GEOMORPHOLOGY

The geomorphology of the Barkly region, which includes the Mount Isa Sheet area, has been described by Stewart (1954) and summarized by Carter et al. (1961). The distribution of Stewart's geomorphological units in the Mount Isa Sheet area is shown in Figure 3, and the genetic relation between these units in Figure 4. Stewart's Erosional Land Surface subdivision corresponds to Twidale's (1964, 1966a) Isa Highlands physiographic division, which is described on the adjoining Sheet area to the east; Stewart's Depositional Land Surface corresponds to Twidale's Inland Plains.

Geomorphological subdivisions

The terrain in Stewart's Erosional Land Surface subdivision varies from immaturely dissected plateaux and ranges of resistant rocks with residual planated surfaces at elevations of 470 to 480 m, to steep ridges and low hills with narrow V-shaped valleys (Fig. 5) where altitudes are less than 450 m. Planated surfaces are generally ferruginized or lateritized, and represent remnants of a Tertiary land surface. Areas underlain by granite are characterized by pediments from which rise inselbergs (Fig. 6); Little erosion has apparently affected these pediments since the Tertiary, particularly in the northern part of the Sheet area, where deeply weathered granite crops out. The drainage pattern is dense; minor streams are structurally controlled, but larger streams such as Spring Creek, Sandy Creek, Lena Creek, Mica Creek, and Sybella Creek are superimposed or subsequent.

The terrain in Stewart's Depositional Land Surface subdivision includes the black-soil plains, shown as Czb on the geological map, and the sandy plains, shown as Cza, in the west of the Sheet area. The altitude of these areas range between 340 and 360 m. The drainage system shows a gradual change from the narrow channels in V-shaped valleys in the immaturely dissected country to wide braided channels in the open plains.

Erosion surfaces

Three erosion surfaces are recognized in the Sheet area. They were developed in the Early Cambrian before the deposition of the Beetle Creek Formation; and in the early Mesozoic; and in the mid-Tertiary.

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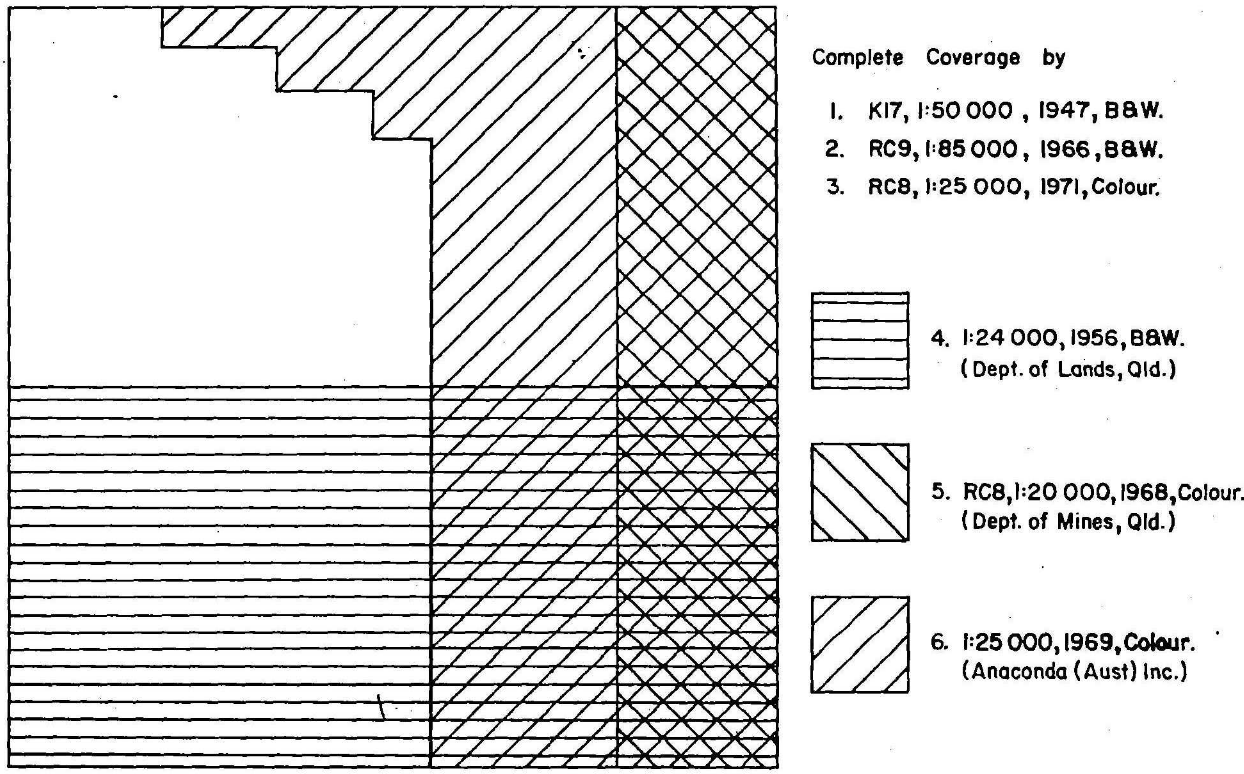

Fig. 2 Airphoto coverage of Mount Isa 1:100 000 Sheet area

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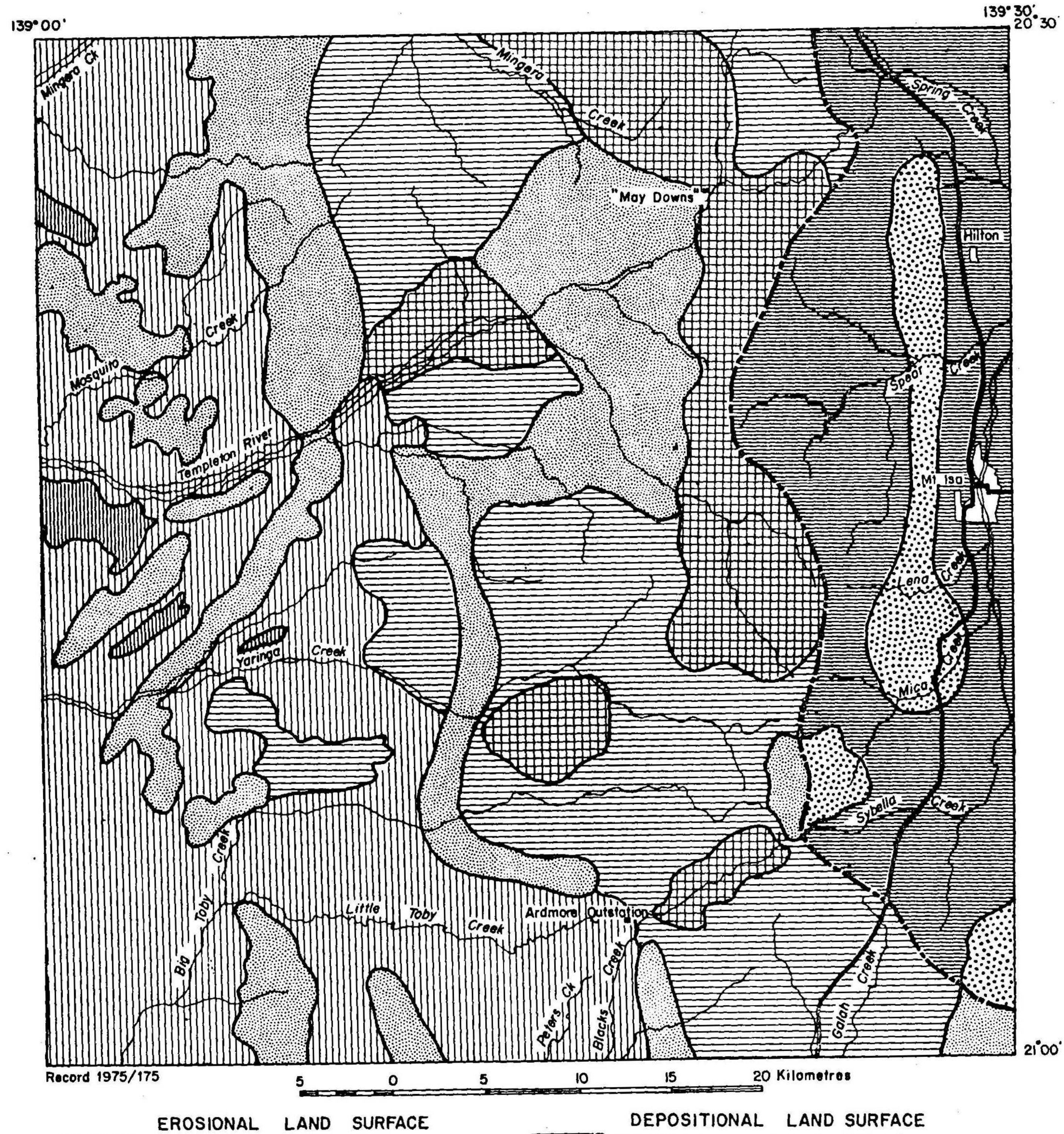

EROSIONAL LAND SURFACE

Dissected country of Gulf Fall with lateritic remnants

Dissected country of Gulf Fall without lateritic remnants

Dissected country of Georgina Basin with lateritic remnants

Dissected country of Georgina Basin without laterite remnants

Pediments forming parts of this unit

DEPOSITIONAL LAND SURFACE

Post Miocene coarse textured alluvia of Georgina Basin

Post Miocene fine textured alluvia of Georgina Basin

Drainage divide

Figure 3 Geomorphological units, Mount Isa 1 100 000 Sheet Area F54/A1/37

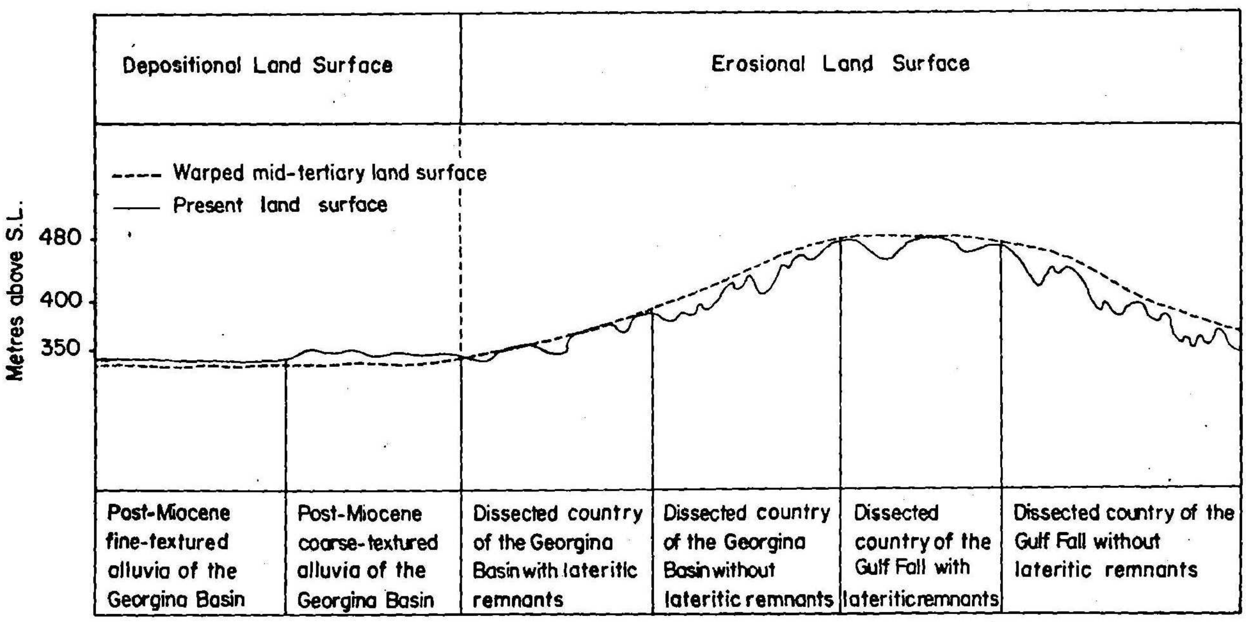

Figure 4 Diagrammatic cross section across northern part of Sheet area showing relations between geomorphological units (after Stewart, 1954)

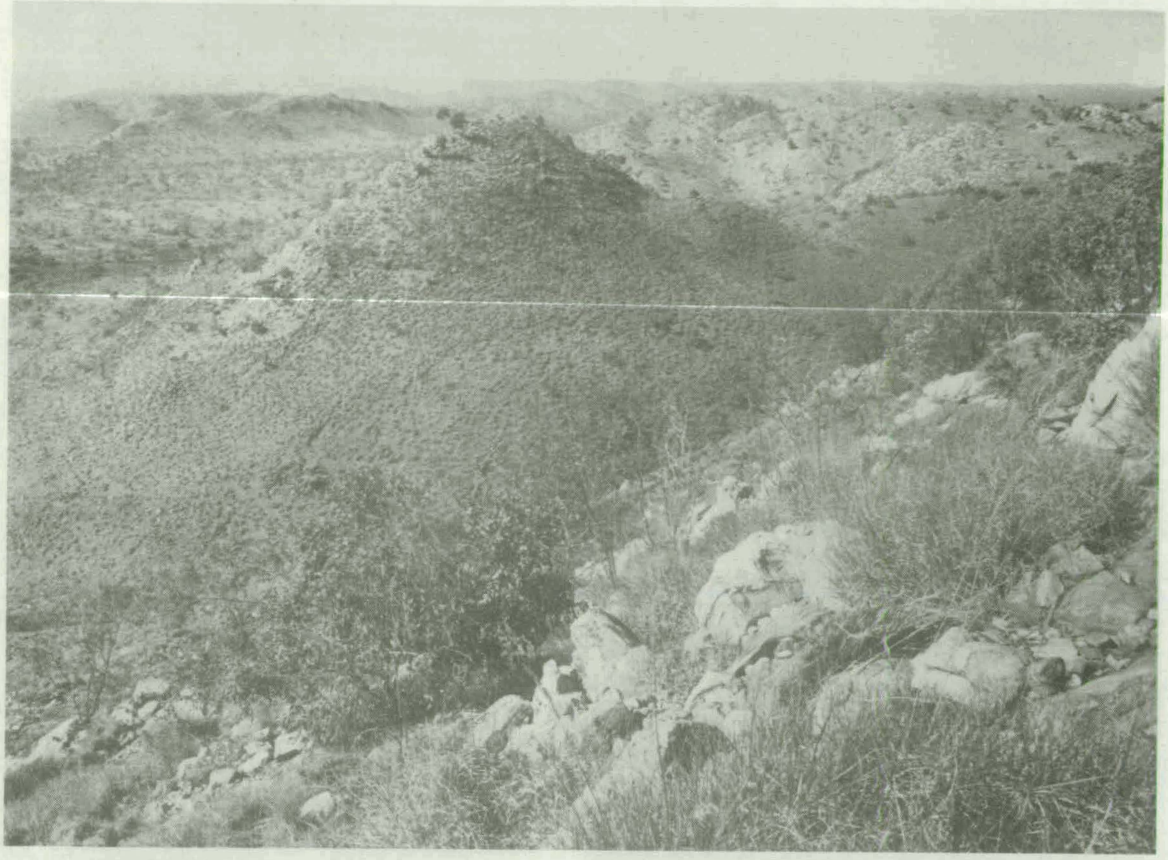

Fig. 5. Typical Expression of dissected country of the Gulf Fall without lateritic remnants. The steep-sided ridges separated by narrow V-shaped valleys are developed over the Judenan Beds
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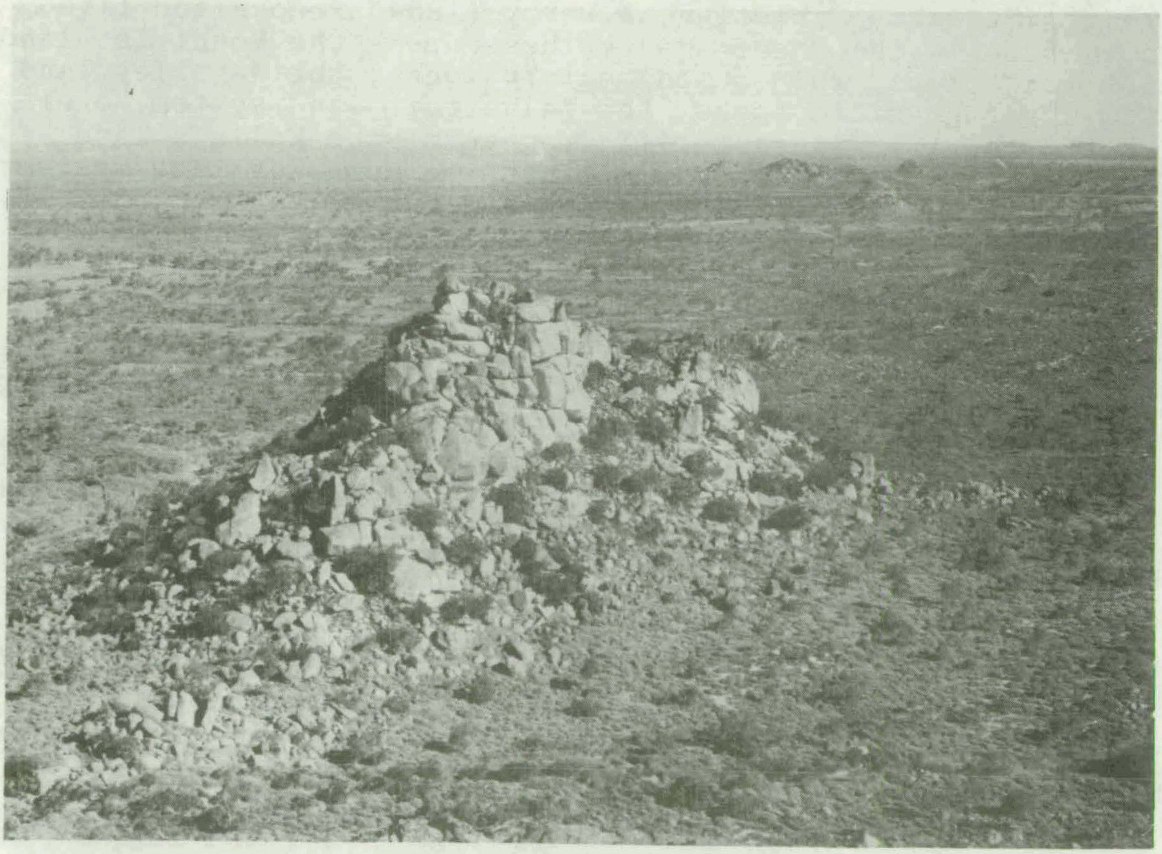

Fig. 6. Pediments with inselbergs of granitic rocks - characteristic of the dissected country of the Georgina Basin without lateritic remnants 19
M/1337 11 R.M.H.

Twidale (1966a) considers that by the early Mesozoic the whole Mount Isa region had been peneplaned. This erosion was terminated by earth movements which warped the plain surface and allowed the incursion of an epeiric Mesozoic sea in which was deposited a widespread cover of sediments. Grimes (1972) has shown that farther east these sediments consist of a Jurassic to Lower Cretaceous continental sequence and a Cretaceous marine sequence.

Uplift and warping in the Late Cretaceous or Early Tertiary initiated widespread subaerial erosion of the Mesozoic sediments. By the mid-Tertiary the region once again had a low relief and, at about this time, was affected by extensive deep weathering and lateritization. Grimes (1972) has recognized two major periods of deep weathering in the Carpentaria Basin - one in the Mesozoic, the other in the Teritary - but considers that the mid-Tertiary lateritic phase was more important in the Mount Isa region. The present main rivers were developed upon the mid-Tertiary erosion, and have been superimposed on the present surface. This mid-Tertiary surface was uplifted and warped in middle to Late Tertiary times, and a new cycle of erosion began; this cycle is still in progress.

The Sheet area contains remnants of both the early Mesozoic and mid-Tertiary surfaces, the latter being the most prominent. The old plateau indicated by the present summit accordances is taken to be of mid-Tertiary origin.

Land systems*

Stewart, Christian, & Perry (1954) recognized five land systems in the Sheet area. These are: the Mount Isa land system, on steeply folded sedimentary rocks; the Waverley land system, over granitic rocks; the Yelvertoft land system, over dissected country with lateritic remnants; the Kallala land system, on the black-soil plains; and the Bundella land system, on the sandy plains in the west of the Sheet area.

STRATIGRAPHY**

Introduction

The stratigraphy of the Mount Isa 1:100 000 Sheet area is summarized in Tables 1 and 2. Most of the area consists of Precambrian rocks of the Cloncurry Complex (Carter et al., 1961), and form part of the Mount Isa Geosyncline (Brown,

* A 'land system' is a natural association of landform, soil, and vegetation, i.e., an ecological unit.

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

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Campbell, & Crook, 1968). This geosyncline consists of two major north-trending basins, termed the 'Eastern Geosyncline' and 'Western Geosyncline' by Carter et al. (1961), separated by an elevated block of crystalline basement rocks. This has led to the tripartite geographic division of the Cloncurry Complex into eastern succession, the Kalkadoon-Leichhardt basement block, and the western succession (Derrick et al., 1974). The Mount Isa Sheet area contains mainly rocks of the western succession together with small areas of basement separate from but partly equivalent to the Kalkadoon-Leichhardt block.

A major fault, the Mount Isa Fault, divides the western succession into two similar and probably equivalent sedimentary sequences, parts of which have been given different names across the fault.

Stratigraphic nomenclature in the Sheet area generally follows that of Carter et al. (1961), although some of the units are redefined and some are new units. The following changes to the previous nomenclature have been made:

(a) One new formation has been recognized; this is the 'Carters Bore Rhyolite', which consists of acid volcanics that possibly overlie, unconformably, the Judenan Beds and are overlain unconformably by the Mingera Beds.

(b) The essentially conformable sequence of Mount Guide Quartzite, Eastern Creek Volcanics, and Myally Beds east of the Mount Isa Fault, and their equivalents to the west - the Mount Guide Quartzite, Eastern Creek Volcanics Judenan Beds, and possibly the 'Carters Bore Rhyolite' - are placed within the 'Haslingden Group'.

(c) A large area of quartzite and gneiss west of the Mount Isa Fault previously included within the Sybella Granite is now mapped as Mount Guide Quartzite. A distinctive gneiss unit at the base of the unit is termed the 'May Downs Gneiss Member' - a name first used by Wilson (1972).

(d) The quartzite previously included at the top of the Myally Beds about 15 km south of Mount Isa (the 'Quartzite Marker' of Bennett, 1965), is renamed 'Warrina Park Quartzite' and included in the Mount Isa Group.

(e) The granite formerly mapped as a part of the Sybella Granite which intrudes the Yaringa Metamorphics is now termed the 'Big Toby Granite'. The rest of the Sybella Granite has been subdivided into three major

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TABLE 1. SUMMARY OF STRATIGRAPHY, WEST OF THE MOUNT ISA FAULT, MOUNT ISA 1:100 000 SHEET AREA

Age	Rock unit	Symbol	Thickness (m)	Description	Stratigraphic relations	Remarks
CAINOZOIC		Cza		river bed and flood plain deposits: fine to coarse alluvium		
		Czb		black soil plains: fine alluvium in shallow depressions	superficial veneer	
		Czg		conglomerate, alluvial fan deposits		
		Czr		residual sand and silt		
MESOZOIC		M		ferruginous grit, ferricrete	unconformable on Cambrian and Proterozoic rocks	small outliers N and W of 'May Downs'
PALAEOZOIC CAMBRIAN	Inca Formation	€ai		siliceous shale and chert with limestone interbeds	conformable and disconformable on Beetle Creek Formation	
	Beetle Creek Formation	€ae		chert, siliceous shale with trilobite fossils, basal conglomerate	unconformable on Proterozoic units	
PROTEROZOIC ADELAIDEAN	Philpah Sandstone	*Pui_b		brecciated chert, laminated chert, shale-pellet conglomerate	irregularly distributed lenses	Pui_b generally cannot be distinguished from Pui_b
		Pui_2	Total thickness about 300 (probably less in Mount Isa Sheet area)	feldspathic sandstone	generally conformable on Pui_1	
		*Pui_{2f}		deeply weathered ferruginous sandstone	probably weathered equivalent of Pui_2	
		Pui_1		shale, fine feldspathic sandstone and siltstone, shale-clast conglomerate	unconformable on Mingera Beds; generally Pui_1 is basal in observed sections	
		Pui_{1b}		brecciated chert, shale, conglomerate	lenses at base on Pui_1	
PROTEROZOIC CARPENTARIAN	Paradise Creek Formation	Px		dolomite, siltstone, sandstone, stromatolitic chert	conformable on Mingera Beds, unconformable below Pilpah Sandstone and Cambrian sediments	small outcrop on W edge of Sheet area
		do		dolerite, pyroxene-bearing, ophitic texture	intrudes Sybella Granite	dykes, stocks, minor intrusions
	Mingera Beds	Pv_4	100-500	black shale, laminated silty and micaceous shale	conformable on Pv_3, conformably overlain by Paradise Creek Formation	
		*Pv_{4q}	0-200	ferruginous siltstone, sandstone, minor conglomerate	lens at top of Pv_4	present only in S of Sheet area
		Pv_3	100-500	laminated siltstone, micaceous and pyritic siltstone	conformable on Pv_2	
		Pv_2	150-400	fine to medium feldspathic sandstone with minor conglomerate	conformable on Pv_1	
		Pv_1	100-700 (excluding Pv_{1f} and Pv_{1q})	coarse feldspathic sandstone, pebble and cobble conglomerate	unconformable on Yaringa Metamorphics, Sybella Granite, Judenan Beds, and 'Carters Bore Rhyolite'	
		*Pv_{1f}	0-1000	ferruginous siltstone and fine sandstone	lens at base of Pv_1	present only in NW of Sheet area
		*Pv_{1q}	0-1000	ferruginous medium sandstone	lens at base of Pv_1, overlain by Pv_1	

TABLE 1. SUMMARY OF STRATIGRAPHY, WEST OF THE MOUNT ISA FAULT, MOUNT ISA 1:100 000 SHEET AREA (Cont'd)

Age	Rock unit	Symbol	Thickness (m)	Description	Stratigraphic relations	Remarks
PROTEROZOIC CARPENTARIAN	Sybella Granite: 'Mica Creek Pegmatite'	Ꞓgs_4		feldspar-muscovite-quartz pegmatite containing beryl	intrudes Eastern Creek Volcanics and Judenan Beds and Ꞓgs_2	
	(Sybella Microgranite)	Ꞓgs_3		massive fine to medium even-grained granite	intrudes Eastern Creek Volcanics; faulted boundaries with rest of Sybella Granite	dated as 1537 ± 40 m.y.
		Ꞓgs_2		foliated coarse porphyritic biotite granite	intrudes Ꞓhe and Ꞓhj	dated as 1646 ± 15 m.y.
		*Ꞓgs_{2m}		fine to medium granite and gneiss rich in magnetite	minor phase of Ꞓgs_2	
		*Ꞓgs_{2q}		porphyritic quartz diorite with quartz ocelli	marginal phase where Ꞓgs_2 intrudes basic rocks	
		Ꞓgs_1		massive medium to coarse porphyritic granite with distinctive blue quartz phenocrysts	intrudes Eastern Creek Volcanics and Judenan Beds	dated as 1577 ± 13 m.y.
		do		dolerite, metadolerite, amphibolite	intrudes rocks older than Sybella Granite	
	'Haslingden Group': 'Carters Bore Rhyolite'	Ꞓhr	>200	porphyritic rhyolite	probably unconformably overlain by Mingera Beds; probably unconformably overlies Judenan Beds	top not exposed in Mount Isa Sheet area
	Judenan Beds	Ꞓhj		orthoquartzite, feldspathic quartzite, pelitic schist, amphibolite	conformably overlies the Eastern Creek Volcanics; overlain by 'Carters Bore Rhyolite' and Mingera Beds, probably unconformably; intruded by Sybella Granite.	top not exposed in Mount Isa Sheet area; thickness not known; correlated with Myally Beds to E
		Ꞓhj_3		metabasalt, amphibolite, chlorite schist	stratigraphic order unknown, lithological units only	
		Ꞓhj_2		metasiltstone, shale, pelitic schist		
		Ꞓhj_1		quartzite, feldspathic quartzite; minor schist, conglomerate		
	Eastern Creek Volcanics	Ꞓhe		metabasalt, amphibolite, quartzite, and pelitic schists	conformably overlies Mount Quartzite; apparently overlain conformably by Judenan Beds; intruded by Sybella Granite	probably thinner than in E
		*Ꞓhe_q		quartzite, epidotic quartzite	lenses throughout Formation	
		Ꞓhe_b		metabasalt, amphibolite, minor metasediments	conformably overlies Ꞓhe_s conformably overlain by Ꞓhj	
		Ꞓhe_s		pelitic schist, cordierite schist, quartzite and amphibolite	conformably overlies Ꞓhe_a	
		Ꞓhe_a		metabasalt, amphibolite, thin lenses of quartzite	conformably overlies Mount Guide Quartzite	
	Mount Guide Quartzite	Ꞓhg		orthoquartzite, feldspathic and micaceous quartzite, with minor gneiss	conformably overlain by Eastern Creek Volcanics	base not exposed in Mount Isa Sheet
	'May Downs Gneiss Member'	Ꞓhr		plagioclase-microcline-quartz gneiss containing minor biotite, sillimanite	conformable member in lower part of formation	mapped in Sybella Granite aureole
LOWER PROTEROZOIC OR CARPENTARIAN	'Big Toby Granite'	Ꞓgx		adamellite, medium-grained biotite granite minor foliated coarse granite and syenite	intrudes Yaringa Metamorphics; probably intrudes basic volcanics of possible Eastern Creek Volcanics; unconformably overlain by Cambrian.	dated as 1760 m.y.; previously mapped as part of Sybella Granite
	Yaringa Metamorphics	Ꞓy (p€y_1)	>1500	quartz-muscovite and quartz-sericite schists and phyllites, quartz-muscovite-biotite gneiss, minor migmatite	overlain by Mingera Beds and Cambrian sediments with angular unconformity; intruded by 'Big Toby Granite'	structurally complex, neither top nor bottom of unit observed; sedimentary features generally not preserved
		*(p€y_2)		quartz-feldspar porphyry	lenses of acid volcanics in metamorphics	

* The subscripts in these symbols have been replaced on the 1:100 000 Preliminary Edition by pattern symbols

TABLE 2. SUMMARY OF STRATIGRAPHY EAST OF THE MOUNT ISA FAULT, MOUNT ISA 1:100 000 SHEET AREA

Age			Rock unit	Symbol	Thickness (m)	Description	Stratigraphic relations	Remarks
CAINOZOIC				Cza		soil, sand, alluvium		
PROTEROZOIC CARPENTARIAN				do		dolerite, metadolerite, amphibolite	includes dolerite of various ages	
	Mount Isa Group		Magazine Shale	Pic	210	thin bedded calcareous sericitic shale minor pyrite	Mount Isa Group unconformably overlies Myally Beds; to the northeast in Prospector 1:100 000 Sheet area contact is a marked angular unconformity;	descriptions after Bennett (1965)
			Kennedy Siltstone	Pik	310	siliceous and dolomitic siltstone, dolomitic quartzite		
			Spear Siltstone	Pis	170	laminated dolomitic siltstone and shale		
			Urquhart Shale	Piu	910	ferruginous pyritic shale, tuff marker beds		host rocks for Pb, Ag, Zn, Cu mineralization at Mount Isa and Hilton mines
			Native Bee Siltstone	Pin	790	bedded dolomitic siltstone, laminated siltstone, minor tuff		
			Breakaway Shale	Pib	1030	grey shale, minor siltstone		
			Moondarra Siltstone	Pia	1200+	dolomitic siltstone, minor dolomite and shale		
			'Warrina Park Quartzite'	Piw	0-300+	quartzite, ferruginous siltstone		well exposed in Prospector 1:100 000 Sheet area
	Haslingden Group		Myally Beds	Phm_2	up to 650	quartzite and conglomerate	overlain unconformably by the Mount Isa Group	thins to S in Mount Isa Sheet area
				Phm_1	up to 600	Feldspathic quartzite, quartzite, siltstone shale-pellet conglomerate	conformably overlies Eastern Creek Volcanics	
		Eastern Creek Volcanics	Undivided	Phe		metabasalt, amygdaloidal and vesicular, flow-top breccia, minor quartzite	conformably overlies Mount Guide Quartzite conformably overlain by Myally Beds	total thickness ranges from 3600 m to 7200 m
			'Pickwick Metabasalt Member'	Php	700	metabasalt, amygdaloidal metabasalt, flow-top breccia, minor interelated sediments	conformably overlies Phl	
				*Php_q		quartz, epidote quartzite	beds in Php	
			'Lena Quartzite Member'	Phl	170 to 1080	quartzite, feldspathic and arkosic quartzite with rare pebbles	conformably overlies Phc	
			'Cromwell Metabasalt Member'	Phc	1750 to 5430	metabasalt, some amygdaloidal, flow-top breccia, minor sedimentary interelations	conformably overlies Mount Guide Quartzite	
				*Phc_q		quartzite, epidote quartzite	beds in Phc	
			Mount Guide Quartzite	Phg_2	Total greater than 6200	micaceous and feldspathic quartzites, silicified fine sandstone and siltstone	conformably overlies Phg_1; conformably overlain by Eastern Creek Volcanics.	
				Phg_1		friable fine to medium sandstone, greywacke, and siltstone	unconformably overlies Kalkadoon Granite, Leichhardt Metamorphics and Argylla Fm. in Mary Kathleen 1:100 000 Sheet area.	base exposed in Mary Kathleen Sheet area to E

* The subscripts in these symbols have been replaced on the 1:100 000 Preliminary Edition by pattern symbols

phases, and a minor pegmatitic phase which is known as the 'Mica Creek Pegmatite'. The Sybella Granite intrudes the 'Haslingden Group', but is considered to be older than the Mingera Beds and Mount Isa Group.

Most formations have been subdivided into informal members. On the 1:100 000 geological map the members have the same symbol as the formation to which they belong, generally together with a numerical subscript.

All the Precambrian rocks of the Sheet area, except for the Pilpah Sandstone, were designated as Lower Proterozoic by Carter et al. (1961) and given symbols such as Ꝑlg, Ꝑle, etc. (where Ꝑ = Proterozoic, 1 = Lower). In this report the symbols have been changed: Ꝑ, as before, represents the Proterozoic era, but the second letter now indicates the group or formation, and a third symbol is used only for formations which belong to a group. For example, Ꝑhg represents the Mount Guide Quartzite (g) in the Proterozoic (Ꝑ) Haslingden Group (h). Subscripts are used to distinguish members of formations.

PROTEROZOIC

Yaringa Metamorphics

Introduction

The Yaringa Metamorphics, possibly the oldest rocks in the crystalline basement, were formally defined by Carter et al. (1961). They crop out in an area north and west of Gap Bore on Yaringa Creek, and in two small areas 10 and 15 km south-southeast of Gap Bore. The total outcrop area is about 35 km^2.

Stratigraphic relations

The base of the Yaringa Metamorphics is not exposed. They are fault-bounded to the east, but are overlain unconformably by the Mingera Beds about 14 km northwest of Gap Bore, and by Cambrian sediments 15 km south-southeast of Gap Bore. They are intruded by the 'Big Toby Granite'.

Lithology and field occurrence

Quartz-muscovite and quartz-sericite schists and phyllites are the dominant rock types, and quartz-muscovite-biotite gneiss, migmatic rocks, and quartz-feldspar porphyry are also present. The porphyry is a grey, fine-grained foliated rock containing large cream euhedral phenocrysts (up to 1 cm) of potash feldspar and smaller glassy euhedral phenocrysts of quartz, and is distinguished from the rest of the unit on the 1:100 000 map.

TABLE 3. ESTIMATED MODAL ANALYSES OF SCHISTS AND PHYLLITES FROM THE YARINGA METAMORPHICS

Specimen number	3540	3541	3547	3554	3556	3557	3558	3559	3560	3572	3573	3637	R5170	R5177	R5179	R5180	R5189
Mineral																	
Quartz	20	25	70	40	10	45	35	35	55	35	50	65	90	68	15	69	76
K-feldspar					5												
Muscovite/sericite	34	45	20	60	47	47	55	35	40	60	35	18	1	24	75	20	20
Biotite/phlogopite		15	7		15	2	7	27	2		5	15	4			10	
Chlorite	40	10			20		tr	1	2		5			8	10		
Epidote	tr																
Tourmaline	1	1			1	2	1			1	1						
Zircon			1		tr	2	1	1	1		2					tr	
Opaques	5	4	2		2	2	1	1		4	2	tr	1	tr	tr	1	2
Apatite												tr	1				
Sphene													1	tr			
Plagioclase (comp)												2	2 An_{45}				
Rutile															tr		
Limonite																	2
Agd (quartz)	0.4	0.6	0.4	0.8	0.4	0.7	0.8	0.7	0.8	0.8	0.4	1.0	0.5	0.5	0.8	0.6	0.3

The schists and phyllites are greenish grey and generally have steep to vertical dips. They form low outcrops, in contrast to more bouldery outcrops of gneiss, migmatite, and porphyry. These rocks are covered with plants which on the aerial photographs produce a lighter colour than other rocks and the surrounding soil plains. Also the airphoto pattern is characterized by a fine cleavage-controlled striated texture crossed at right-angles by joints and minor faults. The quartz-feldspar porphyry forms distinctive conical hills but has a similar airphoto pattern to the rest of the formation.

Carter et al. (1961) reported conglomerate in the Yaringa Metamorphics, but we identified no pre-metamorphic structures; the only structures recorded are cleavage, compositional layering, minor folds, faults, and joints. Unlike other units in the area the Yaringa Metamorphics have a strong east-west cleavage.

Small stocks of 'Big Toby Granite' are common in the Yaringa Metamorphics near contacts with large granite intrusions. In several exposures, shearing of the granite has formed a quartz-muscovite schist similar in appearance to schists of the Yaringa Metamorphics. Small dykes and stocks of dolerite also intrude the metamorphics, and small areas of sheared amphibolite and biotite schist within the unit may represent metamorphosed dolerite. Quartz veins, some of which are ptygmatic, and black tourmaline crystals are common in some quartz-muscovite schist; some pegmatitic veins are also present.

Petrography

About 20 specimens from the Yaringa Metamorphics have been examined in thin section.

Quartz-muscovite schist and phyllite are weakly foliated and have a waxy lustre; spherical quartz grains are prominent on the weathered surface. In thin section the rocks are weakly lepidoblastic. They consist mainly of strained, sutured, or fractured quartz grains, and mica flakes, enclosed in a sericitic groundmass. Chlorite forms up to 40 percent of some specimens. Tourmaline occurs as large idioblastic post-cleavage crystals. Zircon also is idioblastic, with syntaxial overgrowths on rounded grains. The gneiss is similar to the schist and phyllite, except it contains dark bands of biotite and phlogopite. Estimated modal analyses for these rocks are summarized in Table 3.

The quartz-feldspar porphyry is pale grey and consists of large idiomorphic feldspar (4-10 mm) and quartz (2-6 mm) phenocrysts enclosed in a very fine-grained groundmass. The rock is weakly foliated and consists of 45 percent (20%

phenocrysts, 25% groundmass), 32 percent potash feldspar (7% phenocrysts, 25% groundmass), 5 percent biotite, and 15 percent muscovite. Quartz phenocrysts are high-temperature forms, and are mildly fractured and strained. The potash feldspar phenocrysts contain fine exsolution lamellae, and are partly altered and highly fractured. Biotite forms clots up to 2.0 mm diameter; the muscovite is very fine-grained.

Discussion and conclusions

The quartz-sericite phyllite and schist are probably metamorphosed labile arenites and quartzose arenites (Crook, 1960). A metasedimentary origin is supported by the presence of conglomerate in the sequence recorded in the area by Carter et al. (1961), and by syntaxial overgrowths on rounded detrital zircon grains.

Age and correlations

Carter et al. (1961) considered the Yaringa Metamorphics to be older than other Proterozoic rocks in the area because: they contain abundant migmatite and schist; they exhibit northeast and southeast trends, which are more common than the typical northerly trends in the rest of the region; and they may have been a source of detritus for sediments to the east. However, the unit resembles parts of the 'May Downs Gneiss Member', at the base of the Mount Guide Quartzite, and may be of similar age. Alternatively, it may be a westward shelf facies of acid volcanic/feldspathic quartzite formations - the Leichhardt Metamorphics and the Argylla Formation - to the east.

The quartz-feldspar porphyry in the Yaringa Metamorphics is considered to be probably coeval with the metamorphics, but it may be equivalent to a younger unit in the area, the 'Carters Bore Rhyolite', which underlies the Mingera Beds and is possibly comagmatic with the Sybella Granite.

'HASLINGDEN GROUP'

The 'Haslingden Group' is a conformable sequence of metasediments and metavolcanics forming the lower part of the western succession; it unconformably overlies the Kalkadoon-Leichhardt basement block (Derrick et al., 1974), and is overlain unconformably by the Mount Isa Group east of the Mount Isa Fault and the Mount Isa Group equivalents - the Mingera Beds and Paradise Creek Formation - west of the Mount Isa Fault.

The 'Haslingden Group' consists of the basal Mount Guide Quartzite, overlain by the Eastern Creek Volcanics, which in turn is overlain by the Myally Beds. (The Myally

Beds are to be redefined as the Myally Subgroup for the formal defination of the 'Haslingden Group' (Derrick, Wilson, & Hill, in prep.).) West of the Mount Isa Fault the 'Haslingden Group' consists of the Mount Guide Quartzite, the Eastern Creek Volcanics, the Judenan Beds (geological mapping in the Kennedy Gap 1:100 000 Sheet area - to the north of the Mount Isa Sheet area - is expected to allow redefination of the Judenan Beds to formation or subgroup status), and possibly 'Carters Bore Rhyolite'. The 'Carters Bore Rhyolite' overlies the Judenan Beds, possibly slightly unconformably.

Mount Guide Quartzite

Introduction

The Mount Guide Quartzite, formally defined by Carter et al. (1961), is the basal unit in the western succession of the Mount Isa Geosyncline. It crops out in the southeast of the Sheet area east of the Mount Isa/Mount Novit Fault System, and as an elongate meridional fold belt about 7 km west of Mount Isa. This fold belt was mapped by Hall & Carter (in Blanchard & Hall, 1942) as unnamed quartzite and quartzite schist. Joplin (1955) considered these rocks to be part of an 'older metamorphic complex', similar in age to the rocks now mapped as Yaringa Metamorphics. The southern part of this fold belt was fairly accurately delineated, although not described, by Brooks & Shipway (1960) in their mapping of the 'Mica Creek Pegmatite'; however it was included as part of the Sybella Granite in the maps of Carter et al. (1961). Wilson (1972) mapped part of this belt in detail and divided it into May Downs Gneiss and Mount Guide Quartzite. As a result of our mapping we consider that the quartzite and gneiss are conformable, and the May Downs Gneiss is mapped as the basal member of the Mount Guide Quartzite. The 'May Downs Gneiss Member' is present only west of the Mount Isa Fault. Total area of outcrop of the Mount Guide Quartzite is about 80 km^2.

Stratigraphic relations

In the Sheet area east of the Mount Isa Fault, the base of the Mount Guide Quartzite is not exposed, but the formation is known to unconformably overlie the Leichhardt Metamorphics, Kalkadoon Granite, and Argylla Formation in the Mary Kathleen Sheet area to the east (Derrick et al., 1974). The formation is conformably overlain by the Eastern Creek Volcanics and is intruded by north-trending dolerite dykes.

West of the Mount Isa Fault, the base of the unit is also not exposed. The 'May Downs Gneiss Member', in the lower

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part of the formation, has been deformed into a refolded anticline, and is conformably overlain by quartzite correlated with the upper part of the Mount Guide Quartzite to the east. It is intruded by granite, quartz veins, and tourmaline pegmatite of the Sybella Granite complex.

Lithology and field occurrence

The formation is divided into two units in the southeast corner of the Mount Isa Sheet area: Ehg_1 - friable fine to medium sandstone with heavy mineral banding, and greywacke and siltstone - and the overlying Ehg_2 - micaceous and feldspathic quartzites, grey to fawn silicified fine-grained sandstone, and minor silicified siltstone. These rocks dip mainly west and northwest, and display low greenschist facies metamorphism. They are exposed in fault-bounded blocks, and are extensively silicified adjacent to faults. The thickness of the lower unit has not been estimated in this Sheet area as the base is not exposed, but to the east it has a thickness of about 1800 m; the upper unit is estimated to be at least 500 m thick.

The main rock types west of Mount Isa are gneiss, quartzite, feldspathic quartzite, and micaceous quartzite - all interbedded with sparse gneiss layers. These rocks are intensely weathered. The 'May Downs Gneiss Member', at the base of the formation, consists of banded feldspathic quartz gneiss with some potash feldspar porphyroblasts and biotite clots, muscovite and muscovite-biotite schist, sillimanite-muscovite schist, and minor fine to medium quartzite. Original bedding is outlined by magnetite-rich bands (Fig. 7). The member is thought to be the metamorphosed equivalent of bedded arkosic sands present near the base of the Mount Guide Quartzite in the Mary Kathleen Sheet area to the east. The metamorphism is related to the intrusion of the Sybella Granite, and has reached the low to medium stages of Winkler (1970). The member is tightly folded and displays a moderately to steeply dipping (35-70°) foliation and shallow plunging (15°-35°) minor folds.

The proposed type section for the 'May Downs Gneiss Member' extends 2 km in a northeasterly direction from a point (20°42'30"S, 139°23'35"E) 10 km WNW of Mount Isa Post Office.

Petrography

Estimated modal analyses of two rocks are given in Table 4. One of these rocks is a poorly sorted micaceous, feldspathic quartzite (3630) which is representative of Ehg_1

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in the southeast corner of the Sheet area. It is bimodal, and consists of feldspar grains (average grain diameter 0.6 mm) in a finer-grained matrix (average grain diameter 0.1 mm) of quartz and muscovite. Quartz grains are strained and the mica gives the rock a weak lepidoblastic texture.

The other rock is a white micaceous quartzite (5235) from Ehg_2 east of the Mount Isa Fault. It is classified as a coarse-grained recrystallized sublabile arenite.

Estimated modal analyses of samples from the 'May Down Gneiss Member' are presented in Table 5. In these rocks, quartz and microcline grains up to 1mm across (generally 0.5 mm) form a granoblastic texture, together with varying amounts of plagioclase, actinolite, muscovite, biotite, sillimanite, and opaques. In some rocks (e.g., 3586) the quartz is extremely strained and the feldspars are partly altered to muscovite.

TABLE 4. ESTIMATED MODAL ANALYSES OF MOUNT GUIDE QUARTZITE

	3630	R5253
Quartz	85	75
Plagioclase	3	
Microcline		7
Muscovite	10	1
Sericite		15
Chlorite		1
Epidote	tr	
Zircon		tr
Sphene?		tr
Opaques	2	1
Member	Ehg_1	Ehg_2

Discussion and conclusion

Polymictic conglomerate, arkose, and greywacke in the lower unit of the Mount Guide Quartzite in the Mary Kathleen Sheet area indicate rapid deposition of sediment

TABLE 5. ESTIMATED MODAL ANALYSES OF 'MAY DOWNS GNEISS MEMBER', MOUNT GUIDE QUARTZITE

	R5226*	R5241*	R5242*	R5203	R5240	R5250	3586	3587	1473	1474
Quartz	32	20	30	10	65	30	50	30	48	54
Plagioclase	10			17	10	20	25	24	15	15
composition	An_{30}			An_{45}		An_{40}				
Microcline	55	50	45	45		40		25	20	15
Muscovite	1		10	2		2	4		2	
Biotite	2			15		3	3	10	7	10
Chlorite		30	15				4			
Epidote					15		4	1	1	tr
Sillimanite				5						
Actinolite					7					
Sphene					1	1		1	tr	1
Apatite				1	tr	1	1	1	1	
Zircon						tr	½	1	1	
Opaques	tr		tr	5	2	3	7	3	5	5
Other	Fluorite	Kaolin	Kaolin				Calcite Rutile	Myrmekite		
Agd	0.6	0.4	0.2	0.8	0.4	0.5	0.9	1.0	0.6	0.8
	Acid gneiss	Porphyroblastic acid gneiss	Acid gneiss	Sillimanite-biotite-andesine-microcline gneiss	Actinolite-plagioclase-epidote-quartz granofels	Plagioclase-quartz-microcline granofels	Plagioclase-quartz granofels	Plagioclase-microcline-quartz granofels	Plagioclase-microcline-quartz granofels	Plagioclase-microcline-quartz granofels

*Samples from isolated outcrops north of the main outcrop

Fig. 7. Original bedding and later quartz-feldspar veins in the 'May Downs Gneiss Member' 8 km west of Mount Isa.

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adjacent to an acid volcanic or plutonic region of high relief. The upper unit of more quartz-rich well sorted sands indicate a more cratonic source area and a well washed site of deposition. The feldspathic quartzite were probably deposited as thick sheets of sand thinning westwards from the Kalkadoon-Leichhardt block to the Big Toby-Yaringa block.

Isolated patches of acid gneiss north and south of the main outcrop of 'May Downs Gneiss Member' may be sheared granite, granitized feldspathic sediments, or recrystallized acid volcanics. Their composition and texture favour an acid volcanic origin, but they cannot be correlated with other acid volcanic units in the area, such as the Argylla Formation underlying the Mount Guide Quartzite to the east (Derrick et al., 1974) or the 'Carters Bore Rhyolite' overlying the Judenan Beds.

Eastern Creek Volcanics

Introduction

The Eastern Creek Volcanics consist of basic volcanic rocks interbedded with sediments. The formation was formally defined by Carter et al. (1961), who also reviewed the previous literature on the formation. Robinson (1968) subdivided the Eastern Creek Volcanics east of the Mount Isa Fault into four units, but as his two lower units cannot be readily differentiated from each other we have combined them as the 'Cromwell Metabasalt Member'. Robinson's (op. cit.) upper two members are now named the 'Lena Quartzite Member' and the 'Pickwick Metabasalt Member'. Wilson (1972) divided the Eastern Creek Volcanics west of the Mount Isa Fault into two metabasalt units separated by a predominantly sedimentary unit consisting of pelitic schist; these units cannot be reliably correlated with the members defined east of the Mount Isa Fault.

Exposure

The volcanics crop out along the eastern boundary of the Sheet area in several fault-bounded blocks; in a belt between the Sybella Granite or Mount Guide Quartzite and the Judenan Beds 5 km west of the Mount Isa Fault; and in thin north-northwesterly trending belts within and along the western margin of the Sybella Granite. Poorly exposed metamorphosed basic volcanics and dolerite which possibly belong to the Eastern Creek Volcanics are exposed 2 km southwest of Carters Bore. A thin wedge of volcanics along the eastern side of the Mount Isa Fault, and fault wedges of chloritic schist surrounded by the Judenan Beds west of the Mount Isa Fault are also considered to belong to the Eastern Creek Volcanics. The total area of outcrop of Eastern Creek Volcanics in the Mount Isa Sheet area is 150km^2.

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The basalt members form low gently undulating hills and plains covered with a thin veneer of red-brown soil; sandstone and quartzite interbeds form low ridges; the 'Lena Quartzite Member' forms rounded hills in the southeast and northeast of the Sheet area.

Stratigraphic relations

East of the Mount Isa Fault the Eastern Creek Volcanics conformably overlie the Mount Guide Quartzite. The 'Cromwell Metabasalt Member' (Ꝑhc), at the base, is conformably overlain by the'Lena Quartzite Member' (Ꝑhl), which in turn is conformably overlain by the'Pickwick Metabasalt Member' (Ꝑhp). The formation is overlain by the Myally Beds with apparent conformity.

West of the Mount Isa Fault the Eastern Creek Volcanics conformably overlie the Mount Guide Quartzite and are intruded by the Sybella Granite. Wilson (1972) recognized three units within the volcanics immediately west of Mount Isa, and correlated the sequence with the lowest member east of the Mount Isa Fault. The formation is overlain with apparent conformity by the Judenan Beds, although the contact is usually faulted.

Lithology and field occurrence

Basalt flows with well preserved amygdaloidal tops and some flow-top breccias predominate in the 'Cromwell Metabasalt Member'. Intercalations of fine to medium quartzite, medium-grained ferruginous sandstone, and shale occur with increasing frequency towards the top of the member. In the southeast, the flows are rarely more than 20 m thick and the intercalations are fairly continuous. In the northeast the intercalations are lenticular, and comprise calcareous shale up to 20 m thick, epidote quartzite, and cross-bedded white fine to medium quartzite.

The 'Lena Quartzite Member' is a white to buff coarse-grained arkosic quartzite containing rare pebbles and some cross-beds. Fine to medium cross-bedded quartzite and laminated ripple-marked orange to brown fine-grained ferruginous sandstone are present near the top of the unit. Silicification and brecciation are common adjacent to faults.

The 'Pickwick Metabasalt Member' is a sequence of intercalated sediments and basalt lavas. In the south the individual lavas are 10 to 20 m thick; their tops are brecciated, and contain vesicles, and amygdales of quartz, calcite, and chlorite. Lavas with quartz amygdales predominate near the top of the unit.

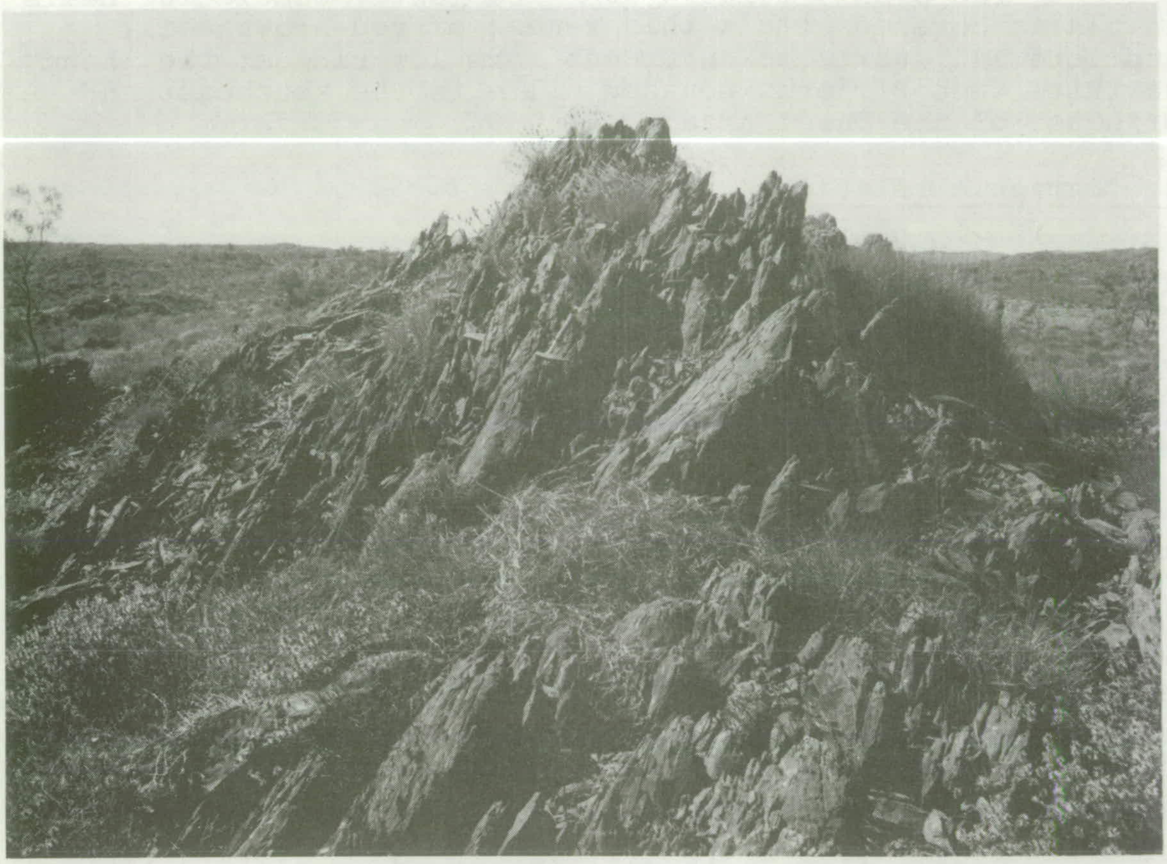

Fig. 8. Schistose amphibolite (metabasalt) from the Eastern Creek Volcanics 8 km west of Mount Isa.
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The thin wedge of Eastern Creek Volcanics along the eastern side of the Mount Isa Fault consists of biotite-chlorite schist, in which, in the north, some amygdales have been recognized. Fault wedges of similar schist, also mapped as Eastern Creek Volcanics, are surrounded by the Judenan Beds west of the Mount Isa Fault.

The Eastern Creek Volcanics west of the Mount Isa Fault are schistose (Fig. 8), and primary igneous and sedimentary structures are not as well preserved as in the east. The lowest and most western unit consists of strongly foliated amphibolite containing deformed amygdales and vesicles together with thin lenses of quartzite. In places the amphibolite has been retrogressively metamorphosed to chlorite schist. The middle pelitic unit consists of quartz-muscovite schist, cordierite schist, and minor amphibolite, chlorite schist, and quartzite, and the top unit is similar to the lowest unit.

The Eastern Creek Volcanics west of the Mount Isa Fault have been intruded by dolerite, granite, and pegmatite and are extensively metamorphosed. Quartz-epidote veins are commonly developed adjacent to dolerite, and tourmaline crystals are common in the volcanics and sediments adjacent to granite and pegmatite veins. Calcite-actinolite veins, some with small amounts of copper, are present in some fault zones cutting metabasalt. The Sybella Granite intrudes the volcanics in this belt, and has been extensively hybridized near some contacts; hybrid diorite rocks are well developed east of Gidya Bore.

Petrography

Estimated modal analyses of specimens from the Eastern Creek Volcanics are listed in three groups, metabasalts (Table 6), amygdaloidal metabasalts (Table 7), and metasediments (Table 8).

Metabasalts of Ehc show low greenschist facies metamorphism; relict quartz-filled amygdales with some chlorite-calcite rims and relict plagioclase phenocrysts are set in a fine-grained groundmass of epidote, albite, and chlorite, with minor quartz, biotite, and opaques, and accessory apatite, calcite, and sphene.

Metabasalts of Ehp also fall in the low greenschist facies. The groundmass consists of calcite, albite, chlorite, and minor opaques, apatite, and sphene. Acicular plagioclase crystals are now mainly pseudomorphed by granular albite.

TABLE 6. ESTIMATED MODAL ANALYSES OF METABASALTS FROM THE EASTERN CREEK VOLCANICS

	R5224	R5230	R5235	R5249	R5254	3503	3511	3524	3533	1469
Plagioclase	60	45	60	30	40	35	35		30	25
composition	An_{35}	An_{35}	An_{30}	An_{10}						
Tremolite/actinolite	26		30							
Hornblende		47			48	50	60			50
Biotite			3							
Chlorite	1	tr	tr	39	5			70	65	
Epidote						tr				
Calcite				25						
Quartz		5				10	1	25		10
Sphene	2		2	2		1	1			5
Opaques	10	2	5	3	7	4	3	5	5	10
Apatite	1	1		1	tr					
Agd. (mm)	0.3	0.5	0.8	0.4	0.2	0.2	0.4	0.6	0.6	0.2

TABLE 7. ESTIMATED MODAL ANALYSES OF AMYGDALOIDAL METABASALTS FROM THE EASTERN CREEK VOLCANICS

	R5240	R5239	R5212	R5252	3504	3505	3528	3537	1470	1471	3585
Plagioclase	8	20	25	31			20	20	30	45	40
composition	An_{10}	An_{10}		An_{50}							
Tremolite/actinolite			66				10				
Hornblende				60	60	10			45	15	40
Clinopyroxene									10	20	
Biotite		8						30			
Chlorite	50	37		1				tr			
Epidote	34		2		tr	45	40	2			
Calcite	2		1		3	4	10	5			
Quartz	1	28	3	5	32	40	15	40	10	10	10
Sphene	2	4	1	1	3						
Opaques	2	2	2	2	2	1	5	3	5	7	10
Apatite	1	1									
Zircon			tr	tr							
Agd. (mm)	0.1	0.01	0.1	0.08	0.1-.5	0.2	0.3	0.08	0.3	0.5	0.5
Amygdales Volume %	1	30	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Size (mm)	n.d.	n.d.	n.d.	n.d.	2-6	10	n.d.	6	n.d.	n.d.	n.d.

n.d. = not determined.

TABLE 8. ESTIMATED MODAL ANALYSES OF METASEDIMENTS FROM THE EASTERN CREEK VOLCANICS

	R5259	R5195	3506	3507	3509	3512	3520	3521	3523	3527	3530	3534	3552	1466	1467	1468
Quartz	82	40	52	50	10	85	15	38	20	60		47	77	20	15	85
Plagioclase					30	7		35	45	20				37	10	
Microcline					10									15	37	10
Muscovite	3			25		3	5				10	40	15			3
Phlogopite	15								15			5				
Biotite		5	tr.			2							2			1
Chloritoid								2								
Chlorite		tr.		23		tr.	5	3	2	2	88	2	5			
Diopside					25										10	
Hornblende					15									15	10	
Cordierite		20					73	15	15	10						
Anthophyllite		33														
Epidote			45		1									3	10	
Apatite	tr.						1				tr.	1				
Spinel	tr.															
Tourmaline		tr.		1				1			tr.	2				
Sphene					3	1	½							5	3	
Zircon			2	1	1	1	½	1	1		tr.	1	1			
Rutile											2					
Opaques		2	1		5	1		5	2	8		2		5		1
Agd	0.4	0.4	0.2	1.0	0.2	4	4	0.6	0.3	0.3	0.4	0.4	0.4	0.5	0.4	2
	Phlogopite quartzite	Porphyritic cordierite-anthophyllite schist	Epidote quartzite	Chlorite-muscovite-quartz schist	Hornblende-diopside-plagioclase granofels	Quartzite	Chlorite-quartz-cordierite rock	Cordierite-quartz-plagioclase granofels	Phlogopite-cordierite-quartz-plagioclase rock	Cordierite-plagioclase-quartz granofels	Muscovite-chlorite schist	Muscovite-quartz schist	Muscovite-quartz schist	Hornblende-microcline-qtz-plag. granofels	Hornblende-qtz-microcline granofels	Feldspathic quartzite

Metabasalts from west of the Mount Isa Fault are amygdaloidal and slightly porphyroblastic. They consist of plagioclase, actinolite, and hornblende, and, in some, biotite and epidote. Metabasalt from the northern part of the Sheet area has more abundant plagioclase.

A variety of rocks form sedimentary intercalations west of the Mount Isa Fault. Cordierite schsist are common; the cordierite occurs as sieve-textured and xenoblastic porphygoblasts up to 10 mm in diameter set in a fine-grained groundmass of quartz, anthophyllite, biotite, and minor opaques, chlorite, and tourmaline. Other rock types include forstenite marble Wilson (1972), and quartzite consisting predominantly of a granoblastic quartz mosaic with minor muscovite, phlogopite, and plagioclase, and accessory apatite and spinel.

Discussion and conclusions

The Eastern Creek Volcanics represent the first major volcanic episode during the deposition of the Western succession. In the lower part of the lowest member (Ehc) sedimentary intercalations are rare but increase towards the top. According to Robinson (1968) this indicates that, initially, numerous basalt flows were extruded in a basin of low relief. As the basin deepened, erosion became more pronounced, and an increasing proportion of sediments was deposited as interbeds; eventually the underlying Mount Guide Quartzite was exposed at the basin margins and began to provide detritus for the interbeds. The 'Lena Quartzite Member' (Ehl) represents a prolonged period of deposition of quartzose sediments, and a break in volcanic activity; the top member (Ehp) represents the return of volcanicity . The extensive basic dyke systems in the underlying formations and lower members of the Eastern Creek Volcanics are considered to be the feeders for the eruptions.

Evidence for a terrestrial origin includes the extensive sheet-like character of the lava flows, the uniform amygdaloidal layers and flow-top breccias on the flows, the absence of any pillow structures, and the relative paucity of sediments. Robinson (1968) reported that the composition of the Eastern Creek Volcanics indicates a spilite-keratophyre association of orogenic regions, but that their structure is more consistent with that of flood basalts of non-orogenic continental regions. The geochemical properties of the basalts closely resemble those of continental flood tholeiites (Glikson, pers. comm., 1975).

Judenan Beds

Introduction

The Judenan Beds were defined by Carter et al. (1961). Subsequent work by company geologists has established various subdivisions of the unit (Hruska, 1970, 1971), but the only published maps which show some of these subdivisions are those of Brooks & Shipway (1960) and Wilson (1972). Wilson mapped the Judenan Beds in three fault blocks near Mount Isa, in each of which there is a different metamorphic grade. The dominant rock types are quartzite and quartz-muscovite schist, but chlorite schist, actinolite (tremolite) schist, metasiltstone, carbonaceous quartz-muscovite schist, and phyllite also occur. In our mapping three subdivisions have been made, but their stratigraphic relations to one another have not been established*. The subdivisions are -

- Bhj_3: metabasalt, amphibolite, and chlorite and biotite schist
- Bhj_2: metasiltstone, and pelitic and psammitic schist
- Bhj_1: quartzite, feldspathic quartzite, and rare conglomerate.

Exposure

The Judenan Beds are restricted (by definition) to areas west of the Mount Isa Fault. They crop out in a belt, 2 km wide, immediately west of the fault, and in another belt trending north-northwest across the middle of the Sheet area. The total area of outcrop is 130 km^2, of which about 88 km^2 is quartzite (Bhj_1), 30 km^2 is metasiltstone and psammitic schist (Bhj_2), and 12 km^2 is basic schist (Bhj_3).

The quartzite (Bhj_1) forms steep, rugged, and in places flat-topped ridges (Fig. 5), and schist and metasiltstone (Bhj_2 and Bhj_3) form gently undulating terrain and valleys between quartzite ridges.

Stratigraphic relations

The Judenan Beds are conformable on the Eastern Creek Volcanics and are overlain probably unconformably by 'Carters Bore Rhyolite' and the Mingera Beds. This contrasts with the conclusions of Carter et al., (1961), who considered that the contact between the Judenan Beds and the overlying

* See Addendum at end of section

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Mingera Beds and Gunpowder Creek Formation (to the north of the Sheet area) was conformable. The Judenan Beds are most probably correlatives of the Myally Beds east of the Mount Isa Fault. The Judenan Beds are intruded by some phases of the Sybella Granite: the eastern belt of the Judenan Beds flanks the granite but is intruded only by the 'Mica Creek Pegmatite' (Pgs_4) and possibly by Sybella microgranite (Pgs_3); in the central-southern part of the Sheet area the Judenan Beds are intruded by coarse-grained foliated Sybella Granite (Pgs_2).

Lithology and field occurrence

The unit consists of psammitic and pelitic sediments and minor volcanics which have been regionally metamorphosed to the greenschist facies. Most of the unit in the Sheet area was also thermally metamorphosed to at least the amphibolite grade during the intrusion of the Sybella Granite. A later retrograde dynamic metamorphism accompanied meridional faulting. The complex metamorphic history has resulted in a wide variety of rock types which have been broadly grouped into three subdivisions as quartzite, metasiltstone, and basic rock.

The quartzite (Phj_1) is mostly white, pink, or cream, flaggy to blocky, fine to medium, and micaceous or feldspathic. Bedding planes are generally poorly preserved, but primary structures such as micro-crossbedding, torrential cross-bedding, and ripple marks have been recorded where the rocks are least deformed. Quartz veins are common, especially in fault zones, and quartz-tourmaline veins occur in some southern outcrops. Ferruginous quartzites occur adjacent to outcrops of basic rocks and in some weathered outcrops.

The metasiltstone (Phj_2) is cream to grey when fresh but readily weathers brown or buff. It is generally laminated and locally spotted. Cleavage is poorly developed. Secondary silicification has occurred near faults. Rare dolerite dykes and sills cut this unit. Also present in this unit is a pale grey to fawn, fine to medium-grained mica-quartz schist; sillimanite, cordierite, and chlorite are less common.

The basic rocks (Phj_3) are mostly greenish black or dark grey fine-grained schistose rocks containing abundant biotite or chlorite and, less commonly, amphibole. Amygdales suggest an intrusive origin for at least some of these rocks to the north of Spear Creek. Some laminated tremolitic grenofels with thin metasiltstone and fine-grained quartzite intercalations crop out 4 km northwest of Mount Isa and 2 km north of Carters Bore; the laminated rock may be altered tuff. Some local cross-cutting dark grey blocky dolerite intrusions are cut by quartz veins.

Petrography

Estimated modal compositions of 13 specimens from the Judenan Beds are given in Tables 9, 10, and 11.

The quartzite (Ehj_1) has a medium to coarse granuloglastic texture and contains varying amounts of quartz, plagioclase, muscovite, and rare microcline. Tourmaline crystals occur in quartzite adjacent to the Sybella Granite and pegmatite veins.

The metasiltstone (Ehj_2) has a granoblastic texture and consists of quartz, microcline, and plagioclase, with minor amounts of muscovite, biotite, phlogopite, chlorite, and opaques, and accessory apatite, sphene, and tourmaline. Metasiltstone rich in mica has a sublepidoblastic texture but is not schistose. The mica quartz schist is fine to medium, contains more than 20 percent micaceous minerals, and has a well developed lepidoblastic texture; accessories include opaques and tourmaline.

TABLE 9: ESTIMATED MODAL ANALYSES OF JUDENAN BEDS QUARTZITE (Ehj_1)

	R5245	R5193	3501	3563	3631
Quartz	85	60	85	95	87
Microcline					10
Plagioclase			11	2	1
Muscovite	15	20	3	3	1
Phlogopite		6			1
Chlorite		10		tr.	
Garnet		1			
Opaques	tr.	1			tr.
Apatite		tr.			
Sphene	tr.	tr.			
Tourmaline	tr.	2	1		
Zircon		tr.	tr.		tr.
Agd	0.6	0.2	0.3	0.6	1.2

R5245 Micaceous quartzite
R5193 Quartzose schist
3501 Feldspathic quartzite
3563 Quartzite
3631 Feldspathic quartzite

TABLE 10: ESTIMATED MODAL ANALYSES OF JUDENAN BEDS METASILTSTONE AND MICA-QUARTZ SCHIST (Ehj$_2$)

	R5213	R5255	3597	3636
Quartz	45	35	45	60
Microcline	40	40		
Plagioclase	5			
Muscovite	5	15	35	30
Phlogopite	1			
Biotite		5	15	
Chlorite	1		tr.	10
Opaques	2	1	4	tr
Apatite	tr.	1		
Sphene	1	3		
Tourmaline	tr.		1	tr
Agd	0.1	0.1	0.1	0.3

R5213 Metasiltstone
R5255 Metasiltstone
3597 Biotite-muscovite-quartz schist
3636 Chlorite-muscovite-quartz schist

TABLE 11: ESTIMATED MODAL ANALYSES OF JUDENAN BEDS BASIC ROCKS (Ehj$_3$)

	R5211	R5246	3562	3633
Quartz	2	10	5	10
Plagioclase			30	45
Phlogopite	1	5		
Chlorite		80		
Tremolite	97			
Hornblende			55	36
Opaques	tr	1	tr	2
Apatite	tr	1		1
Rutile		tr		1
Sphene		3	5	
Epidote			5	5
Agd	5	0.1	0.1	

R5211 Tremolite granofels
R5246 Quartz-chlorite schist (metabasic)
3562 Quartz-plagioclase amphibolite (metabaslt)
3633 Quartz-plagioclase amphibolite

Most basic rocks (Ehj_3) are schistose and consist almost entirely of chlorite and biotite, but plagioclase and hornblende are preserved in less metamorphosed rocks - amphibolites - and minor amounts of quartz, opaques, sphene, apatite, and rutile also occur. The tremolite rocks have a coarse-grained granuloblastic texture.

Discussion and conclusions

The stratigraphy of the Judenan Beds has not been fully worked out during the present work in the Mount Isa Sheet area, but future work on less deformed Judenan Beds in the Kennedy Gap Sheet area to the north should provide a better understanding of this unit*.

The boundary between the underlying Eastern Creek Volcanics and the Judenan Beds is not well defined, as the upper member of the Eastern Creek Volcanics contains 20 to 50 percent interbeds of quartzite (Robinson, 1968) similar to the quartzite in the Judenan Beds, and the Judenan Beds in the Mount Isa Sheet area contain numerous basic intercalations, especially in the south.

The upper boundary of the Judenan Beds is also poorly defined. In the west of the Sheet area the beds are overlain unconformably by the Mingera Beds, and in the east they are faulted against the Mount Isa Group along the Mount Isa Fault. Some workers believe that basal Mount Isa Group sediments may occur in a fault wedge on the west side of the Mount Isa Fault (van den Heuvel, 1969; C.J.L. Wilson, pers. comm.), but we have included these sediments within the Judenan Beds on our maps, and Wilson (1972) mapped them as the 'rocks between the Mount Isa Fault and Fault I'. Wilson describes the rocks here as consisting of a basal lenticular conglomerate overlain by foliated quartzite, quartz-muscovite schist, carbonaceous quartz-muscovite schist, and phyllite. The quartzite, unlike other quartzites from the Judenan Beds, contains some detrital tourmaline which may have been derived from tourmaline-rich phases of the Sybella Granite.

The Judenan Beds, at least in part, may be correlated with the Myally Beds. Both units are in similar stratigraphic positions, have generally similar lithologies (although the Judenan Beds tend to be slightly finer-grained, less well sorted and bedded, and more argillaceous), and are overlain by or contain near their tops rhyolite and rhyolitic tuff beds (Carter et al., 1961).

* See Addendum at end of section

The unit is structurally complex because of numerous strike faults and tight to isoclinal folds. Wilson (1972) suggests that part of the stratigraphic sequence has been faulted out, and that isoclinal folding and faulting may have repeated some sequences. Overturned beds are common, especially in the north of the Sheet area where beds facing east dip steeply to the west under Sybella microgranite. Overturned beds also occur in the isoclinally folded rocks mapped by Wilson (1972).

Shearing has destroyed many of the original textures in the rocks, and little can be deduced about their depositional environment. The quartzite represents poorly sorted fine to medium sand and silt which were probably deposited in moderately shallow water in a relatively low-energy environment. Within any local stratigraphic sequence there is a gradational decrease in grainsize upwards, which may indicate a transgression from the underlying mainly terrestrial Eastern Creek Volcanics to a marine or lacustrine environment.

Addendum (August 1975)

Since this Record was written, detailed geological reconnaissance mapping during 1974 in the Kennedy Gap 1:100 000 Sheet area, to the north of the Mount Isa Sheet area, has helped to elucidate the stratigraphy of the Judenan Beds. The Judenan Beds in the Kennedy Gap Sheet area conformably overlie the Eastern Creek Volcanics and are overlain unconformably by 'Carters Bore Rhyolite' and the Gunpowder Creek Formation (or equivalent Mingera Beds). The stratigraphic succession within the Judenan Beds is from a quartzite unit (Ꝑhj_1) at the base, through a metasiltstone unit (Ꝑhj_2), to a quartzite unit at the top; no metabasalt has been mapped within the Judenan Beds so it is concluded that the amphibolites mapped as Ꝑhj_3 in the Mount Isa Sheet area are fault wedges of Eastern Creek Volcanics.

Myally Beds

The Myally Beds were defined by Carter et al. (1961), who named them after Myally Creek, a tributary of the Leichhardt River north of the Sheet area. The Myally Beds crop out over about 1.5 km^2 15 km south of Mount Isa, and about 0.5 km^2 20 km north of Mount Isa on the eastern edge of the Sheet area.

Only the lower part of the Myally Beds (Ꝑhm_1) is present in the Mount Isa Sheet area; an overlying quartzite unit previously mapped as Myally Beds is correlated with the 'Quartzite Marker' described by Bennett (1965), and is included with the Mount Isa Group as a new formation, the 'Warrina Park Quartzite' (Derrick et al., 1974).

The Myally Beds form low scree-covered conical hills and ridges. They consist of well bedded medium to coarse light brown to grey feldspathic quartzite, some pebble beds with quartzite clasts, and shale-pellet conglomerate.

Derrick et al. (1974) considers that the Myally Beds are derived from quartzite, granite, and volcanic rocks of the basement to the east.

'Carters Bore Rhyolite'

Introduction

The 'Carters Bore Rhyolite' is a thin discontinuous unit of porphyritic rhyolite overlying the Judenan Beds. It is named after Carters Bore in the southern part of the Sheet area where the formation is best exposed.

Exposure

The formation is exposed discontinuously in a zone extending south-southeastwards from near the middle of the Sheet area. The outcrops cover about 2 km^2. Owing to shearing and deep weathering, the formation is more readily eroded than the underlying and overlying quartzites, and consequently is poorly exposed. Typical exposures consist of angular to slightly rounded blocks that are elongated parallel to the cleavage plane. Loose scree and a characteristic granule sand are common around outcrops.

Stratigraphic relations

The 'Carters Bore Rhyolite' probably unconformably overlies the Judenan Beds but this is not clear as it lies in a highly deformed zone associated with the May Downs Fault*. The formation is overlain unconformably by the Mingera Beds and is probably at least 200 m thick.

Lithology and field occurrence

The unit consists of porphyritic rhyolite which ranges in deformation from blocky porphyry to fissile muscovite schist with relict quartz phenocrysts. Phenocrysts become slightly smaller and the colour of the porphyry becomes very slightly paler towards the top. Elongate clasts of volcanic material have been recognized in rare bands near the base of the unit (Fig. 9).

* Mapping in the Kennedy Gap Sheet area, to the north, in 1974 indicates that the 'Carters Bore Rhyolite' unconformably overlies the Judenan Beds.

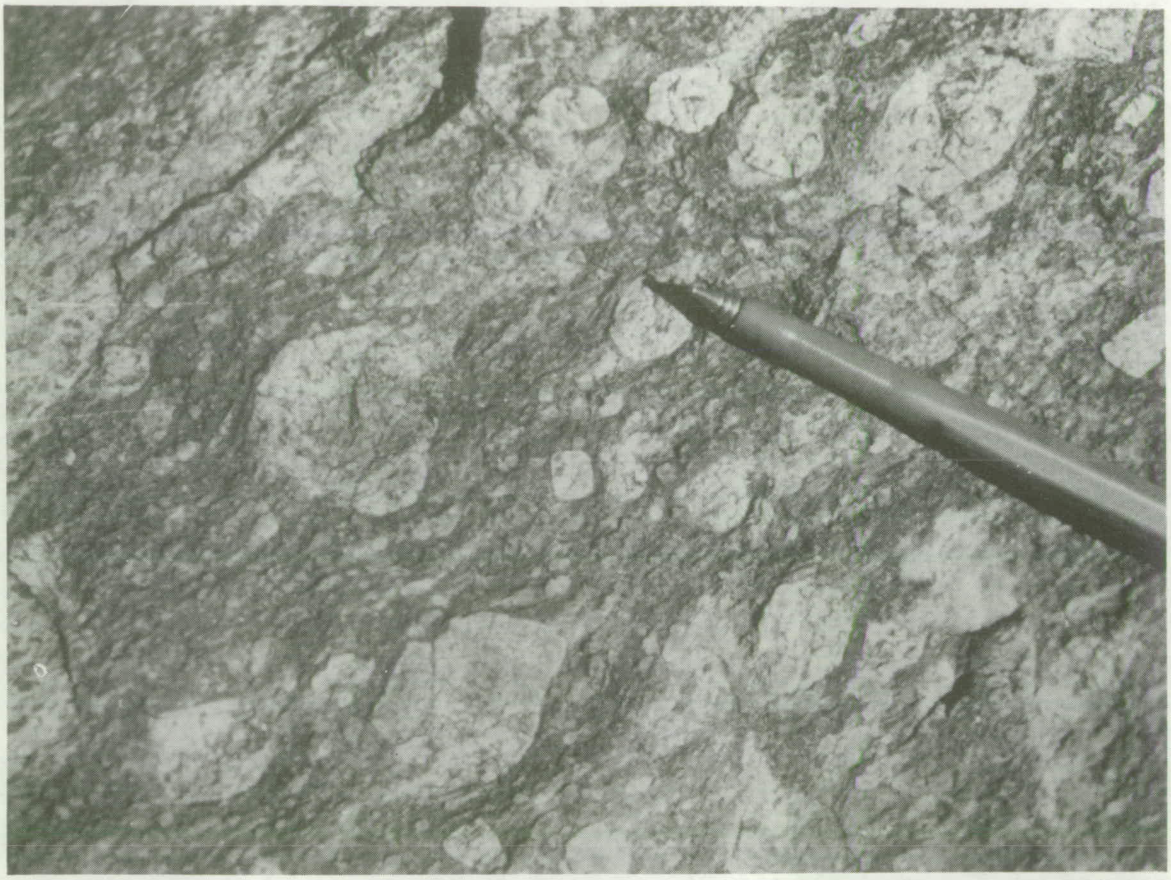

Fig. 9. Agglomeratic band near the base of 'Carters Bore Rhyolite' 6 km north-northwest of Carters Bore.
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Petrography

Undeformed rhyolite contains 5 to 20 percent phenocrysts of rounded quartz up to 3 mm across and euhedral potash feldspar up to 5 mm long in a granoblastic groundmass of quartz, potash feldspar (in the ratio of roughly 3:2), and minor amounts of muscovite, apatite, epidote, zircon, and opaques.

In deformed specimens, the potash feldspar phenocrysts are rounded, fractured, recrystallized at the margins, and partly sericitized. The groundmass is also sericitized. Where shearing is extreme the potash feldspar phenocrysts are completely replaced by sericite, and the quartz phenocrysts are elongated and completely recrystallized.

Discussion and comments

The porphyritic texture indicates a probable volcanic origin, which is supported by the basal agglomeratic bands. The formation may be comagmatic with the nearby Sybella Granite, which intrudes the underlying Judenan Beds and Eastern Creek Volcanics.

Mingera Beds

Introduction

The Mingera Beds were first mapped in the northwest of the Sheet area by Shepherd (1934), who described them as an unnamed sequence of quartzite, mica schist, and phyllite surrounding the May Downs Gold Field (Fig. 14). They were formally defined as the Mingera Beds by Carter et al. (1961), who excluded the mica schist, phyllite, and quartzite to the east of the fold field which they mapped as Judenan Beds. Carter et al. started that the Mingera Beds were conformable on the Judenan Beds, but our work has shown that the two units are unconformable, and that some areas previously mapped as Judenan Beds are in fact Mingera Beds. The Mingera Beds extend from the May Downs Gold Field to the southern edge of the Sheet area (Fig. 15) and are tightly folded.

Stratigraphic relations

The Mingera Beds unconformably overlie the Yaringa Metamorphics, the Sybella Granite, the Judenan Beds, and 'Carters Bore Rhyolite'. They are overlain conformably (Carter et al., 1961) by the Paradise Creek Formation, and unconformably by the Pilpah Sandstone.

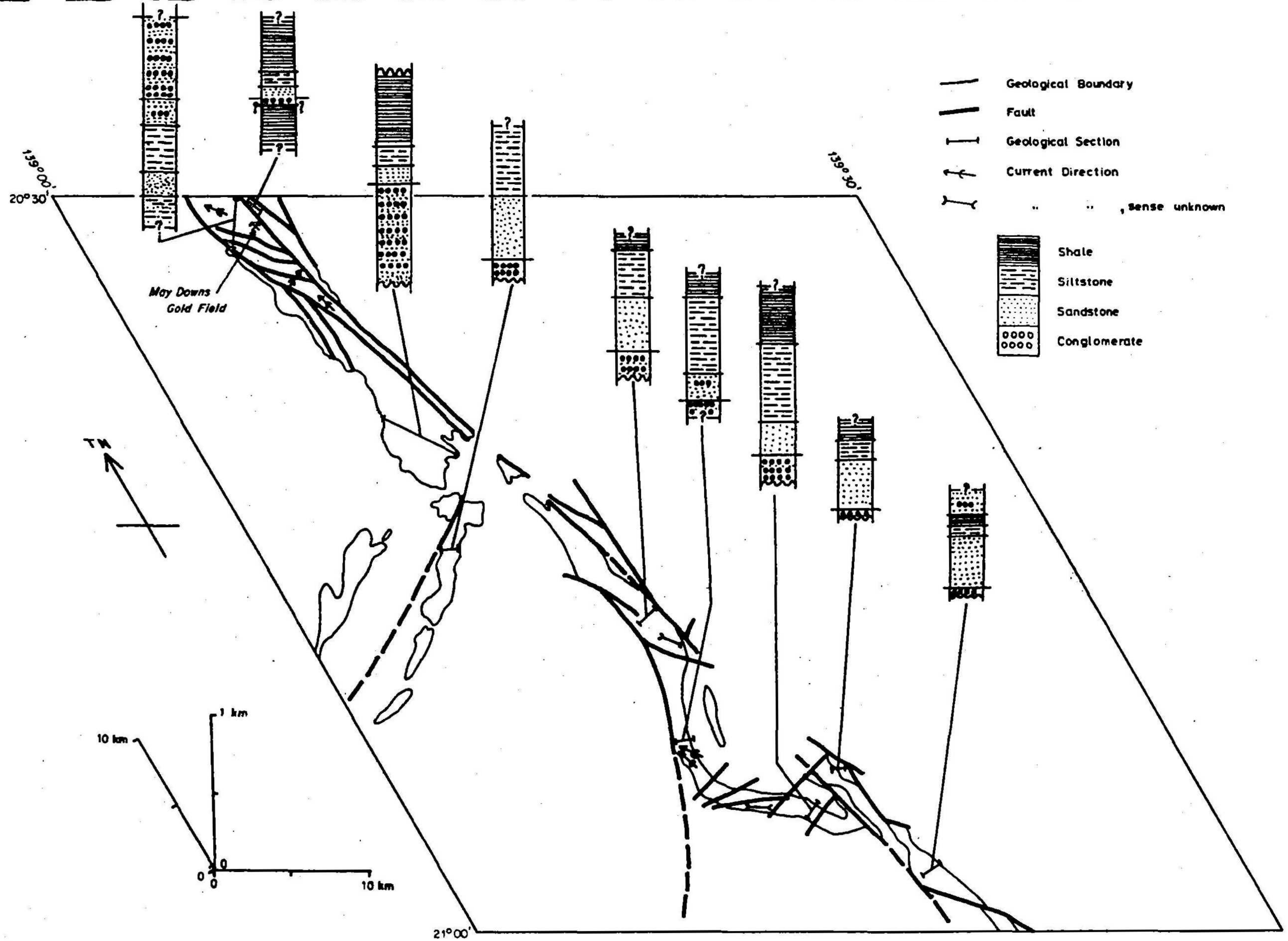

Fig. 14 Outcrops of Mingera Beds and local stratigraphic columns on an isometric projection of the Mount Isa 1:100 000 Sheet area

F 54/A1/38

<u>Lithology and field occurrence</u>

The Mingera Beds grade upwards from coarse-grained feldspathic sandstone and conglomerate into medium to fine sandstone, siltstone, and shale, and are divided into four conformable units labelled Ew_1, Ew_2, Ew_3 and Ew_4. Stratigraphic sections of the Mingera Beds are shown in Figure 14.

Trough cross-bedding and ripple marks throughout the Mingera Beds indicate that most current directions were from the southwest and east. Some south, southeast, and northwest current directions have also been recorded.

<u>Unit Ew_1</u> crops out over 20 km^2, and forms low rises and valleys between quartzite ridges. It is poorly exposed and consists of pink to white coarse feldspathic sandstone, pebble and cobble conglomerate (Fig. 10), feldspathic grit, coarse micaceous sandstone, and fine to medium feldspathic sandstone. Clasts in the conglomerate are mainly white medium-grained feldspathic quartzite, and less commonly vein quartz, quartz-tourmaline rock, mica schist, porphyritic rhyolite, granite, and fine-grained basic rock. The clasts are generally well rounded and range from 1 to 40 cm in diameter, though most are less than 10 cm; they are highly deformed near fault zones.

*In the north, a sequence of sandstone, quartzite, and siltstone at least 1000 m thick conformably underlies the conglomerate, and is faulted against the Judenan Beds. The sandstone is brown, ferruginous, and medium grained, and is interbedded with some clean-washed fine quartzite and siltstone. It also contains zones of sedimentary or replacement ironstone. The siltstone is ferruginous and contains interbeds of fine-grained ferruginous and white kaolinitic sandstone and quartzite. It is pebbly near the top, and grades into overlying conglomeratic sandstone. Convoluted bedding indicates some slumping. The siltstone is 600 to 1000m thick, and thins westwards.

<u>Unit Ew_2</u> crops out over 48 km^2 and forms narrow ridges. It consists of white, pink, or fawn laminated to thin-bedded fine to medium feldspathic sandstone, and intercalations of fine to coarse sandstone. Minor pebble beds are common near the base of this unit. Cross-bedding sets up to 0.3 m thick, graded bedding, and heavy mineral layering are common (Fig. 11); ripple marks are rare. The sandstone is kaolinitic and ferruginous in places owing to intense weathering.

* See addendum at end of section

Unit $Ꝑw_3$ forms low undulating hills and ridges, and crops out over 46 km^2. It consists of laminated, micaceous, and pyritic siltstones and minor calcareous siltstone. These rocks are mostly grey when fresh, but range from maroon to white, cream, buff, and purplish grey when weathered. Colour banding parallel to bedding is a common feature and red (maroon) and grey, and grey and white, banded rocks are abundant. Black silicified bedded ironstone of apparently replacement origin is found at several localities north of Gap Bore. Thin bedding, ripple marks, convoluted bedding (Fig. 12), and pyritic balls and casts are present at a few localities. Microfolds, quartz veins, and cleavage occur near fault zones. Both this unit and unit $Ꝑw_4$ are cut by gold-bearing quartz veins in the north of the Sheet area.

Unit $Ꝑw_4$ forms low flat-topped hills, rounded hills, and low undulating areas of poor exposure, and crops out over 25 km^2. The main rock types are black shale and laminated grey and maroon shale; less common are laminated silty and micaceous shales. Some beds are confoluted. Pyrite casts occur in the lower part of this unit, and some shales have holes where rounded mineral grains (pyrite?) have been weathered out. Weathered shales are pale grey, buff, or red, and commonly banded. The unit has been affected by complex faulting associated with drag-folding and the development of a prominent cleavage (Fig. 13). A small lens at the top of $Ꝑw_4$ south of Carters Bore consists of highly feldspathic ferruginous siltstone, sandstone, and minor conglomerate; it is poorly exposed in the core of a tight syncline.

Petrography

Estimated modal analyses of 27 specimens from the Mingera Beds are presented in Tables 12, 13, 14, and 15.

Conglomerate of $Ꝑw_1$ is polymicitic. The clasts lie in a matrix of coarse-grained feldspathic sandstone containing subrounded to elongate strained quartz grains with sutured boundaries. Feldspar grains are sericitized.

Sandstone of $Ꝑw_2$ shows poor to moderate sorting; mudballs were observed in one specimen and sparse quartzite fragments occur in several specimens. Quartz grains (80-95 percent) are subangular to rounded, slightly strained, but rarely fractured. Some contain strings of opaque minerals, and a rim of opaque dust marks the original detrital grain boundary if the sandstone is silicified. Feldspar forms xenomorphic grains which are extensively altered to sericite and caly minerals.

Siltstone of $Ꝑw_3$ is moderately well sorted. Quartz, the most abundant mineral, forms subangular, slightly strained grains with sutured boundaries. Sericite is commonly present as a weakly oriented fine-grained mesh; rare large muscovite flakes are also present. Plagioclase is present in some specimens as xenomorphic untwinned grains extensively altered to sericite. The opaque minerals include hematite and possibly amorphous carbon. Tourmaline grains, where present, have dark green centres and pale outer rims owing to post-depositional overgrowth.

The shale of Ew_4 is well sorted, banded or rhythmically graded, and composed mainly of quartz grains. Sericite forms some very fine-grained bands. Some flakes of muscovite are slightly oblique to the foliation. Minute crosscutting quartz veins are abundant.

Discussion and conclusions

The sequence from conglomerate at the base through sandstone and siltstone to shale at the top indicates that the Mingera Beds were probably deposited in a transgressive sedimentary environment. Petrographic features indicate that the sediments of the basal Mingera Beds were probably derived from the adjoining Sybella Granite complex; abundant quartzite and rare basic and acid volcanic clasts indicate derivation mainly from 'Haslingden Group' rocks.

Sedimentary features in the lower units indicate a relatively high-energy, possibly fluvial, depositional environment adjacent to a mountainous area of sedimentary and plutonic rocks.

To summarize, the Mingera Beds are inferred to have been formed in a rapidly subsiding trough on the eastern margin of a transgressive sea that lay to the west of mountainous terrain formed of Sybella Granite and the 'Haslingden Group'.

Addendum (August, 1975)

Since this Record was written, detailed geological reconnaissance mapping during 1974 in the Kennedy Gap 1:100 000 Sheet area, to the north of the Mount Isa Sheet area, has helped to elucidate the stratigraphic relations of the Mingera Beds. The Mingera Beds cropping out on the Mount Isa Sheet area can be traced along strike into the Gunpowder Creek Formation cropping out in the Kennedy Gap Sheet area; hence it is proposed to discontinue the use of the name of Mingera Beds in favour of Gunpowder Creek Formation. The Gunpowder Creek Formation unconformably overlies the 'Mammoth Formation' (named by R.J. Cavaney, pers comm., 1975) 'Carters Bore Rhyolite', Judenan Beds, and Eastern Creek Volcanics, and is conformably overlain by the Paradise Creek Formation.

The stratigraphic sequence of the Gunpowder Creek Formation, consisting of four conformable units ranging from conglomerate at the base to siltstone and shale at the top, is similar to that in the Mingera Beds and a direct correlation can be made. The lens of ferruginous sandstone and siltstone recorded below the conglomerate at the base of Ᵽw_1 in the north possibly belongs to the 'Mammoth Formation'.

The 'Mammoth Formation' is a variable sequence of fine-grained sandstone, siltstone, shale, and rare conglomerate underlying the Gunpowder Creek Formation, the base of which is defined by a distinctive well developed conglomerate unit (cf., Ᵽw_1). The 'Mammoth Formation', which is preserved in only a few sections, unconformably overlies 'Carters Bore Rhyolite'.

TABLE 12. ESTIMATED MODAL ANALYSES OF UNIT Ᵽw_1 OF THE MINGERA BEDS

	R5172	R5173
Clasts		
Quartzite	25	10
Siltstone	5	
Acid volcanics	2	5
Basic volcanics	1	
Grains		
Quartz	56	65
Feldspar	8	4
Opaques	1	1
Sphene	tr	tr
Tourmaline	tr	tr
Zircon	tr	tr
Matrix		
Sericite	2	10
Limonite	tr	
Agd (mm)	2	2

R5172 Silicified conglomerate

R5173 Conglomeratic sandstone

TABLE 13 ESTIMATED MODAL ANALYSES OF UNIT Bw_2 OF THE MINGERA BEDS

	3625	3539	3550	3551	3564	3569	R5198	R5216
Mud balls?								5
Quartz	94	95	81	85	92	90	68	94
K-feldspar		tr						
Altered feldspar	3		15	13	5	6		
Muscovite	2	4					10	
Opaques	1	tr	1	2	2	1	15	
Sericite								1
Tourmaline	tr		2			2	2	
Zircon	tr	1	1		1	1	2	
Sphene							1	
Agd (mm)	0.5	0.3	0.4	1.5	0.7	0.3	0.1	0.3

3625 White medium sandstone
3539 White fine to medium sandstone
3550 White medium feldspathic sandstone
3551 White coarse feldspathic sandstone
3564 White medium to coarse sandstone
3569 Medium quartzite
R5198 Fine-grained heavy-mineral-layered sandstone
R5216 Medium quartzose sandstone

TABLE 14. ESTIMATED MODAL ANALYSES OF UNIT Bw_3 OF THE MINGERA BEDS

	3538	3548	3549	3565	3568	3571	R5171	R5178	R5182	R5190	R5217	R5222
Quartz	75	45	25	70	20	90	30	5	24	40	70	40
Plagioclase		45					60?					
Epidote									tr			
Muscovite	17	3	5	3	5	5	6	10	17	5	5	
Chlorite										35		
Opaques	4	2	2	2	1	1	1	5	1	20	3	2
Sericite			62	10	73			80	56		10	58
Hematite (Limonite)				10							2	
Tourmaline	2	3	5	4	1	2	1		1		tr	
Zircon	2	2	1	1		2	tr					
Sphene							1		1			
Apatite							1					
Agd (mm)	0.1	0.15	0.05	0.05	0.01	0.1	0.04	0.005	0.005	0.02	0.02	0.003

3538 Pale grey laminated micaceous siltstone
3548 Pale greenish grey siltstone
3549 Purple to greenish grey spotted siltstone
3565 Striped red-brown (hematite-rich) and grey (hematite-poor) siltstone
3568 Grey siltstone
3571 Grey siltstone
R5171 Grey labile siltstone
R5178 Salmon pink silty shale
R5182 Micaceous fine siltstone
R5190 Carbonaceous? fine siltstone
R5217 Ferruginous fine siltstone
R5222 Pale grey shale

TABLE 15 ESTIMATED MODAL ANALYSES OF UNIT Pw$_4$ OF THE MINGERA BEDS

	3574	3575	R5192	R5218
Quartz	72	70	60	70
Muscovite		5	25	10
Sericite	20	20		
Opaques	7	2	13	20
Tourmaline	1	2	2	tr
Zircon		1	tr	
Agd (mm)	0.05	0.05	0.05	0.004

3574 Banded red and grey fine siltstone
3575 Banded grey siltstone/shale
R5192 Grey muscovite siltstone
R5218 Banded fine shale

Fig. 10. Underformed conglomerate in the basal unit (Ꝑw$_1$) of the Mingera Beds 2 km south of Golden Sunset mine. Most of the clasts are of quartzite
M/1250 24 G.M.D.

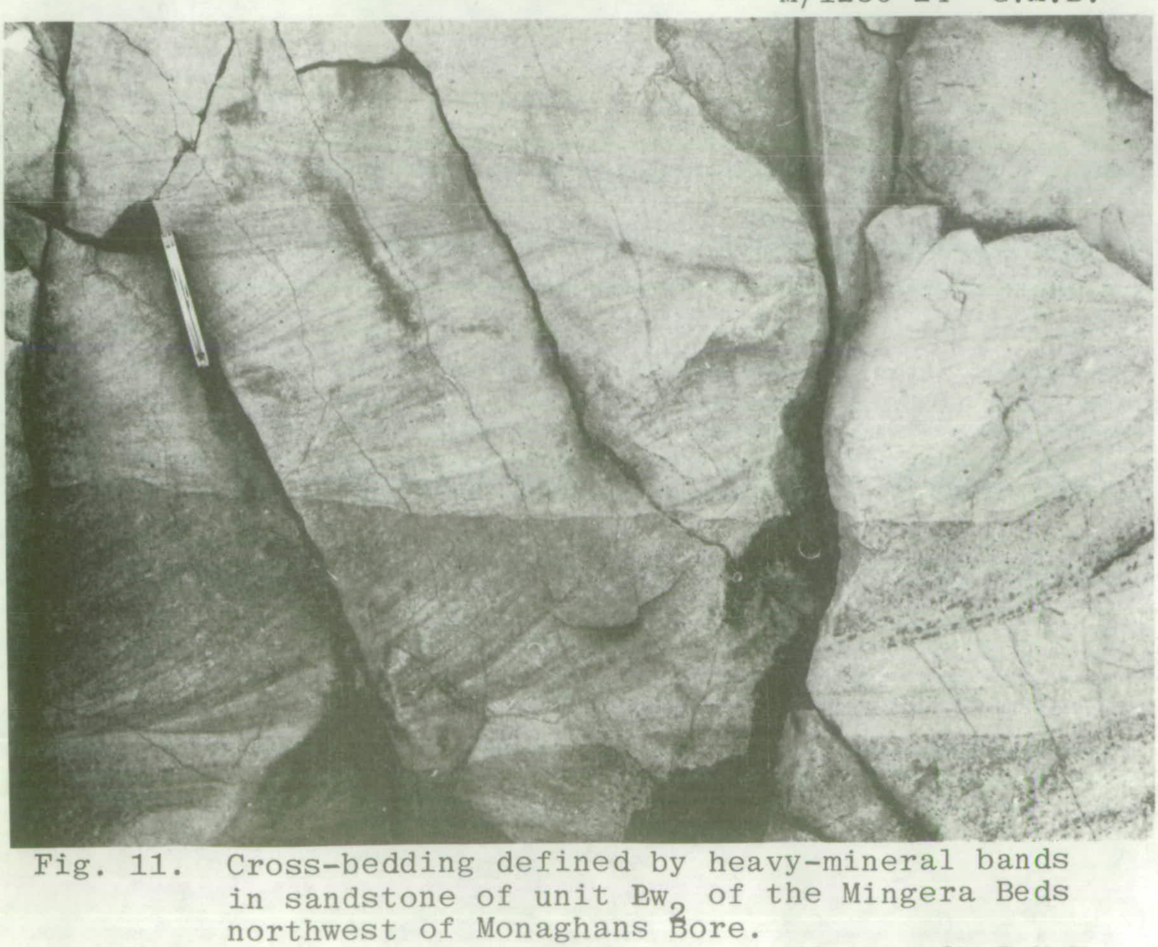

Fig. 11. Cross-bedding defined by heavy-mineral bands in sandstone of unit Ꝑw$_2$ of the Mingera Beds northwest of Monaghans Bore.
M/1337 8 R.M.H.

60

Fig. 12. Conroluted bedding in siltstone of unit Pw_3 of the Mingera Beds 4 km north of Gap Bore
GA 7603 I.H.W.

Fig. 13. Tight folds, probably drag-folds near a fault, in the red and pale grey banded shale (Pw_4) of the Mingera Beds 2 km north of Golden Sunset gold mine
GA 7607 I.H.W.

MOUNT ISA GROUP

Derivation of name

In 1923 the Mount Isa ore deposit was discovered and named. In the following year Saint-Smith (1924a) used the term 'Mount Isa Series' to refer to rocks cropping out west of Mount Isa, but did not describe these rocks. Shepherd (1932c) used the same term for a quartzite and shale sequence cropping out mainly to the east of Mount Isa, a sequence which David (1932) and AGGSNA (1936) called the Mount Isa Shales. AGGSNA (1937) applied the same term to sedimentary and volcanic rocks to the north, and to quartzitic and calcareous sediments near Cloncurry, to the east. Blanchard & Hall (1937) referred to the 'Mount Isa Shale series' as a 'thin evenly bedded shale between quartzites' (i.e. underlain by Myally Beds to the east and faulted against Judenan Beds to the west). Knight (1953) proposed restricting the usage of 'Mount Isa Shale Group' to shales and dolomitic quartzite west of the Leichhardt Fault*. A formal definition of the Mount Isa Shale was given by Carter et al. (1961), who mainly followed the usage of Shepherd (1932c, 1946, 1953) and Blanchard & Hall (1937), but also included a basal sequence about 100 m thick of quartzite and thin conglomerate (now named the 'Warrina Park Quartzite').

A subdivision of the Mount Isa Shale was proposed by Murray (1961) and Battey et al. (1961), and further subdivisions were made by Cordwell, Wilson, & Lord (1963). The unit was raised to group status by Bennett (1965), who proposed a subdivision into 7 formations. The basal quartzite and conglomerate called the Quartzite Marker, was not included in the Mount Isa Group but was placed at the top of the Myally Beds. However the oldest formation recognized by Bennett, the Moondarra Siltstone, is now known to be conformable on the Quartzite Marker, which in turn is unconformable on the Myally Beds (McKenna, 1963; Muceniekas, 1964). Hence Smith (1969, table II) suggested that the Quartzite Marker should be regarded as the base of the Mount Isa Group. We agree with this, and the Mount Isa Group as described here consists of the following formations described by Bennett (1965) together with the Quartzite Marker, for which we propose the name 'Warrina Park Quartzite'. The formations are listed below from top to bottom together with their maximum known thicknesses:

* The Leichhardt Fault referred to by Knight (1953) extended due north from its position shown on the accompanying 1:100 000 map beyond its northern Sheet area boundary parallel to and 2 km west of the eastern Sheet area boundary.

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Magazine Shale, 210 m
Kennedy Siltstone, 310 m
Spear Siltstone, 170 m
Urquhart Shale, 910 m
Native Bee Siltstone, 790 m
Breakaway Shale, 1030 m
Moondarra Siltstone, 1200 m+
'Warrina Park Quartzite', 300 m+

Considerable difficulty has been experienced in differentiating between Kennedy Siltstone and Spear Siltstone and between Urquhart Shale and Native Bee Siltstone in areas away from the type sections of the formations.

Stratigraphic relations

The Mount Isa Group is the topmost unit of the western succession of the Mount Isa Geosyncline and unconformably overlies the 'Haslingden Group'. The formations within the Group are conformable and have gradational contacts.

Distribution

The Mount Isa Group has a total outcrop area of about 360 km^2 (Carter et al., 1961), and crops out over about 150 km^2 in the Mount Isa Sheet area. It is exposed in a meridional belt near the eastern boundary of the Sheet area and extends north into the Kennedy Gap and Prospector Sheet areas, east into the Mary Kathleen Sheet area, and south into the Oban Sheet area.

Lithology

The Group consists of shale, siltstone, minor quartzite, possible tuff, and rare conglomerate. The shales range from dolomitic to siliceous, carbonaceous, and pyritic. Cleavage is poorly developed within the group, but a well developed fissility parallels the bedding planes. Adjacent to the major faults the shales and siltstones are phyllitic. A detailed account of the sedimentology of the upper formations in the group has been given by van den Heuvel (1969), and a detailed report on the geochemistry of the upper formations near Mount Isa Mine can be found in Smith & Walker (1971). Modal analyses of rocks within the group are given in Table 16.

Environment of deposition

The conglomerate lenses at the base of the group were described as fans by McKenna (1963), who also noted their proximity to the Mount Isa Fault. The conglomerate indicates a high-energy depositional environment, possibly due to active tectonism. A rapid gradation from sand upwards to silt and shale suggests that the Mount Isa Group sediments were deposited during a rapid transgression that may well have been tectonically controlled. Large-scale and small-scale slumping have been recognized in siliceous dolomitic shale near the top of the group (Carter et al., 1961), indicating some tectonic instability. Van den Heuvel (1972) suggested that the upper Mount Isa Group sediments were deposited in an intermontane, highly saline basin, and that volcanic ash was deposited intermittently as thin tuff beds.

Carter et al., (1961) reported that the proportion of sandstone to siltstone and shale in the group increases both north and south of Mount Isa, indicating possible shallowing of the sedimentary basin to the north and south. Carbonaceous shales are well developed in the southern part of the Mount Isa Sheet area and persist farther south. Syngenetic pyrite, and possibly also the sulphide ores at Mount Isa, indicate a reducing environment. The possibility of reef structures in the Urquhart Shale is discussed below.

'Warrina Park Quartzite'

The best exposures, including the type section, of this formation are in the Prospector Sheet area, to the north-east of the Mount Isa Sheet area. In the Mount Isa Sheet area the formation forms discontinuous outcrops covering a total area of less than 1 km^2. The main outcrop is a narrow belt 5 km long south of Native Bee Mine. The formation also crops out in two small faulted blocks east of this mine. The formation contains rock types similar to the Myally Beds and the two formations are difficult to distinguish where the unconformity is not noticeably angular; some rocks mapped as Myally Beds in the northeastern corner of the Sheet area may be 'Warrina Park Quartzite'.

Lithology and field occurrence

The characteristic rock type is buff to cream fine to medium-grained slightly micaceous quartzite containing lenses of poorly sorted conglomerate near the base. The quartzite grades upwards into alternating beds of ferruginous fine sandstone and grey siltstone. Cross-bedding, heavy-mineral banding, and pyrite casts have been recorded within the formation.

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Moondarra Siltstone

The formation is exposed near the eastern boundary of the Sheet area, in a belt 2 to 3 km wide trending north and covering 46 km^2. It forms low-lying flat to gently undulating plains and is generally poorly exposed except along watercourses. The type section is southeast of Lake Moondarra, in the Mary Kathleen Sheet area.

Lithology

The main rock type is grey laminated siltstone which in places grades into silty shale. Shale bands are common near the top of the formation, and beds rich in muscovite occur throughout. Bennett (1965) reports that the siltstone is dolomitic and that the formation contains minor beds of black dolomite. The weathered siltstone is buff to cream, or pink, purple, and red where ferruginized. Primary sedimentary structures include lamination, banding, rare ripple marks, and minor slumping. Pyrite is present in some siltstone. In deformed zones the siltstone is cleaved and, in places, phyllitic. Quartz veins, siliceous breccia, and calcite (dolomite?) veins have also been recorded within the formation.

Petrography

Three thin sections from the Moondarra Siltstone have been examined and the estimated modal analyses of these rocks are presented in Table 16. The rocks are generally well-sorted. Mica flakes are moderately well oriented parallel to bedding and some show micro-dislocations. Shale bands are rich in opaques, possibly carbonaceous material.

Breakaway Shale

This formation is exposed in a continuous northerly trending belt up to 1 km wide that extends from 5 km south of Mount Isa to the northern boundary of the Sheet area. It also crops out in a fault block northeast of Mount Isa and in elongated north-south fault blocks in the southern part of the Sheet area. The total outcrop area is roughly 31 km^2. The type section is from 1.5 to 0.8 km east of the Barkly Highway 5.5 km north of Mount Isa Post Office.

The formation is moderately well exposed and forms low rounded hills and strike ridges. Bennett (1965) reports that all exposed rocks are oxidized.

Lithology

The main rock types are laminated pale to dark grey shale, micaceous shale, and, especially near the base, grey siltstone. Some massive sequences of silty or micaceous shale are present but uncommon, and there is some rare chert and silty dolomite. Where highly weathered, the rocks are cream, white, pink, or purplish black. Laminae, bedding, and pyrite casts are abundant, and Bennett (1965) reports load casts and cross-bedding from the siltstone interbeds. Near major faults the rocks are tightly folded and cleaved; some are silicified and crosscut by quartz-hematite veins. Lineations are present at a few localities.

Petrography

Estimated modal analyses of two thin sections are presented in Table 16. In the shale, quartz grains are angular to subangular, mica flakes are ragged and poorly aligned, and the opaque material is granular to pulverescent; dolomite is intergranular. The rocks are generally moderately well sorted, although the mica flakes, which may be detrital, are larger than the granular minerals and give the appearance of poor sorting.

The dolomite consists of subhedral to anhedral dolomite crystals and minor very fine-grained opaques, ragged biotite flakes, and subrounded quartz grains.

Native Bee Siltstone

This formation is exposed in a nearly continuous belt up to 2 km wide near the eastern boundary of the Sheet area. In the far north and south the formation is repeated by faulting. It covers about 35 km^2, and is poorly exposed in a flat to gently undulating plain broken by low strike ridges formed of shale and chert, which are more resistant to erosion than the siltstone, the main rock type. The type section is from 1 km to 120 m east of the Barkly Highway 4.4 km north of Mount Isa Post Office. A slight unconformity has been recognized between the Native Bee Siltstone and the underlying Breakaway Shale in an area north of Mount Isa (van den Heuvel, 1969).

Lithology

The formation consists of pale to dark grey, cream, and fawn laminated siltstone and bedded dolomitic siltstone,

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and minor pale grey to black laminated silty shale, cream to buff micaceous fine-grained sandstone, pale grey impure limestone, black chert, jasper beds, and tuff containing up to 20 percent albite (Bennett, 1965). Chert and jasper are restricted to the lower part of the formation. Slump structures, graded bedding, cross-bedding, and pyrite casts have been recorded in some beds.

Petrography

Bennett (1965) notes that the siltstone is composed predominantly of dolomite, biotite, microcline, sericite and quartz, and that there is some local enrichment in carbonaceous material. An albitic siltstone is reported from this formation by van den Heuvel (1969), who distinguished a lower zone of chloritic siltstone with a low carbonate content from an upper zone of cross-bedded siltstone composed of carbonate, quartz, and potash feldspar. An estimated modal analysis of ferruginous chert from the base of the formation 4 km south of Mount Novit is given in Table 16.

Urquhart Shale

This formation was named by Murray (1961). It crops out in a north-trending belt 28 km long to 1.2 km wide which extends from 5 km south of Mount Isa to within 5 km of the northern boundary of the Sheet area. The formation covers 20 km^2, and is characterized by ferruginous outcrops forming strike ridges on slightly elevated undulating plains. In the type section, located just south of King Gully, on the northern outskirts of Mount Isa, the formation is about 910 m thick (Bennett 1965); however, it thins to the north and south (van den Heuvel, 1969). The Urquhart Shale is of particular importance as it contains the base metal deposits at Mount Isa and Hilton.

Lithology

The characteristic rock type exposed is banded ferruginous shale, which is the oxidized equivalent of well bedded unweathered pyritic shale at depth. Other rock types present are pale to dark grey dolomitic, volcanic, and graphitic shales, fine-grained bedded dolomite and dolomitic siltstone, and tuff which forms the 'Tuff Marker Beds' (Bennett, 1965) and locally grades into overlying sediments. Individual beds range in thickness from 0.05-2 mm in mineralized shale, 2-300 mm in unmineralized shale and most other rock types, and 5 mm to 2 m in tuff. Over 80 'Tuff Marker Beds' have been mapped, persisting along strike lengths for up to over 2 km. Cross-bedding, graded bedding, and scour-and-fill structures have been recognized in dolomitic siltstone and pyritic shale (Blanchard & Hall, 1942; Bennett, 1965).

Both silver-lead-zinc and copper orebodies are present in the Urquhart Shale. The silver-lead-zinc orebodies are conformable bands of galena and sphalerite interbedded with finely laminated siliceous and graphitic shale (Blanchard & Hall, 1942). Zonation of the sulphide beds from sphalerite at the margins to galena near the middle was noted by McDonald (1970). The copper orebodies, which are not stratabound, consist of chalcopyrite and minor pyrite, pyrrhotite, quartz, and carbonates; they are restricted to what is known as the 'silica-dolomite', highly deformed brecciated recrystallized dolomitic shale which occurs in zones transgressing bedding (Bennett, 1965). Pyritic shale, 0.3 to 20 m thick, alternating with pyrite-free shale is more abundant near the orebodies than elsewhere (Blanchard & Hall, 1937).

Petrography

Where unmineralized, the shale generally consists of quartz, dolomite, and muscovite, with minor potash feldspar, albite, and opaques, and accessory apatite. (see Table 16 and Van den Heuvel, 1969). The texture is very finely granular, with muscovite flakes aligned parallel to the bedding. The pyritic shale has a similar mineralogy and texture to the unmineralized shale, but in addition contains varying amounts of rounded pyrite grains 0.02 mm in diameter which are commonly encased in graphite (Grondijs & Schouten, 1937; Carter, 1953a; Love & Zimmerman, 1961). The 'Tuff Marker Beds' are finely granular rocks consisting of 70 to 80 percent potash feldspar, 15 to 20 percent dolomite, and up to 5 percent quartz (Bennett 1965); Van den Heuval expresses doubts they are of volcanic origin (Smith & Walker, 1971). The orebodies are discussed in the Economic Geology section of this Record.

The 'silica-dolomite', which contains the copper orebodies, is composed of an intimate mixture of four rock types (Bennett, 1965), which are listed below in order of decreasing degree of deformation.

(1) Medium to coarse crystalline dolomite

(2) Irregular brecciated dolomitic shale in a crystalline carbonate-quartz matrix

(3) Partly recrystallized shale: interbedded shale and fine to coarse dolomite commonly cut by carbonate and quartz veins

(4) Fractured and brecciated siliceous shale.

Discussion

The Urquhart Shale is characterized by an abundance of pyrite, and the presence of stratiform base metal orebodies and 'Tuff Marker Beds,' all of which tend to occur together and are not uniformly distributed throughout the formation. Unmineralized sediments in the Urquhart Shale are similar to those in other formations within the Mount Isa Group.

The fine lamination, fine-grained detritus, and absence of ripple marks throughout the formation indicate a low-energy depositional environment, probably below wave base and unaffected by currents. Laminated shale and dolomite indicate either a lacustrine or marine environment. Van den Heuvel (1972) concluded from a detailed study of the upper part of the Mount Isa Group that it was deposited in an intermontane basin.

The restriction of pyritic beds to areas enclosing the orebodies can be explained either as an effect of epigenetic mineralization and an associated pyrite halo, or as an effect of syngenetic mineralization, localized in depressions in the basin of deposition. The latter explanation is considered more likely, and has been widely supported since the mineragraphic study of Grondijs & Schouten (1937) showed that the fine grains of pyrite are spherical and are associated with graphite; an organic origin for this pyrite was proposed by Love & Zimmerman (1961).

The pyritic shale is inferred to have formed in a reducing environment, and may have formed at greater depths than the non-pyritic shale. The depth of formation is not known, but similar pyritic shales at the McArthur River deposit were laid down in water depths probably greater than 60 m. (Brown, in prep.). Depth variation may be due to penecontemporaneous faulting (Smith, 1969).

The origin of the 'silica dolomite' is uncertain. It formed later than the pyritic shale, blocks of which occur within it (Bennett, 1965). It transgresses bedding in the formation and is found in progressively higher stratigraphic levels from north to south. Three possible origins of this rock type are:

(a) it is a tectonic feature that preceded and facilitated the introduction of the copper mineralization (Blanchard & Hall, 1942),

(b) it represents sedimentary breccia or reef talus deposits which migrated southward with time (Fisher, 1960)

(c) it is a hydrothermal feature that accompanied the copper mineralization (Murray, 1961).

We favour the first alternative, although some remobilization the carbonate-rich 'silica dolomite' was probably partly remobilized during periods of tectonism after the mineralization took place.

Spear Siltstone

This formation forms discontinuous outcrops over an area of about 6 km^2 in a narrow north-trending belt extending from 5 km south-southwest of Mount Isa to 20 km north of Mount Isa. The formation is moderately well exposed on a low undulating plain from which rise some rounded strike ridges. The type section runs east-west a few hundred metres south of Spear Creek 5.5 km north-northwest of Mount Isa Post Office.

Lithology

As described by Knight (1953) this formation consists of 12 m of poorly exposed dolomitic siltstone succeeded by 8 m of shale (not exposed), 15 m of thin-bedded blue carbonate rock, 120 m of fawn to grey dolomitic siltstone with shale interbeds which are especially common near Mount Isa, and 15 m of very thin-bedded siliceous fine dolomite known locally as the 'A Marker Bed', which weathers white. 'Tuff Marker Beds' similar to those found in the Urquhart Shale, sedimentary breccia, and slump structures occur near the base of this formation, and cross-bedding is present in the upper part (Bennett, 1965). A bed 5 cm thick consisting mainly of albite is present in the 'A Marker Bed', and is exposed discontinuously over the full length of outcrop; it is known as the 'Albite Marker' and may be a tuff.

Petrology

The rocks in this formation have generally high carbonate contents and both dolomite and calcite have been identified (van den Heuvel, 1969). Quartz, albite, and potash feldspar are subordinate constituents, and chlorite, sericite, and opaques occur in minor amounts. The 'Tuff Marker Beds' are similar to those of the Urquhart Shale: the 'Albite Marker' consists of 70 percent albite and 30 percent dolomite. An estimated modal analysis of an interbedded dolomitic shale and siltstone is given in Table 16.

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Kennedy Siltstone

This formation is generally similar to the Spear Siltstone but tends to be thicker bedded. It crops out over a strike length of 25 km as low rounded ridges that cover about 8 km^2 in the Sheet area. The type section runs east-west to the north of King Gully about 4 km north-northwest of Mount Isa Post Office.

Lithology

As described by Knight (1953) this formation consists of 260 m of massive to very thick-bedded siltstone with variable amounts of dolomitic cement (the dolomite content is higher in the north), and rare thin-bedded laminated shale, overlain by 24 m of thin-bedded cross-bedded dolomite which contains the 'B Marker' (a discontinuous bed, 3 m thick), of cavernous-weathering dolomite), and 52 m of grey thick-bedded siltstone containing some dolomite.

In addition sericitic shale and feldspathic quartzite have been recorded by Bennett (1965), who also recognized sedimentary (slump) breccias at several localities and cross-bedding near the top of the formation.

Petrology

According to Bennett (1965) the carbonate contents of these rocks varies from 10 to 80 percent; quartz, potash feldspar and plagiocalse are the other main constituents, and minor muscovite, tourmaline, zircon, pyrite, rutile and apatite are also present. An estimated modal analysis of dolomitic siltstone is given in Table 16.

Magazine Shale

This formation is restrigted to a narrow north-trending outcrop 22 km over an area of 4 km^2, and forms rounded strike ridges. The type section is about 4 km north-northwest of Mount Isa Post Office, and runs east-west north of King Gully.

Lithology

Exposures consist of oxidized pale grey, pink, or reddish brown laminated sericitic shale. Bennett (1965) reports that the unoxidized equivalents in the subsurface are grey to black calcareous sericitic shale with some carbonaceous shale and pyrite cubes.

TABLE 16. ESTIMATED MODAL ANALYSES OF SEDIMENTS OF THE MOUNT ISA GROUP

	Moondarra Siltstone			Breakaway Shale		Native Bee Siltstone	Urquhart Shale	Spear Siltstone	Kennedy Siltstone
	R5237	R5238	R5247	R5236	R5256	R5257	R5214	R5209	R5210
Quartz	30	52	25	70	10	60	30	39	44
Dolomite				4	84		5	60	50
Microcline									
Muscovite	65	45	67	20		tr	55	tr	1
Biotite			2		5				3
Opaques	5	1	2	5	1	tr	10	1	2
Limonite			1			40			
Apatite		1	1	tr		tr			
Tourmaline		1	2	1			tr		
Zircon							tr		
Agd (mm)	0.005	0.01	0.01	0.002	0.02	0.1	0.002	0.002	0.002

5237 Micaceous fine siltstone with shale interbeds

5238 Micaceous fine siltstone

5247 Micaceous fine siltstone

5236 Weathered micaceous shale

5256 Silty dolomite

5257 Recrystallized banded ferruginous chert

5214 Dolomitized shale

5209 Dolomitic interbedded shale and siltstone

5210 Dolomitic poorly sorted siltstone

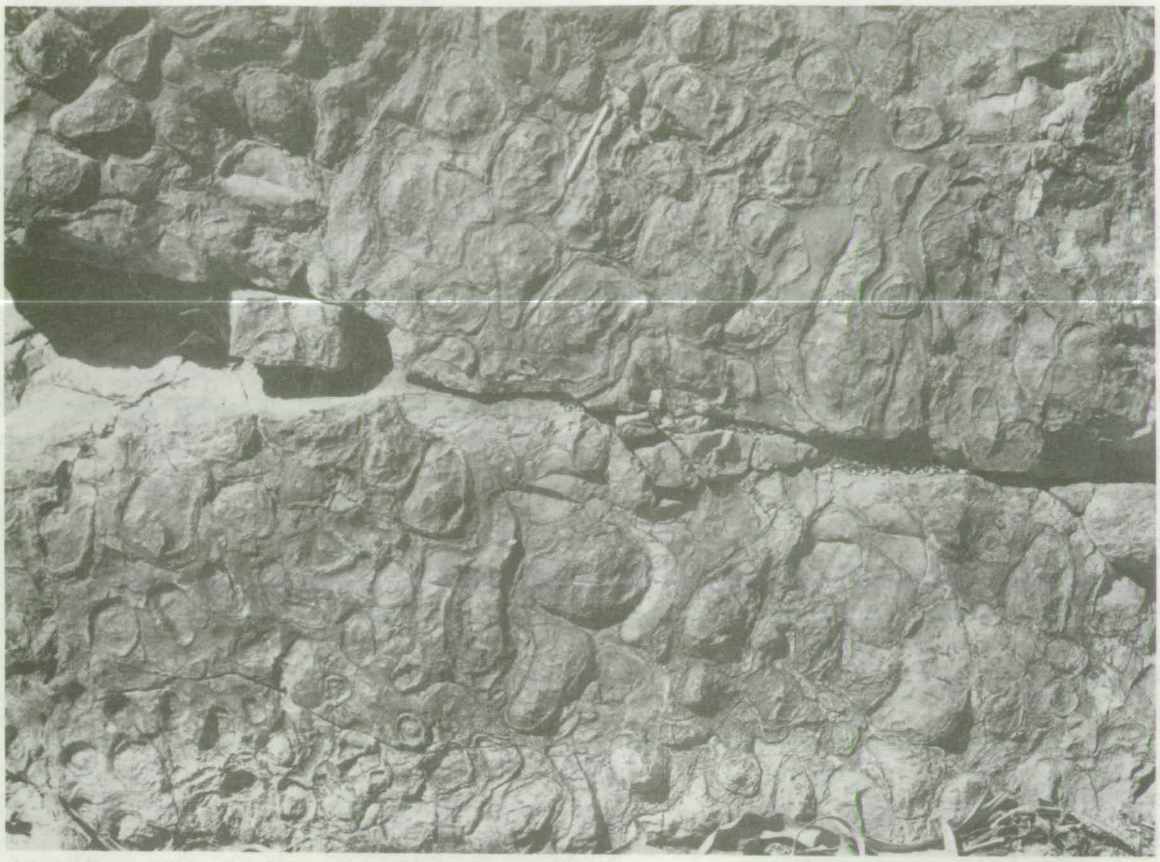

Fig. 15. Colonial stromatolites in the Paradise Creek Formation 8 km west northwest of Golden Sunset gold mine and about 400 m north of the Mount Isa Sheet area.
M/1250 28 G.M.D.

Fig. 16 Stromatolite colony in the Paradise Creek Formation 14 km west of Golden Sunset gold mine
M/1250 19 G.M.D.

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Paradise Creek Formation

Introduction

The Paradise Creek Formation was defined by de Keyser (1958), who named it after Paradise Creek - a tributary of Gunpowder Creek in the Mammoth Mines 1:100 000 Sheet area. The only outcrop mapped in the Mount Isa Sheet area is near the western Sheet area boundary about 14 km west of Golden Sunset gold mine. Exposures are mostly deeply weathered and rubble-covered, and surrounded by soil plains. The rocks dip northeast, and are assigned to the Paradise Creek Formation as they contain stromatolites similar to those described and classified by Robertson (1960).

Stratigraphy and lithology

The Paradise Creek Formation is conformably underlain by the Mingera Beds, and unconformably overlain by the Pilpah Sandstone and Cambrian sediments (Carter et al., 1961).

The exposed sequence consists of thinly to thickly bedded, blocky, deeply ironstained feldspathic fine sandstone at the base, overlain by stromatolitic (Figs. 15 and 16) grey to white chert up to 16 m thick; above are flaggy white to cream laminated siltstone and fine sandstone with some chert beds and interference ripples; the uppermost beds are partly brecciated silicified and ironstained sandstone.

Conclusions

The Paradise Creek Formation was deposited in the southern part of a shallow basin mainly west of the present-day Mount Gordon Fault zone north of the Mount Isa 1:100 000 Sheet, and may be correlated with the stromatolitic sequence in the McArthur Group, 400 km to the northwest.

Pilpah Sandstone

Introduction

This formation was named by Noakes & Traves (1954) and defined by Carter et al. (1961). During the current mapping program the following four units have been recognized within the formation;

Bui_b - laminated chert, chert breccia shale-pellet conglomerate, minor sandstone interbeds

Ᵽui$_{2f}$ - deeply weathered ferruginous sandstone covered by scree

Ᵽui$_{2}$ - white feldspathic and ferruginous sandstones

Ᵽui$_{1}$ - shale, white to grey feldspathic fine sandstone and siltstone, shale-pellet conglomerate

The outcrop areas of each unit in the Sheet area are 10 km^2, 6 km^2, 20 km^2, and 8 km^2 respectively. The formation is exposed on low rises and along stream channels in the northwestern corner of the Sheet area.

Stratigraphic relations

The Pilpah Sandstone unconformably overlies the Mingera Beds, and is not seen to be overlain by other Precambrian units in the Sheet area. It may be equivalent to the Constance Sandstone in the South Nicholson Group, about 250 km to the northwest (Carter et al., 1961).

Ᵽui$_{1}$ is overlain conformably by sandstones of Ᵽui$_{2}$; Ᵽui$_{2f}$ is probably a deeply weathered equivalent of Ᵽui$_{2}$; and Ᵽui$_{b}$ overlies Ᵽui$_{2}$. However, silicified shale-pellet conglomerate in Ᵽui$_{1}$ is difficult to distinguish from Ᵽui$_{b}$, and some outcrops of Ᵽui$_{b}$ shown on the map may be Ᵽui$_{1}$.

Lithology and field occurrence

Unit Ᵽui$_{1}$. Several cycles of shale to finely laminated fine sandstone consisting of well sorted quartz grains in a kaolinitic matrix are present, together with some laminated ferruginous siltstone. Shale-pellet conglomerate is generally confined to the base of the unit, but is locally interbedded with other sediments; it consists of abundant dark grey rounded shale fragments in a dark clay matrix.

Unit Ᵽui$_{2}$. This unit consists of feldspathic medium sandstone containing well sorted and well rounded quartz grains. Most of the feldspar is altered to form a kaolinitic matrix; some samples from this unit are extensively iron-stained. Ripple marks are common, but cross-bedding is rare.

Unit Ᵽui$_{2f}$. The deeply weathered ferruginous sandstone of this unit is made up of well rounded and well sorted quartz grains in an ironstained matrix. These rocks have a texture that resembles that of the sandstones of Ᵽui$_{1}$ and Ᵽui$_{2}$; they are probably the product of deep weathering of the formation during the Tertiary, and not a separate stratigraphic unit.

Unit Ƀui$_b$. In this unit granular chert grit at the base is overlain by chert breccia and interbedded fine sandstone and laminated chert beds, which in turn are overlain by white fine sandstone with chert clasts. The top of the formation as exposed in the Sheet area is a sequence of slumped laminated chert overlain by massive to poorly bedded chert.

The Pilpah Sandstone is folded about a predominant northeast-trending fold axis, and by a later and weaker east-trending axis. Dips are mostly gentle and seldom exceed 45°.

Petrography

Estimated modal analyses of 12 samples from the Pilpah Sandstone are presented in Table 17. Most are from Ƀui$_2$, which is relatively well exposed.

Sample 3577 is a very fine sandstone. The sandstone from Ƀui$_2$ are well sorted, and typically contain well rounded quartz grains with syntaxial rims. Most quartz grains contain abundant oriented fractures along which are traces of opaque minerals.

One sample (3601) from Ƀui$_b$ contains well rounded quartz grains in a semi-opaque matrix of clay minerals. Chert fragments from 2 to 50 mm across make up 20 percent of specimen R5215; rounded quartz grains and quartz fragments are also present and very fine-grained epidote constitutes an important part of the matrix. The rounded quartz grains resemble these in Ƀui$_2$ and the shale fragments resemble other rocks in the formation, and Ƀui$_b$ may have been derived from them either by autobrecciation or by penecontemporaneous erosion and redeposition.

Discussion

The outcrop of Paradise Creek Formation in the Sheet area might well be part of the Pilpah Sandstone, but only detailed mapping in better exposed areas to the north will elucidate this problem.

Some of the Pilpah Sandstone may have been deposited under local deltaic conditions (Carter et al., 1961) but most of the formation was probably deposited in a broad shelf environment which received sediment from the older granitic and sedimentary areas to the east.

TABLE 17. ESTIMATED MODAL ANALYSES OF PILPAH SANDSTONE

	3577	3566	3567	3570	3576	3600	3602	3628	3629	3599	3601	R5215
Unit	1	2	2	2	2	2	2	2	2	f	b	b
Quartz	50	92	70	65	80	95	84	90	88	85	75	60
Muscovite	45		2	1								
Feldspar		7	20	30	16							
Chlorite						5						
Epidote												15
Tourmaline	tr		1	1	2		1			1		tr
Opaques	5	1	7	3	1		15	2	2	14		5
Zircon		tr	tr	tr	1						1	
Clay											24	
Rock Frags								8	10			20
Agd	0.1	0.4	0.2	0.2	0.6	0.5	0.5	0.4	0.2	0.5	1.0	

PALAEOZOIC

CAMBRIAN

The Cambrian sediments of the region have been studied by Opik (1956 a, b, 1960), who recognized two units - the Beetle Creek Formation and the Inca Formation - in the Mount Isa Sheet area. The Beetle Creek Formation unconformably overlies Precambrian rocks; it is overlain conformably and disconformably by the Inca Formation just west of May Downs in an outlier mapped by Opik, and de Keyser & Cook (1972). Information on the Cambrian is also presented by Smith (1972).

MESOZOIC

Several small outcrops of ferruginous, conglomeratic, and deeply weathered sediments north and west of May Downs homestead have been mapped as Mesozoic. They overlie the Cambrian sediments, but as they appear to be unfossiliferous their age is uncertain.

Extensive outcrops of Mesozoic sediments have been mapped to the northwest by Opik (Opik, Carter, & Noakes, 1961) in the Mount Isa and Camooweal 1:250 000 Sheet areas. Twidale (1966a) considers that during the Mesozoic, the Precambrian was peneplaned; earth movements halted the erosion, and allowed the incursion of a Mesozoic sea and the deposition of a thin but widespread cover of sediments. Carter et al. (1961) and Grimes (1972) found a progression from an older continental sequence to a younger marine sequence in the Mesozoic sediments deposited on and around various parts of the Precambrian block.

CAINOZOIC

Four Cainozoic units have been mapped in the Sheet area as follows.

Czr consists of residual unconsolidated silt and fine to coarse sand. It is more common over granitic areas where it occurs as medium to coarse quartz-feldspar sands on slightly elevated plains.

Czg is a recent conglomerate consisting of quartzite pebbles in a coarse quartz sand matrix 10 km northwest and 15 km west of Carters Bore. The pebbles were probably shed from nearby hills of conglomerate and quartzite of the Mingera Beds.

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Fig. 17. Flat-lying conglomerate mapped as Cainozoic in the northwest corner of the Sheet area. The conglomerate has an iron oxide cement.
M/1250 26 G.M.D.

Czb forms black soil plains; it consists of fine alluvium which has been deposited in shallow depressions and other areas of restricted drainage.

Cza consists of alluvium in river beds and on flood plains. It is generally a coarse to medium quartz sand. In river beds the sand contains pebble and cobble beds, and on flood plains it contains a large proportion of silt and fine sand.

From the northwest corner of the Sheet area, south to the Templeton River and then east to the outcrop of the Mingera Beds, several of the rivers and creeks contain small areas of angular gravel and boulder deposits, up to 4 m thick, cemented by iron oxides (Fig. 17). These deposits appear to be recently consolidated and cemented river and creekbed sediments; they have not been mapped separately from the other units.

IGNEOUS INTRUSIVE ROCKS

The main igneous intrusive in the Mount Isa Sheet area is the Sybella Granite complex, which forms a belt 12 to 20 km wide running north-south across the Sheet area and is subdivided into three major phases Pgs_1, Pgs_2, and Pgs_3 and a minor pegmatic phase Pgs_4. Granite west of the continuation of May Downs Fault north and west of Gap Bore is now considered to be older than the rest of the Sybella Granite and is mapped as 'Big Toby Granite'.

Microgranite, aplite, and pegmatite are associated with all the major granite phases. Contamination of granite by dolerite has resulted in a belt of hybrid dioritic rocks along the eastern margin of the Sybella Granite. Dolerite in the area, both antedates and postdates the intrusion of the Sybella Granite.

All the igneous intrusions in the area appear to be Carpentarian.

PROTEROZOIC

'Big Toby Granite'

Introduction

In the southwest part of the Sheet area, granite west and north northwest of Gap Bore gives a Rb-Sr age of 1744 ± 47 m.y. (R.W. Page, pers. comm, 1974), and has been separated from

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the younger Sybella Granite, phases of which have been dated from between 1646 and 1537 m.y. (R.W. Page, pers. comm., 1974). The name 'Big Toby Granite' is proposed for the older granite; it is named after Big Toby Creek, which drains the main outcrop area of the granite.

<u>Exposure</u>

North of Gap Bore the granite forms isolated boulder-covered rises and ridges; in the central part of the outcrop, west of Gap Bore the granite forms easterly trending ridges, low granite tors, and patches of boulders in thin sandy soil; in the south the granite is much weathered, and forms low outcrops along Little Toby Creek and on the slopes of the Cambrian-topped mesas.

The northern, central, and southern outcrop areas cover 7 km^2, 12 km^2, and 3 km^2 respectively.

<u>Stratigraphic relations</u>

The 'Big Toby Granite' intrudes the Yaringa Metamorphics, and probably intrudes basic volcanics of possible Eastern Creek Volcanics southwest of Carters Bore. It is faulted against the Mingera Beds, and unconformably overlain by Cambrian shale, chert, and minor conglomerate.

<u>Lithology and field relations</u>

In the northern outcrop area the 'Big Toby Granite' consists of adamellite containing fine-grained basic xenoliths cut by aplite veins (Fig. 18). Large aligned feldspar porphyroblasts are developed in the muscovite-quartz gneiss of the Yaringa Metamorphics in contact with the adamellite, and minor muscovite-microcline-quartz pegmatites cut both the adamellite and the gneiss.

In the central area the main rock type is a foliated medium to coarse biotite granitic rock containing some microcline phenocrysts and rare basic xenoliths. The granite is more melanocratic and porphyritic in the east. Strong east-west shearing has converted the granite to dark banded gneiss with concordant quartz veins. Quartz-hematite, aplite, and tourmaline-muscovite-quartz-microcline pegmatite veins cut the granite.

At the southern exposures, the 'Big Toby Granite' consists of very weathered medium to coarse, even-grained biotite granite and syenite cut by micaceous, quartz-veined shear zones.

Fig. 18. Contorted aplite veins cutting fine-grained adamellite of the 'Big Toby Granite' north of Gap Bore

M/1260 34 G.M.D.

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TABLE 18. ESTIMATED MODAL ANALYSES OF 'BIG TOBY GRANITE'

	R5185	R5186	R5187	R5188	3542	3544	3545	3546	3553
Quartz	25	20	20	25	3	5	10	4	20
Orthoclase		15		}	60	60	60	70	25
Microcline	53	20		}75	8	12		20	23
Plagioclase	15 An25	39 An25		}	20 An40	12 An30		2	25
Biotite	5	5			4	5		4	2
Muscovite	1								
Sericite					2	4	30	tr	3
Chlorite			60		2	2			2
Epidote	tr		1		tr	tr			
Zircon	tr	tr							
Apatite	tr		tr		tr	tr			
Sphene		1			1	tr			
Opaques	tr	tr			tr	tr			
Limonite			19						

R5185	Biotite granite
R5186	Altered biotite adamellite
R5187	Quartz-chlorite schist (sheared granite?)
R5188	Weathered fine-grained granite
3542	Biotite syenite
3544	Biotite syenite
3545	Altered granite?
3546	Alkali syenite
3553	Adamellite

Petrography

Estimated modal analyses of thin sections of the granite are presented in Table 18.

Most specimens of 'Big Toby Granite' are coarse to medium, pink to pale grey, slightly porphyritic, and range from massive to very strongly foliated. In thin section the massive specimens have a hypidiomorphic granular texture, except where sheared.

All specimens examined in thin section show some evidence of strain: alkali feldspar and quartz grains show undulose extinction and sutured boundaries, and all stages of comminution of large alkali feldspar grains to fine-grained aggregates have been noted. The deformation was accompanied by partial sericitization of the original feldspar, and by chloritization and epidotization of biotite.

Discussion and conclusions

The 'Big Toby Granite' is similar petrographically to the Sybella Granite, but is significantly older (Page & Derrick, 1973; Page, pers. comm., 1974). As it has sharp discordant contacts with chilled margins it is probably a higher-level intrusion (Buddington, 1959), and may be comagmatic with the quartz-feldspar porphyry in the Yaringa Metamorphics.

East-west shearing is a characteristic of both the Yaringa Metamorphics and the 'Big Toby Granite', and may be due to the stress rearrangement in the area resulting from drag-folding along the May Downs Fault, which postdates the intrusion of the 'Big Toby' and Sybella Granites.

Sybella Granite

Introduction

The Sybella Granite was formerally defined by Carter et al. (1961). As a result of the current mapping program it has been divided into three main phases, each of which contains several local variants; these phases have been shown as Ᵽgs$_1$, Ᵽgs$_2$, and Ᵽgs$_3$ on the map. A minor pegmatite phase, the Mica Creek Pegmatite is shown as Ᵽgs$_4$. In addition, an area of gneiss 10 km west-northwest of Mount Isa, previously mapped as part of the Sybella Granite, has been remapped as the 'May Downs Gneiss Member' of the Mount Guide Quartzite; and the older 'Big Toby Granite', previously regarded as part of the Sybella Granite, is mapped as a separate unit.

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The Sybella Granite, previously called the Templeton Granite (Shepherd, 1932c), has been described by Joplin (1955), Joplin & Walker (1961), Carter et al. (1961), and Wilson (1972).

Distribution and exposure

The Sybella Granite forms a north-northwest-trending composite pluton which covers 750 km^2; it is broadest near the northern boundary of the Sheet area. Pgs_1, which is characterized by an absence of foliation and the presence of distinctive rounded phenocrysts of bluish quartz, forms the northwest part of the pluton, while the southern part is formed of foliated biotite granite, Pgs_2. Pgs_3 consists of microgranite which forms a separate intrusion in the north-east. Pgs_4 forms pegmatites on the northern edge of Pgs_2, 10 km southwest of Mount Isa. The phases Pgs_1, Pgs_2, and Pgs_3 account for about 30 percent, 60 percent, and 10 percent respectively of the total outcrop.

The granite is generally well exposed near the outer contacts, and moderately to poorly exposed towards the middle of the pluton, especially along the Templeton River and near Cambrian strata unconformably overlying very weathered granite. Pgs_2 is well exposed on some boulder flats, and also forms tors on plains covered by red feldspathic sand in the south (Figs. 6, 19), but in its northernmost outcrops it is deeply weathered, especially where it is overlain by Cambrian rocks, and fresh granite is exposed only in valleys. Pgs_3 is the best exposed phase and forms rugged boulder-strewn hills (Fig. 20).

Minor variants include fine-grained magnetite-rich gneissic granite, which is well exposed but deeply weathered at several outcrops of Pgs_2, and ocellar quartz diorite, a basic variant of Pgs_2, forms tors and bouldery hills 10 to 12 km west of Mount Isa.

Stratigraphic relations

Stratigraphic relations of the Sybella Granite are uncertain from field evidence because it contains at least three phases of possibly different ages, and many granite contacts are either faulted, or concealed. Several age determinations have been made but they do not fully resolve the relations.

Pgs_1, in the northwest, apparently intrudes the Eastern Creek Volcanics, but contacts are extensively faulted and the relations are uncertain. It is faulted against the

Mingera Beds by the May Downs Fault, but as conglomerate in the Mingera Beds contains granite clasts and abundant blue rounded quartz grains identical to phenocrysts in Ꝑgs$_1$ the Mingera Beds are inferred to be younger than phase Ꝑgs$_1$ of the Sybella Granite.

Ꝑgs$_2$, the southernmost mass, intrudes the Mount Guide Quartzite and Eastern Creek Volcanics, and probably the Judenan Beds, and it is faulted against the Mingera Beds. Basal conglomerate in the Mingera Beds contains clasts of quartz-tourmaline rock possibly derived from pegmatite which intrudes Ꝑgs$_2$, indicating that the Mingera Beds may be younger than Ꝑgs$_2$. Hence the Mount Isa Group, a partial equivalent of the Mingera Beds, may also be younger than phase Ꝑgs$_2$ of the Sybella Granite. An abundance of detrital tourmaline in the lower units of the Mount Isa Group is further evidence for this relation (c.f., Farquharson & Wilson, 1971; Wilson, 1972).

Ꝑgs$_3$, the northeastern mass, intrudes the Eastern Creek Volcanics and the Judenan Beds.

Ꝑgs$_4$, the 'Mica Creek Pegmatite', intrudes the Eastern Creek Volcanics and Judenan Beds and possibly the phase Ꝑgs$_2$ of the Sybella Granite.

Isotopic age determinations from the Sybella Granite have been reported by Nier, Thompson, & Morphey (1941), Murray (1961), Wilson (1961), Richards (1963), Richards, Cooper & Webb (1963), Richards (1966), Farquharson & Richards (1970a, 1970b), Farquharson & Wilson (1971), and Page & Derrick (1973). Sybella microgranite (Ꝑgs$_3$) and pegmatite have concordant whole-rock Rb-Sr and U-Th-Pb isochron ages of 1555 to 1670 m.y. (Farquharson & Richards, 1970b). The remaining phases of the Sybella Granite have Rb-Sr isochron ages of 1656 $\pm$ 21 m.y. (Farquharson & Wilson, 1971). A reappraisal of this data shows that the two results for samples of the 'old phase' of the Sybella Granite (i.e., Ꝑgs$_1$) would plot much better on an older isochron. Zircon from this phase was dated as 1760 m.y. by Richards et al. (1966).

According to Page & Derrick (1973) and Page (pers. comm., 1974), whole-rock Rb-Sr isochrons ages indicate that Ꝑgs$_1$ has an age of 1577 $\pm$ 13 m.y., Ꝑgs$_2$ has an age of 1646 $\pm$ 15 m.y., and Ꝑgs$_3$ has an age of 1557 $\pm$ 40 m.y. Further age determinations are in progress.

No evidence has been found of the old weathered core of Sybella Granite reported by Joplin (1955).

Description

Ꝑgs$_1$ is a pink to grey medium to coarse, slightly porphyritic granite which grades into finer-grained granite and microgranite near its northeastern and northwestern contacts. Phenocrysts of euhedral potash feldspar and rounded beta-quartz are set in a groundmass of microcline, quartz, and minor oligoclase, muscovite, biotite, opaques, and fluorite. Rare elongate and poorly defined basic xenoliths occur near the northwestern contact. Patches in the granite of fine-grained acid gneiss with sparse potash feldspar megacrysts may be xenoliths of the 'May Downs Gneiss Member' of the Mount Guide Quartzite. Aplite, quartz, quartz-feldspar pegmatite veins, and dolerite dykes intrude the granite.

Within 300 m of the May Downs Fault the granite is sheared, silicified, kaolinized, and quartz-veined. Kaolinization of feldspar and replacement of quartz by chalcedony is common where the granite was deeply weathered before the Middle Cambrian sediments were deposited, and the granite is enriched in iron within the Tertiary weathering profile in the northeast.

Ꝑgs$_2$ is made up of several separate intrusions of grey to pink, variably porphyritic medium to coarse biotite granite. In all intrusions the granite is strongly foliated and fine-grained within 1 or 2 km of the contacts, and more massive and coaser-grained towards the centre. Some of the granite has large potash feldspar phenocrysts (Fig. 21) and local aggregates of opaque minerals.

Near the western contact of Ꝑgs$_2$ north of Yaringa Creek, fine-grained porphyritic microgranite crops out. This rock may be a fine-grained contact, an aplitic phase of the main biotite granite, or an entirely younger phase.

In the east of Ꝑgs$_2$ a dark granitic phase covers about 10 km^2; it is generally grey and medium to coarse, ranges from granite to granodiorite and quartz-diorite in composition, and contains numerous fine-grained basic xenoliths and quartz ocelli. Several internal contacts between different granitic types are exposed, the younger types generally being the less basic. Rare calcite veins are also present.

Ꝑgs$_3$ is mainly a pink, slightly porphyritic, massive to weakly foliated medium-grained granite. It is finer-grained and less porphyritic near its margins, and at its contacts with the Eastern Creek Volcanics it shows evidence of hybridization. The contact phase is various tones of grey and contains fine-grained basic xenoliths and magnetite xenocrysts or porphyroblasts; it is intruded by aplite, quartz, quartz-tourmaline, and minor pegmatite veins, and is locally altered to muscovite schist along shears trending northwest to north-northwest.

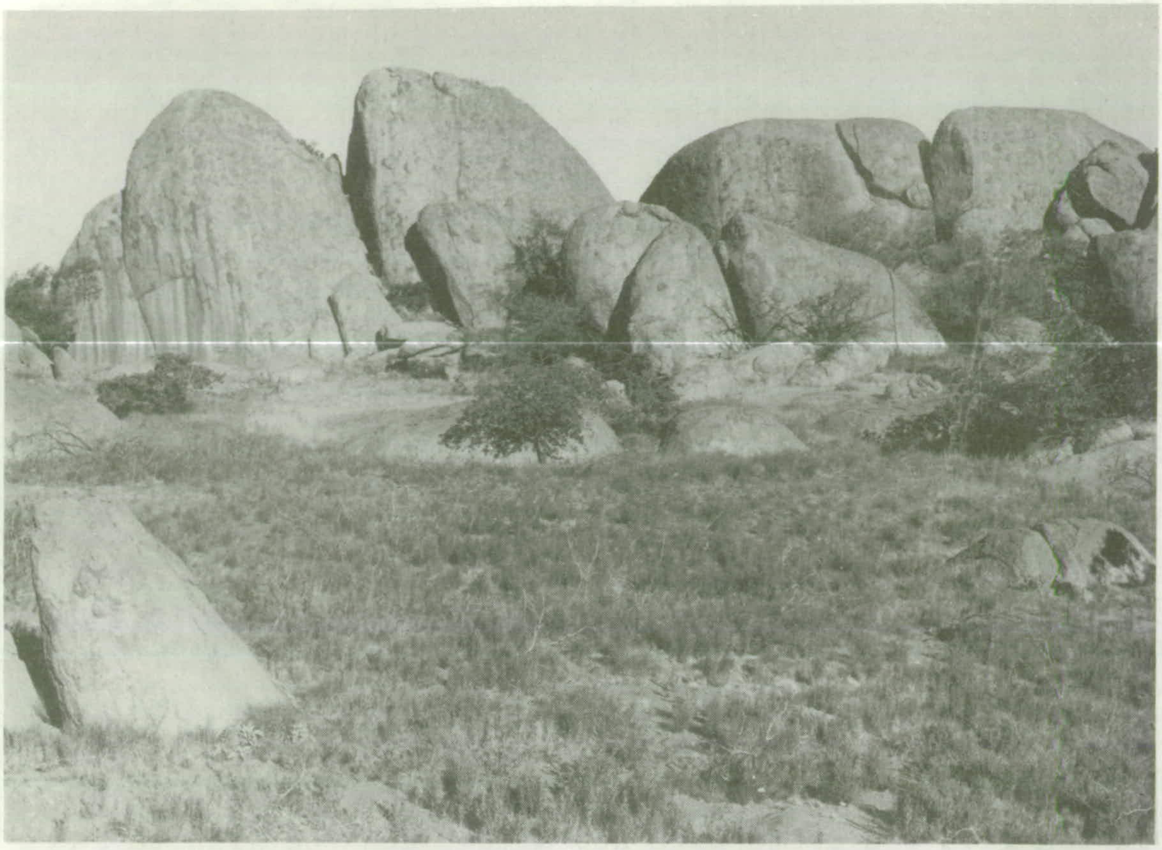

Fig. 19. Large tors of Pgs_2, the foliated biotite-rich phase of the Sybella Granite, 8 km south of May Downs Homestead.

M/1337 9 R.M.H.

Fig. 20. Typical boulder-strewn hills formed of Sybella microgranite, Pgs_3, 6 km east of May Downs homestead

GA 7882 R.M.H.

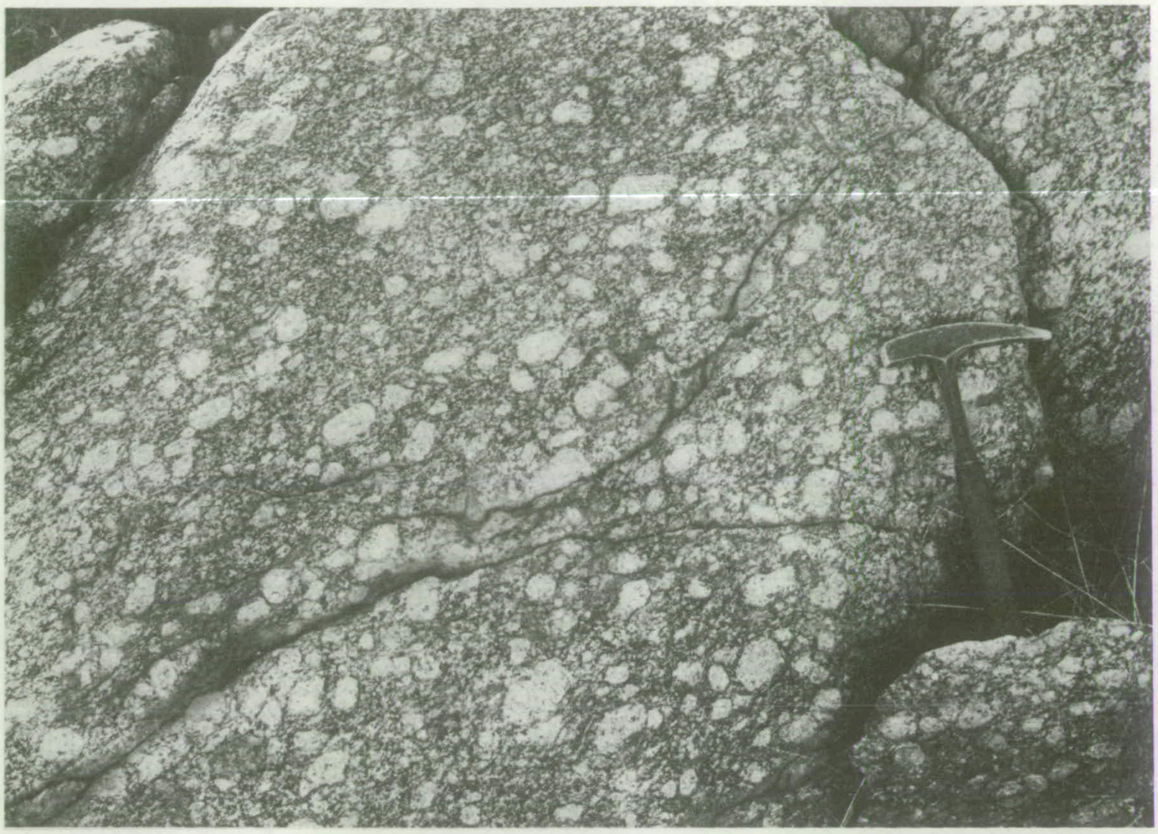

Fig. 21. Coarse-grained foliated Sybella Granite, Pgs$_2$, containing large feldspar phenocrysts 0.5 km west of McKellars Well

M 1102 G.M.D.

Pgs$_4$, the 'Mica Creek Pegmatite', forms dykes and veins in both Pgs$_2$ and the surrounding metamorphic rocks. The largest of the pegmatites extends south from Big Beryl Mine for a distance of 2 km, has a maximum width of 1 km, and at its southern end adjoins and intrudes the Sybella Granite. Generally, however, the pegmatites occur as individual tabular or lenticular bodies which range up to 200 m long and 100 m wide. In most instances they are concordant with the surrounding rocks.

They consist of microcline (generally forming up to 90% of the rock) quartz, albite, muscovite, and minor beryl, black tourmaline, garnet, tantalite-columbite minerals, cassiterite, monazite, and fluorite. The microcline occurs as crystals up to 60 cm across but averages 5 cm; quartz is locally intergrown with the microcline to give the feldspar a graphic appearance. The muscovite occurs as very coarse plates or booklets randomly oriented and widely scattered throughout the pegmatite bodies.

The 'Mica Creek Pegmatite' has been mined for beryl and mica and explored for other minerals (see other pegmatite minerals, Economic Geology); it has been mapped and described by Brooks & Shipway (1960) and Wilson (1972).

Some silicification has occurred adjacent to quartz veins in minor faults cutting the Sybella Granite, and mylonitization occurs in a zone up to 200 m wide at the western faulted contact between foliated biotite granite and the Mingera Beds. The mylonite is extensively altered to kaolinite and chlorite.

Petrography

Estimated modal compositions of 60 specimens of Sybella Granite are presented in Tables 19, 20, 21, and 22.

Granite of Pgs$_1$ is porphyritic and has a hypidiomorphic granular texture. Microcline forms both subhedral phenocrysts and anhedral crystals in the groundmass. Quartz phenocrysts have the rounded bipyramidal form typical of beta-quartz; in some specimens they are strained and slightly recrystallized, and in others - from relatively fine-grained granite from near the northwestern contact - they are embayed. Plagioclase, generally of oligoclase composition is subhedral to euhedral and extensively sericitized. Ragged deformed anhedral books of biotite, the main mafic mineral, define an indistinct foliation in some specimens. Deformed muscovite books are less common.

90

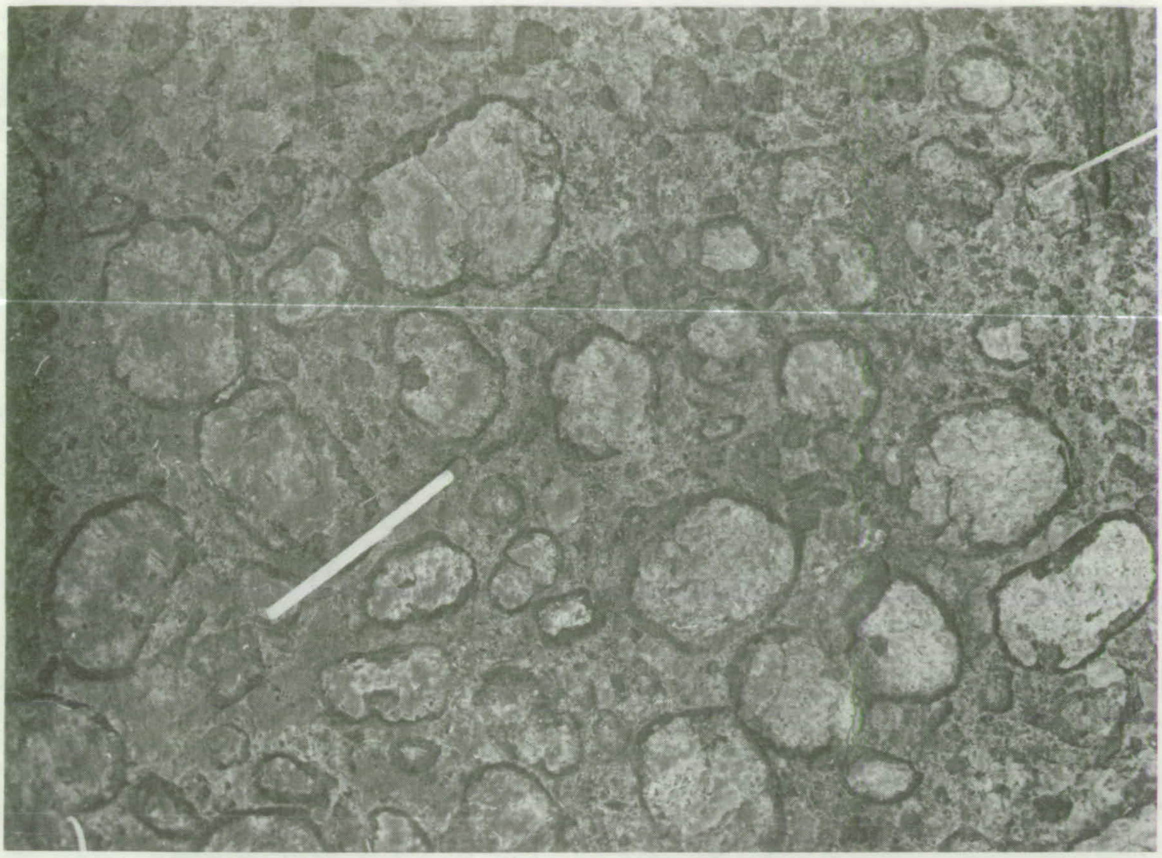

Fig. 22. Potassium feldspar phenocrysts rimmed by plagioclase laths, hornblende, and biotite in hybrid diorite 10 km west of Mount Isa

M/1260 31 G.M.D.

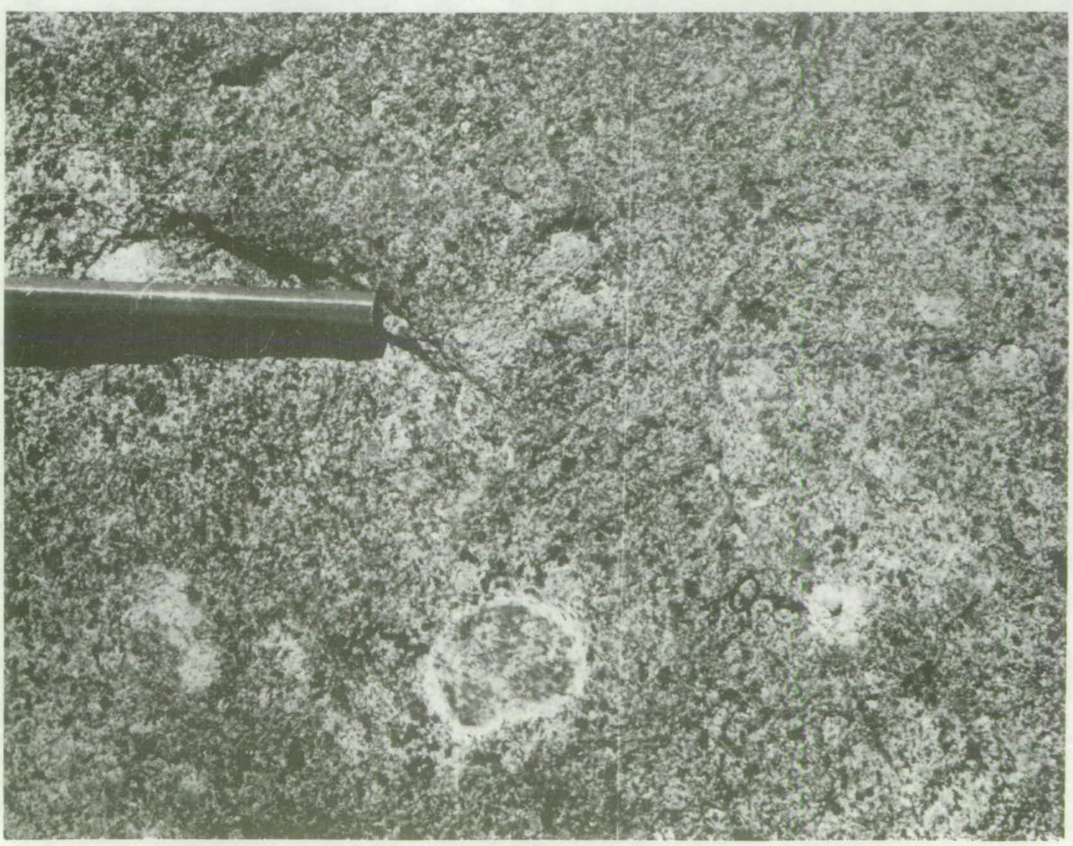

Fig. 23. Quartz ocelli (Q) in rapakivi-textured (potassium-feldspar rimmed by plagioclase (K)) diorite 10 km west of Mount Isa

M/1511 7 I.H.W.

91

Foliated granite of Ꝑgs$_2$ has a porphyritic to gneissic texture with a pronounced foliation due to the parallelism of mica flakes. Microcline occurs as subhedral recrystallized phenocrysts up to 15 mm long and as anhedral crystals in the groundmass. Other major minerals are anhedral inequigranular strained quartz, subhedral to anhedral oligoclase, and dark olive green to brown biotite partly altered to chlorite. Amphibole, present in some specimens, has a low negative 2V and a deep blue-green Z absorption colour; it is probably ferrohastingsite. Wilson (1972) noted that the grainsize of the granite decreases where the mica content is highest.

The hybridized rocks on the eastern edge of Ꝑgs$_2$ show considerable variation in texture and composition. They range from pink, slightly porphyritic granite to dark grey coarse-grained porphyritic quartz diorite and diorite. They contain large (up to 2.5 cm) pink potash feldspar phenocrysts rimmed by fine-grained grey plagioclase (An_{28}), forming rapakivi textures (Fig. 22), and glassy quartz ocelli up to 1 cm rimmed with clinopyroxene, hornblende, and biotite (Fig. 23).

The microtexture is allotriomorphic granular and some recrystallization is evident. Plagioclase also forms large subhedral zoned laths and anhedral aggregates ranging in composition from An_{25} to AN_{35}. In some samples (e.g., 3588) large ovoids of quartz are mantled by a finer-grained quartz and microcline microperthite; clinopyroxene in the groundmass and in quartz-ocelli rims is commonly mantled by hornblende. A characteristic of many of the samples is the abundance of very fine apatite needles - a typical feature of hybrid rocks.

The microgranite and porphyritic granite of Ꝑgs$_3$ are of variable grainsize; they consist of subhedral phenocrysts and anhedral grains of microcline, granoblastic mosaics of partly recrystallized quartz, and subhedral sericitized oligoclase laths. Myrmekite comprises up to 20 percent of some rocks, and forms patches up to 5 mm across.

Discussion

The decrease in grainsize of the phases of Sybella Granite towards their contacts, and the occurrence of beta-quartz crystals in Ꝑgs$_1$, and of sharp and locally discordant contacts - despite some local hybridization of country rocks - are features of epizonal plutons, but the foliation and the well developed broad contact metamorphic aureole of Ꝑgs$_2$, and the regional concordant contacts of all three phases, are more typical of mexozonal plutons (Buddington, 1959). We conclude that the three phases of the Sybella Granite intruded at relatively shallow depths, and that in some areas deformation and subsequent erosion has led to the exposure of deeper, mesozonal, levels.

TABLE 19. ESTIMATED MODAL ANALYSES OF PHASE Bgs_1 OF THE SYBELLA GRANITE

	R5220	R5223	R5225	R5226	R5227	R5228	R5229	R5241	R5242
Quartz/feldspar			75						
Quartz	37	12(9)	5	30(2)	21(4)	15(10)	30	20	30
Microcline	50	38(25)	4	55	33	55(5)	63	45(5)	45
Plagioclase	10	5(1)	11(30)	10(30)		6(5)	5		
composition	An_{20}	An_{20}	An_{30}	An_{30}			An_{10}		
Muscovite	tr		1	1	2	1	tr	tr	10
Chlorite			tr		10			10	5
Biotite	2	4	1	2		3	1		
Hornblende		tr							
Kaolin					30			20	10
Calcite			tr						
Opaques	1	1	2	tr		tr	1		tr
Allanite					tr				
Apatite	tr		tr						
Fluorite	tr	tr		tr		tr			
Sphene		1	1			tr			
Zircon		tr	tr			tr			
Agd (mm)	3	0.2(5)	-(5)	0.4	0.2	0.5(3)	0.4	0.2(10)	0.2

R5220 Slightly porphyritic medium to coarse granite
R5223 Porphyritic fine-grained granite
R5225 Spherulitic porphyritic microgranite
R5226 Slightly porphyritic fine-grained acid gneiss
R5227 Relict porphyritic kaolinized sheared granite
R5228 Relict porphyritic recrystallized medium-grained granite
R5229 Microgranite
R5241 Weathered porphyritic granite
R5242 Fine-grained acid gneiss

Percentage phenocrysts is shown in brackets
Agd of phenocrysts is shown in brackets

TABLE 20. ESTIMATED MODAL ANALYSES OF PHASE Egs_2 OF THE SYBELLA GRANITE

	R5174	R5175	R5176	R5184	R5194	R5258	3510	3513	3515	3516	3517	3605	3606	3607	3608	3609	3610	3611	3612	3613	3614
Quartz/feldspar				9																	
Quartz	10	20	25	(5)	25(15)	25	26	50	30	43	45	30	30	33	34	28	35	35	40	30	38
Microcline	1	20	36	(2)	40(10)	44	65	30	20	22	20	30	40	42	35	29	20	35	35	40	30
Plagioclase			35			30	5	12	18	20	15	30	20	10	25	25	25	20	20	20	20
composition			An_{20}			An_{10}						An_{15}					An_{15}	An_{22}	An_8		
Muscovite			tr		10	tr	2					tr	5						tr		
Chlorite	30	20?			tr		tr														
Biotite			3			1			15	7	12	10		13	2	13	10	4		4	8
Amphibole								3	10	5	4	tr		2	4	4	8	6	5	6	3
Epidote			tr					2	1	tr						tr	tr			tr	
Kaolin	59	40?																			
Calcite												tr									
Opaques			tr		2	tr	1	1	1	1	1		4		tr				tr		tr
Allanite									1	1	3	tr	tr			tr		tr	tr		tr
Apatite			tr			1			1	tr	tr	tr		tr		tr	tr	tr		tr	tr
Fluorite												tr	tr	tr	tr	tr	tr			tr	1
Sphene			1		tr			1	3	1		tr	tr	tr		1	2	tr		tr	tr
Zircon			tr							tr	tr			tr		tr		tr			
Tourmaline							1	1													
Agd (mm)	(0.5)	0.1(1)	0.6		0.1(2)	0.2	0.4	0.5	0.4(1)	0.6(3)	1(3)										

Percentage phenocrysts is shown in brackets
Agd of phenocrysts is shown in brackets

R5174 Kaolinized mylonitized granite
R5175 Sheared fine-grained granite
R5176 Fine-grained granite
R5184 Sheared porphyritic microgranite
R5194 Microgranite
R5258 Aplite

3510 Foliated dyke, aplite?
3513 Foliated dyke, aplite?
3515 Foliated biotite granite
3516 Foliated porphyritic biotite granite
3517 Foliated porphyritic biotite granite
3605 Biotite granite
3606 Magnetite-bearing leucogranite
3607 Gneissose biotite granite
3608 Gneissose hornblende granite
3609 Gneissose granite
3610 Granite
3611 Gneissose granite
3612 Leucogranite
3613 Granite
3614 Granite

TABLE 21. ESTIMATED MODAL ANALYSES OF SYBELLA GRANITE, PHASE Bgs_3

	R5231	R5232	R5233	R5234	R5243	3531	3532	3536
Quartz	3	35	35(1)	30(1)	30	40	30	30
Microcline		58	46(2)	39(24)	46	43	40	32
Plagioclase	1	5	5(7)	5	20	10	22	30
composition		An_{20}	An_{40}	An_{20}	An_{30}			
Muscovite	45	1	1	1	1	2	2	1
Chlorite	35					1	3	1
Biotite		1	tr		2	1	tr	3
Phlogopite	16							
Hornblende			2					
Epidote						tr	tr	tr
Opaques		tr	tr	tr	tr	2	2	1
Apatite	tr	tr			tr			
Fluorite			tr			1		1
Sphene	1	tr	1	tr	1		tr	
Zircon		tr	tr		tr	tr	1	tr
Agd (mm)	0.2	1	0.3(2)	0.4(2)	0.4	0.4	0.5	0.5

R5231 Phlogopite-chlorite-muscovite schist
R5232 Silicified fine-grained granite
R5233 Slightly porphyritic fine-grained granite
R5234 Porphyritic fine-grained granite
R5243 Fine-grained inequigranular granite
3531 Slightly porphyritic fine-grained granite
3532 Fine-grained granite
3536 Fine-grained granite

Percentage phenocrysts is shown in brackets
Agd of phenocrysts is shown in brackets

TABLE 22. ESTIMATED MODAL ANALYSES OF OCELLAR QUARTZ DIORITES AND OTHER HYBRIDIZED PHASES OF Egs_2 OF THE SYBELLA GRANITE

	R5201	R5202	R5206	R5207	R5208	R5251	1483	1484	1485	1486	1487	1488	1489	1490	1491	1492	1494	3588	3618	3619	3621	3622
Quartz	5(5)	35	27	2	20(5)	19	10	4	8	37	10	25	40	35	20	1	36	43	35	28	34	30
Microcline	20	30(5)	40	-	20(20)	29(5)											45	35	5	27	35	5
Orthoclase							10			15	53	40	20	30	40							
Plagioclase	45(5)	25	20	60	29	16	45	46	50	40	20	20	25	10	20	40	3	5	50	40	20	40
composition	An_5		An_{40}	An_{55}	An_{35}	An_{30}	An_{35}	An_{40}	An_{40}	An_{30}	An_{30}	An_{32}	An_{32}	An_{28}	An_{35}	An_{60}	An_{20}		An_{24}	An_{20}	An_{30}	An_{30}
Diopside																						1
Augite				20		1	10	20	5	tr	5	4	3	3		20		2				
Orthopyroxene				4			5									11						
Hornblende	6	2	3	2	2	8	5	10	20	5	7	6	5	12	5		6	10	tr		6	15
Biotite	8	5	5	8	2	19	15	10	15	3	5	5	5	10	15	25	10	5	10	5	1	8
Sericite								5							tr	tr						
Chlorite																2			tr	tr		
Epidote																	tr		tr	tr		
Apatite	2	1	2	2		tr	tr	tr	1	tr					tr		tr	tr	tr	tr	tr	tr
Sphene	2	1	2		1	2													tr		tr	tr
Zircon				tr	tr		tr			tr					tr							
Opaques	2	1	1	2	1	1	tr	5	1	tr	tr	tr	tr	tr	tr	1	tr				1	1
Agd (mm)	0.1(4)	0.1(4)	2	0.4	0.1(8)	0.5(5)	0.5(1.5)	0.5(2)	0.5(3)	0.3(1.5)					0.3(1.5)	0.5(3)			2	3	0.5(5)	1.5

R5201 Hybridized granite
R5202 Sheared contaminated granite
R5206 Contaminated foliated biotite granite
R5207 Altered gabbro
R5208 Contaminated foliated porphyritic granite
R5251 Contaminated hornblende-biotite granite
1483 Diorite gabbro
1484 Diorite gabbro
1485 Quartz diorite
1486 Gradodiorite
1487 Syenite
1488 Porphyritic granite
1489 Granite
1490 Porphyritic Granite
1491 Granite
1492 Gabbro
1494 Alkali granite
3588 Alkali granite
3618 Quartz diorite
3619 Grandiorite
3621 Granite
3622 Quartz diorite

Percentage phenocrysts is shown in brackets
Agd of phenocrysts is shown in brackets

The quartz diorites are a product of interaction of phase Pgs_2 with metabasalts and metadolerites of the Eastern Creek Volcanics. Angus (1962) has described similar rocks attributable to hybridization and has found they are especially common in the roof zones of large magmatic complexes.

The 'Carters Bore Rhyolite' may be comagmatic with phase Pgs_1.

Structural relations between the Sybella Granite and the Mount Isa Group

On the basis of age dates from other granites in the region (Farquharson & Wilson, 1971), at least phases Pgs_2 and Pgs_3 of the Sybella Granite are younger than the Kalkadoon Granite, which crops out east of the Sheet area. Farquharson & Wilson use structural data to show that the Sybella Granite is also younger than the Mount Isa Group. They argue that isoclinal folding with a strongly developed axial-plane cleavage developed as the Mount Isa Group was regionally metamorphosed. The cleavage is parallel to the oldest recognizable structure in the Leichhardt Metamorphics, which they attribute to the intrusion of the oldest phase of the Kalkadoon Granite (1930 m.y.) The Sybella Granite cuts across the cleavage, and hence is younger than both the regional metamorphism and the Mount Isa Group. However, no detailed structural studies of either the Leichhardt Metamorphics or the Mount Isa Group have been made. We have recognized isoclinal and tight folding in the Mount Isa Group only near fault zones, and have not recognized any regional cleavage.

In the conglomerate at the base of the 'Mingera Beds', pebbles of porphyritic granite containing phlenocrysts of rounded bluish beta-quartz, almost certainly derived from the Sybella Granite (Pgs_1), indicate that the Mingera Beds are younger than at least phase Pgs_1 of the Sybella Granite. Hence the Mount Isa Group, a partial equivalent of the Mingera Bed, is also younger than phase Pgs_1 of the Sybella Granite. Field evidence suggests that the Mount Isa Group is also younger than phase Pgs_2 (see 'Stratigraphic relations').

In the Mount Isa Mine area, Blanchard & Hall (1937, 1942) have shown that Mount Isa Group was regionally deformed, and that a later brecciation and mineralization are related to the intrusion of the 'Mica Creek Pegmatite'. The relations are based on the cross-fracturing which is inferred to have been caused by an upward movement southwest or west of the mine/ However, the cross-fractures might instead be due to another tectonic event such as the intrusion of a younger granitic body to the east, and Murray (1961), for instance, regards the cross-fractures as being the result of a relaxation of regional pressure.

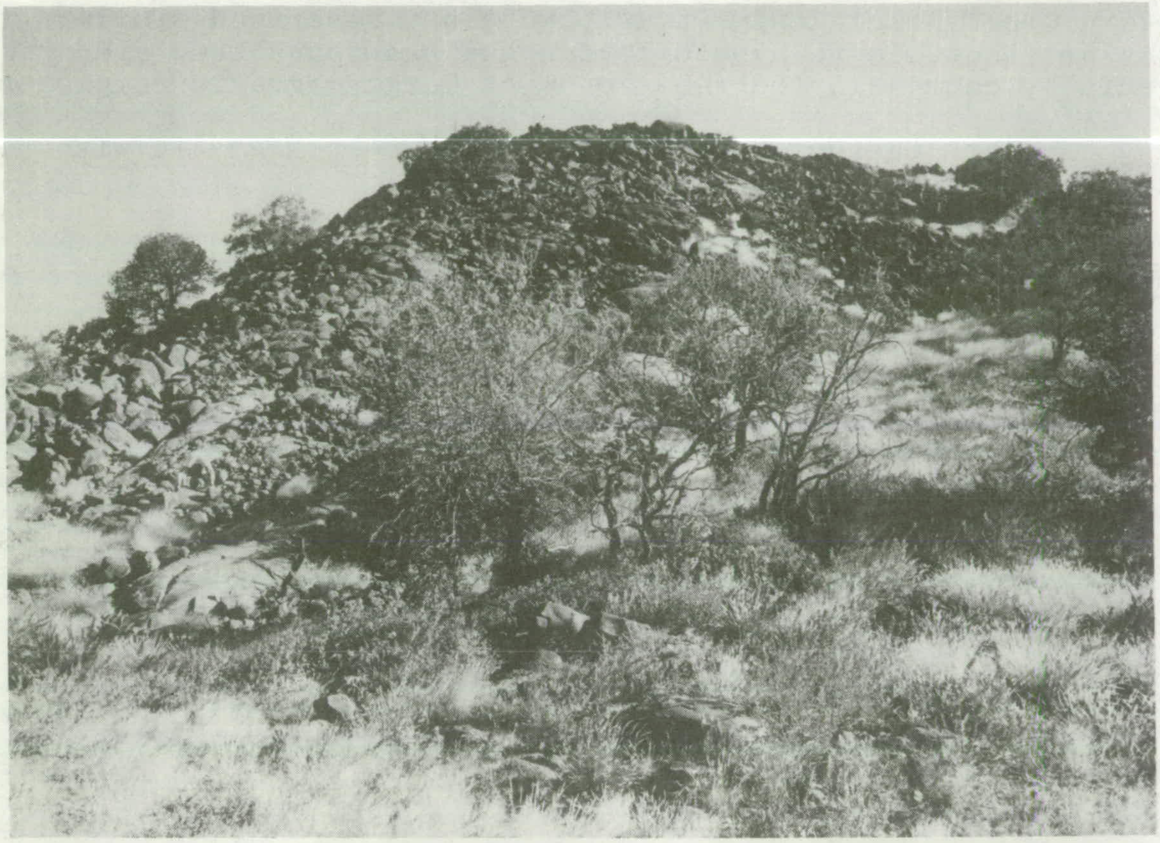

Fig. 24. Typical bouldery exposure of dolerite plug cutting the Sybella Granite; 5 km east of May Downs homestead

M/1338 16 R.M.H.

Dolerite

Introduction

Dolerite intrusions are less common in the Mount Isa 1:100 000 Sheet area than in the Sheet areas mapped to the east. Two groups of dolerite can be distinguished: An older group that antedates the Sybella Granite and intrudes the Judenan Beds, Eastern Creek Volcanics, and Yaringa Metamorphics; and a younger group that postdates Sybella Granite. The older dolerites are generally metamorphosed to blastophitic and schistose aggregates of plagioclase, hornblende, clinopyroxene and minor biotite; the younger dolerites, typically unaltered, have ophitic textures and contain clinopyroxene and minor orthopyroxene rimmed by hornblende. The younger dolerites are exposed as resistant spheroidal boulders (Fig. 24).

Petrography

Estimated modal analyses of 12 dolerites are presented in Table 23. The older dolerites have a range of textures from blastophitic to nematoblastic. In samples which contain clinopyroxene as the main mafic mineral, euhedral plagioclase has undergone only incipient alteration to sericite, and the pyroxene is rimmed by actinolite or hornblende and fox-red biotite. Biotite also rims skeletal opaque minerals. Sparse quartz forms myrmekitic intergrowths with plagioclase. Apatite needles are a common accessory mineral.

In hornblende-rich varieties the texture is more commonly granoblastic and nematoblastic than blastophitic. Hornblende forms porphyroblasts containing minute inclusions of quartz. Most of the plagioclase has recrystallized to an untwinned granoblastic aggregate, and euhedral laths are rare.

The younger dolerites have a well-preserved ophitic texture in which unaltered plagioclase shows albite and Carlsbad twinning.

Correlations

The older dolerites may be equivalent to groups do_3 or do_4, and the younger dolerites to group do_6, mapped in the Sheet areas to the east (Derrick et al., 1971, 1974).

METAMORPHISM

The Lower and Middle Proterozoic rocks of the Mount Isa Sheet area are of fairly uniformly lometamorphic grade except for a broad aureole of rocks around the Sybella Granite which have been metamorphosed to the amphibolite facies.

TABLE 23. ESTIMATED MODAL ANALYSES OF DOLERITES

	Older group										Younger group	
	R5196	R5248	3508	3514	3519	3522	3525	3526	3535	1472	3615	3623
Plagioclase	48	33	30	45	50	45	40	40	50	65	60	33
composition	An_{45-55}			An_{58}					An_{60}		An_{60-30}	An_{53}
Hornblende	30		60	5	4	45	53	45	1		2	45
Orthopyroxene											12	}20
Clinopyroxene		64		32	32				40	15	20	
Biotite	tr		1	10	10		tr		7	15	4	
Chlorite	1		1					tr				
Epidote	15		tr			tr	tr					
Muscovite			3									
Quartz	tr			2		5	tr	8			1	
Sphene	1											
Opaques	5	3	5	2	3	5	7	7	1	3	tr	2
Apatite	tr			1	1				1		1	tr
Myrmekite				3						2		

Upper Proterozoic and younger rocks appear unmetamorphosed. A metamorphic facies map (Fig. 25) has been drawn using information gained during this survey from about 200 selected specimens and from the work of previous investigators, especially Wilson (1972).

The description and classification of the metamorphism is based largely on the concepts of Winkler (1967, 1970). Although Winkler in his later work advocates the abolition of metamorphic facies, we prefer to continue using the fimilar terms 'greenschist facies' and 'amphibolite facies' instead of his new terms 'low stage' and 'medium stage'.

Three prograde metamorphic events have been recognized in the Mount Isa Sheet area. The first regionally metamorphosed the Yaringa Metamorphics to the upper greenschist facies, and was accompanied or followed by the intrusion of the 'Big Toby Granite'. This metamorphism is the least known as the age and structural relations of the Yaringa Metamorphics to the rest of the area are uncertain.

The second metamorphism took place during the intrusion of the Sybella Granite into the 'Haslingden Group'. It was a low-pressure contact metamorphism to the upper amphibolite facies, and was accompanied by some anatexis in the 'May Downs Gneiss Member' of the Mount Guide Quartzite.

After the Mount Isa Group sediments were deposited, folding and faulting accompanied by low-grade regional metamorphism took place; the Mount Isa Group was metamorphosed to the lower greenschist facies, and older higher-grade rocks in the Sybella Granite contact zone suffered retrogression.

Mineral assemblages

The most important indicator minerals in the Sheet area are chlorite, biotite, cordierite, and sillimanite. Andalusite and forsterite and diopside occurring with calcite, although rare, are also improtant as they place stricter limits on the conditions of metamorphism.

The chlorite zone of the greenschist facies is present only east of the Mount Isa Fault, mainly in the Mount Isa Group. The higher-grade biotite zone occurs in a strip west of the Mount Isa Fault, in a poorly defined area, north and south of Carters Bore (Ardmore Outstation), in the Yaringa Metamorphics, and in the southeast corner of the Sheet area.

Winkler (1970) considers that the appearance of cordierite marks the beginning of the medium stage or amphibolite facies, and this usage is followed here, although Wilson (1972) delineated a biotite-cordierite zone within the greenschist facies. The cordierite zone flanks the eastern and southwestern margin of the Sybella Granite. The cordierite forms round porphyroblasts in quartz-biotite schist and is commonly associated with anthophyllite.

Sillimanite-zone rocks are characterized by assemblages containing muscovite-biotite-sillimanite. The sillimanite is difficult to see in the field, but is irregularly distributed throughout the zone. It is most commonly found in the 'May Downs Gneiss Member' of the Mount Guide Quartzite.

Typical mineral assemblages for each rock type in each zone are set out in Table 24.

Conditions of metamorphism

Experimentally determined isograds for various metamorphic minerals are shown in Figure 26 (after Winkler, 1970), in which the alumina silicate triple points 1 and 2 of Holdaway (1971) are preferred in this Record to those of Althaus (1967, 1969) and Richardson, Gilbert & Bell (1969). From this diagram it is seen that the mineral assemblages in the Mount Isa Sheet area fall in the temperature range 450 to 650^{o}.

Several lines of evidence indicate the approximate pressures operating during metamorphism, and hence the depth of burial at the time of metamorphism. They include:

(a) The characteristics of the Sybella Granite (Ꝑgs$_2$) are those of an epizonal to a mesozonal pluton, indicating a depth of intrusion of about 5-15 km (Buddington, 1959).

(b) The upper stability limit of cordierite appears to be at pressures of 4-5 kilobars, which is equivalent to a depth of burial of 15-18 km.

(c) The isograd 'diopside + calcite' is highly pressure-dependant (Winkler, 1970), and the maximum pressure at which this assemblage can coexist before anatexis is about 5-6 kilobars, or at a depth of 18-22 km; the co-existence of calcite and diopside near the Sybella Granite contact is reported by Wilson (1972).

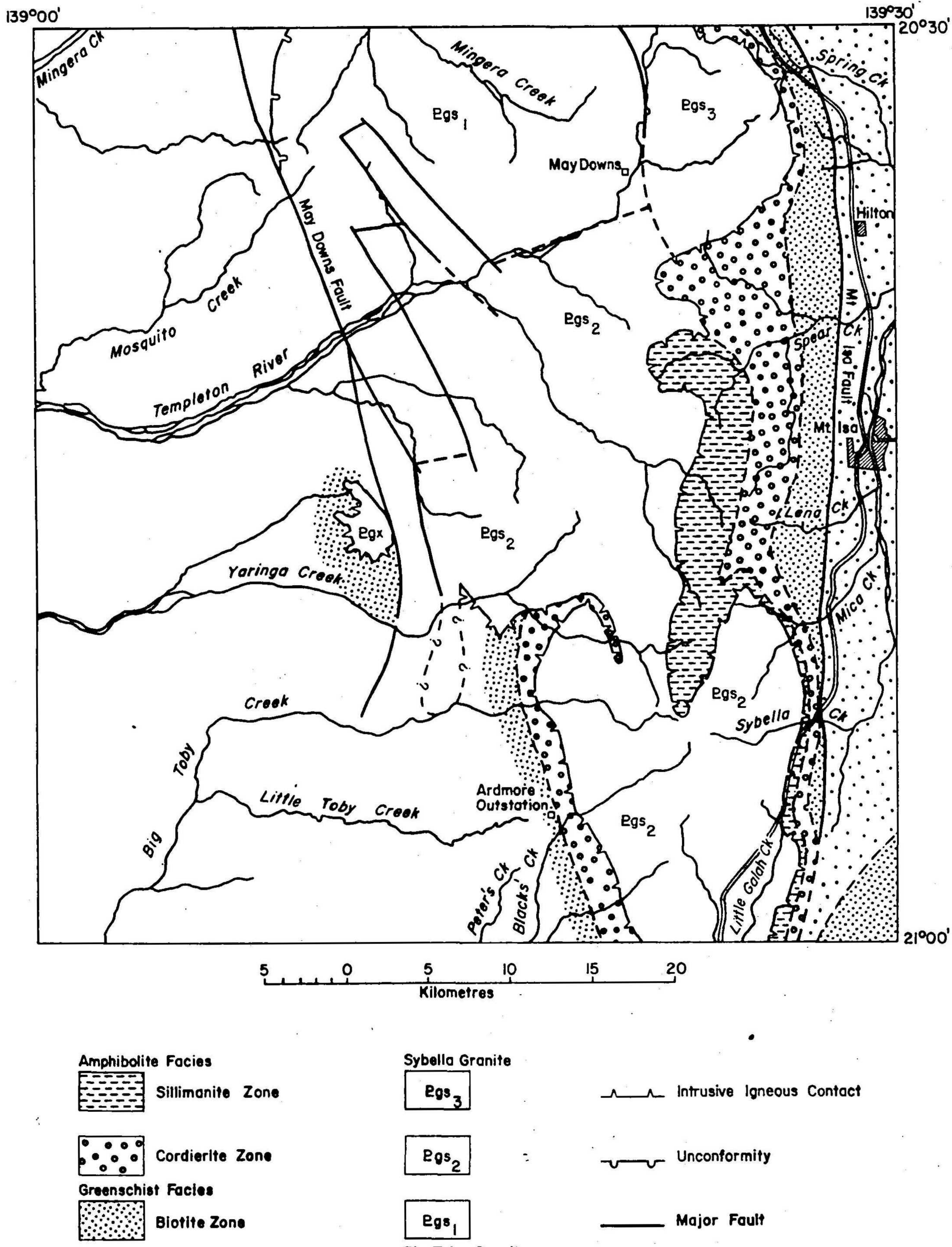

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Fig. 25 Distribution of metamorphic facies, Mount Isa 1:100 000 sheet area.

TABLE 24. METAMORPHIC MINERAL ASSEMBLAGES IN THE MOUNT ISA 1:100 000 SHEET AREA

Facies	Isograd	Pelites and Psammopelites	Carbonate Rocks	Basic Igneous Rocks
Greenschist	Chlorite	Quartz-chlorite-albite-calcite Muscovite-chlorite-quartz Quartz-chlorite-albite	K-feldspar-quartz-dolomite	Chlorite-albite-epidote
	Biotite	Quartz-muscovite-biotite Quartz-muscovite-chlorite		
Amphibolite	Cordierite	Quartz-muscovite-biotite-cordierite(-chlorite) Quartz-biotite-cordierite-anthophyllite Quartz(-chlorite)-cordierite Cordierite-anthophyllite-andalusite-quartz	Calcite-actinolite-quartz	Hornblende-plagioclase (An_{18})-quartz
	Sillimanite	Quartz-muscovite-biotite-plagioclase (An_{40}) Plagioclase (An_{45})-quartz-microcline Quartz-muscovite-biotite-sillimanite	Calcite-diopside-forsterite	Hornblende-plagioclase-quartz

(d) The presence of andalusite indicates a maximum pressure of between 3.5 and 4.2 kilobars, or a depth of 12 to 16 km (Fig. 26). Carter et al. (1961) and Wilson (1972) have reported andalusite, but it has not been found in the Mount Isa 1:100 000 Sheet area during this survey.

The combined evidence allows a maximum depth of burial of about 15 km and a minimum depth of about 5 km. This estimate is compatible with the estimated total thickness of the sedimentary pile, 12 km, at the time of intrusion.

The temperature and pressure limits in the aureole of the Sybella Granite are plotted in Figure 27. The type of metamorphism observed closely corresponds to the Abukuma-type (andalusite-sillimanite) facies series, described by Miyashiro (1961) and Winkler (1967). This type of metamorphism has both regional and contact features, and Miyashiro (1961) points out that synkinematic granites similar to the Sybella Granite are common in the high-grade parts of such a metamorphic terrain.

Metamorphic gradient in the Sybella Granite aureole

Joplin (1955) apparently considered that a metamorphic unconformity exists between the rocks we have called the 'May Downs Gneiss Member' and the rest of the succession west of Mount Isa. Between Sybella Creek in the south and Spear Creek in the north Wilson (1972) noted that the regional metamorphism varies from very low greenschist to amphibolite facies over a distance of 5 km across the regional strike of the area; he attributed this observed steep gradient to the juxtaposition of metamorphic zones by second-generation faults (Wilson, 1973a). However, the conditions of metamorphism indicates that there is no need to postulate either a metamorphic unconformity, an anomalously steep metamorphic gradient on the east side of the Sybella Granite, or faulting.

If we consider the depth of burial to beabout 10 km, the temperature of the country rocks before intrusion would probably be about 200°C. Assuming the temperature of the intrusion was about 700°C, and using the calculations of Jaeger (1957) as simplified by Winkler (1967), the estimated temperature gradient is as plotted in Figure 28. An average diameter of the Sybella Granite of 15 km was used in the calculation. The steepest gradient is in the vicinity and to the south of Mica Creek. By plotting the distance of the cordierite and sillimanite isograds from the contact of the

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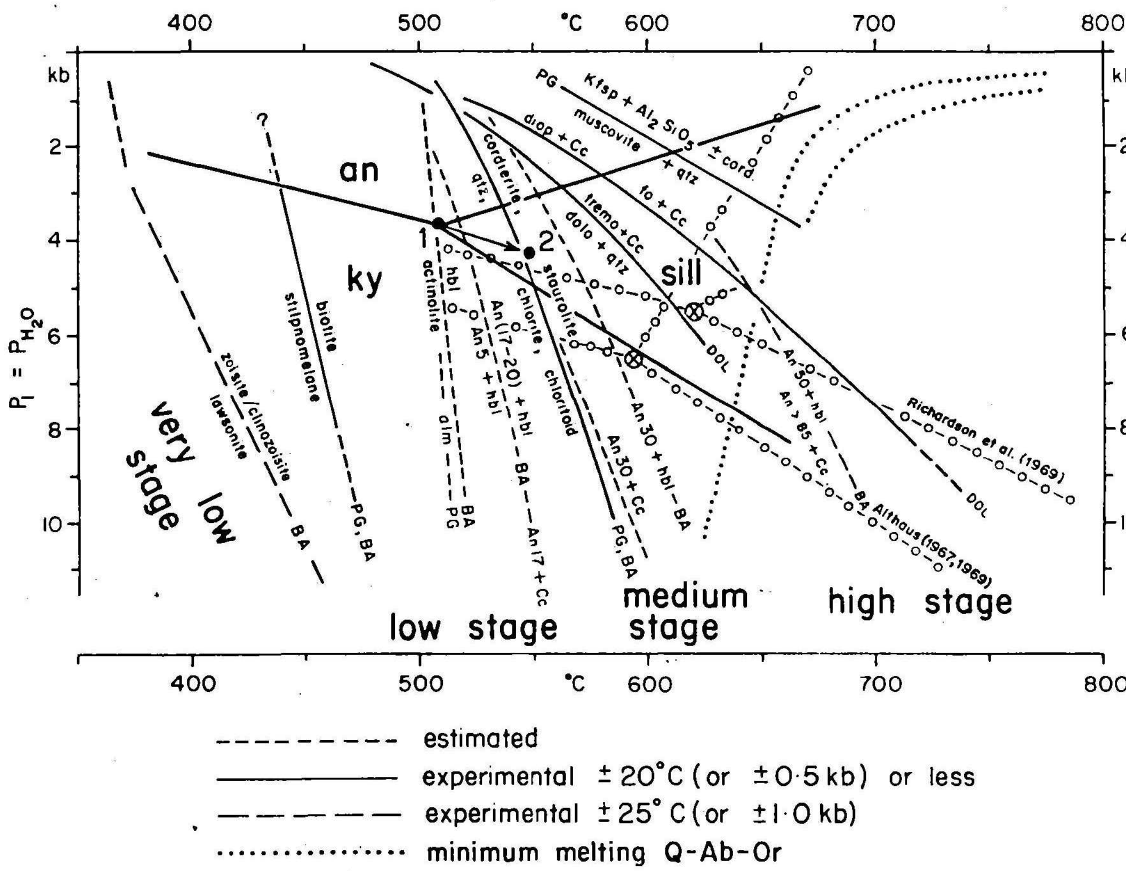


Fig. 26 Isograds in the low and medium stages of metamorphism (after Winkler, 1970).

LEGEND

1 Aluminium silicate triple point after Holdaway (1971).

2 Triple point compromise based on 15 experimental works and numerous geological considerations.

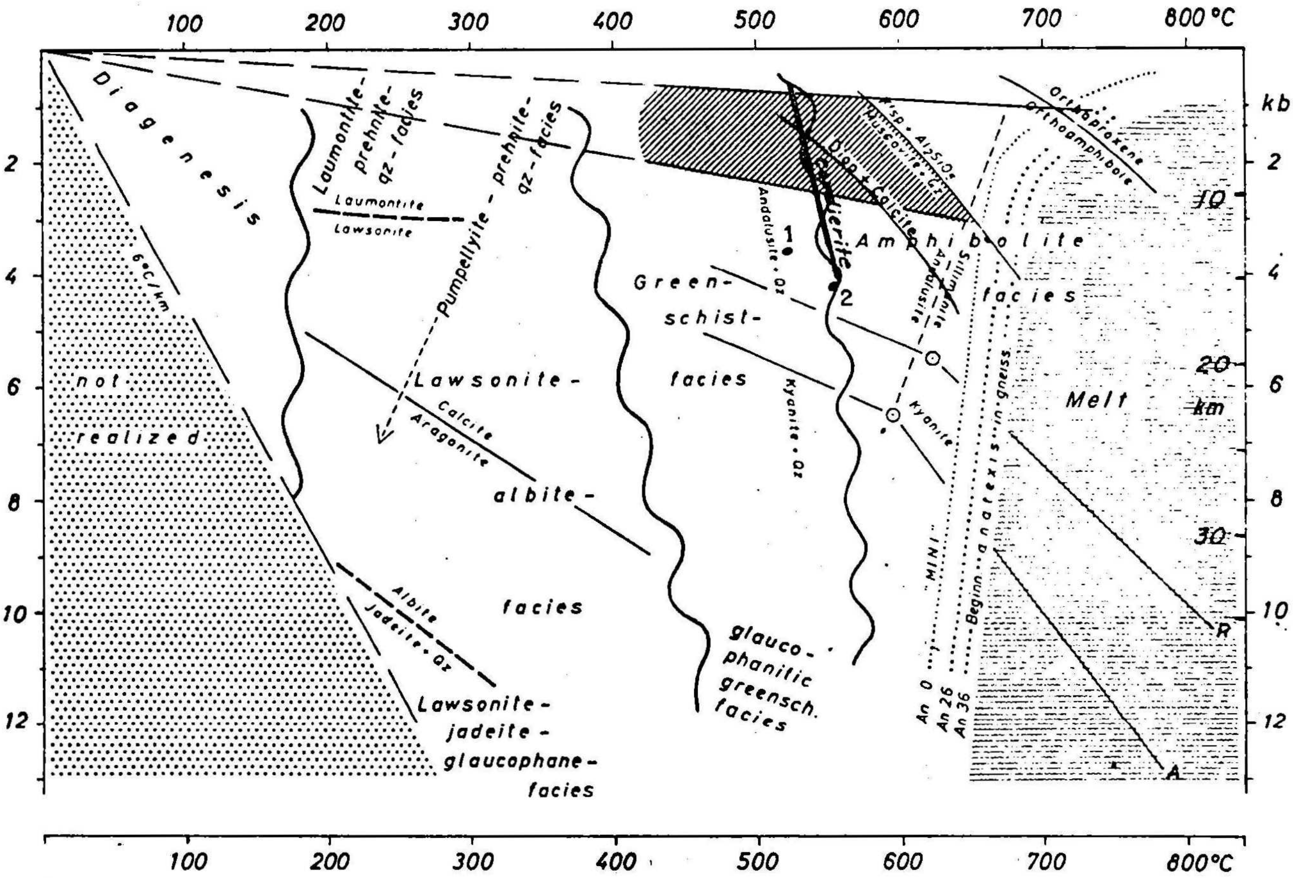
⊗ Triple points of Althaus (1967, 1969) and Richardson et al. (1969).

BA basaltic and andesitic lava, and tuff and greywacke

PG pelitic and greywacke compositions

DOL siliceous dolomite ± calcite

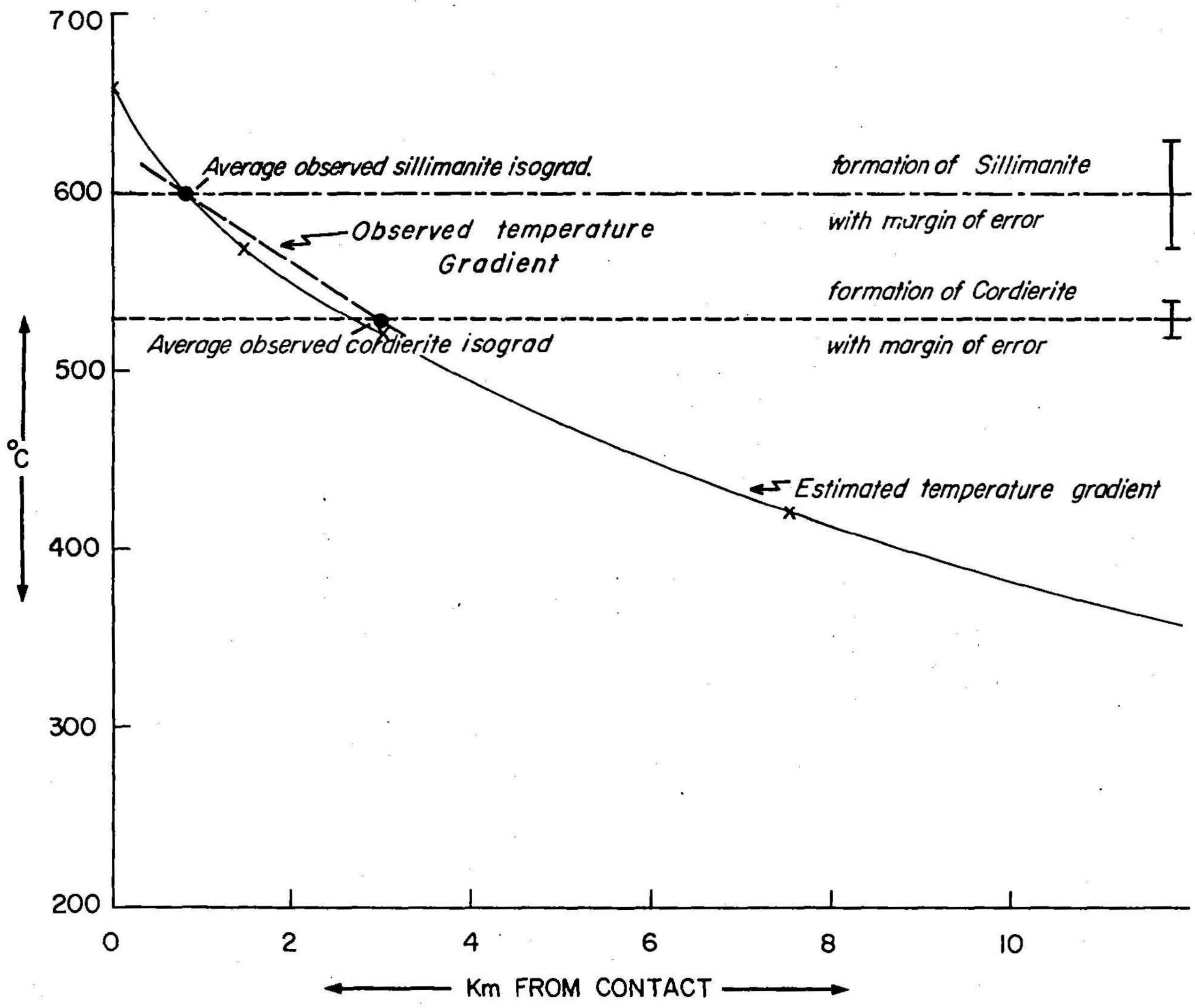
CcAn rocks containing calcite + plagioclase > An10




Approximate limits of metamorphism in the aureole of the Sybella Granite.

• 1,2 Alumina silicate triple points (see Fig. 26)

Fig. 27 Conditions of Metamorphism in Mount Isa Area.
(Modified from Winkler, 1970)



Assumptions -	*Depth of intrusion*	*- 10km*
	Temperature of country rock before intrusion	*- 200°C*
	Temperature of intrusion	*- 700°C*

Estimated gradient based on Winkler (1967) and Jaeger (1957)

Fig. 28 Comparison of estimated and observed metamorphic gradients at the intrusive contact of Sybella Granite between Mica and Sybella Creeks

Sybella Granite, it is evident that the observed temperature gradient closely approximates the estimated gradient. The gradient along a horizontal east-west line collinear with Lena Creek is much more shallow than expected, and together with an abundance of pegmatites and granite veins in the area, indicates that the granite contact is not far below the present surface and is probably shallow-dipping.

Metamorphic unconformities

A major metamorphic unconformity was described by Joplin (1955) between the Yaringa Metamorphics/'Big Toby Granite' complex (of greenschist facies metamorphism) and the adjacent unmetamorphosed Mingera Beds to be east. This metamorphic unconformity coincides with a major extension of the May Downs Fault.

Carter et al. (1961) recorded metamorphic unconformities between basic rocks on Kitty Plain, northwest of Mount Isa. Detailed mapping here has shown that the Sybella Granite is intruded by dolerite which has suffered very little metamorphism or deformation, in contrast to the metabasics of the Eastern Creek Volcanics and to the metadolerites which intrude the Eastern Creek Volcanics, just to the east of Kitty Plain.

A major metamorphic unconformity is represented by the Mount Isa Fault (Fig. 25), which separates Mount Isa Group rocks of chlorite grade to the east from the 'Haslingden Group' rocks of biotite grade to the west. The Mount Isa Group sediments were deposited, and subsequently metamorphosed, after the metamorphism associated with the intrusion of the Sybella Granite.

Metasomatism

The only metasomatism previously noted in the area was recorded by Joplin (1955), who stated that 'on the margin of the stressed granite west of Mount Isa (Sybella Granite, Pgs_2) ... the rocks are greisenized and tourmaline, fluorite, and topaz have been introduced'. We have also noted that chlorite schist and amphibolite in numerous localities adjacent to the Sybella Granite, especially pegmatites (Pgs_4), contain euhedral tourmaline crystals up to 150 mm in length. One of the main localities is about 1 km southeast of Big Beryl Mine.

Retrogression

Almost without exception cordierite-bearing rocks were found to contain chlorite, much of it secondary. Chlorite is not stable in the amphibolite facies (Winkler, 1967), and is probably a product of retrogressive metamorphism attributable to a regional low-grade metamorphism after the Mount Isa Group was deposited; this same metamorphism may be responsible for minor amounts of secondary epidote and chlorite in many of the basic rocks. Localized retrogression to the Lower greenschist facies is also seen in highly deformed zones such as the Mount Isa Fault. Basic rocks commonly contain retrogressive zones of chlorite schist.

STRUCTURE

The Mount Isa 1:100 000 Sheet area can be divided into five areas which have different styles of deformation. These areas are:

(i) the Yaringa Metamorphics/'Big Toby Granite' area in the southwest

(ii) the area of Mingera Beds extending from the northwest to the middle of the southern part of the Sheet area

(iii) the area of Sybella Granite extending north-south across the Sheet area

(iv) the eastern contact zone of the Sybella Granite

(v) the area east of the Mount Isa Fault.

The structure within each area is described below.

Yaringa Metamorphics/'Big Toby Granite' area

South of Yaringa Creek the structural trend is easterly, in contrast to the generally northerly trend of the Mount Isa region. This easterly trend is defined by a strong cleavage in the Yaringa Metamorphics and by metamorphic foliation and jointing in the 'Big Toby Granite'. Faulting, quartz veining,and the granite contact also have a similar trend. Farther south, near the Sheet area boundary, the main trends are east-northeast to northeast, and northwest parallel to a series of shears. Steep north-plunging lineations have resulted from the intersection of these three foliations.

North of Yaringa Creek the structural pattern is more complex. The cleavage trends north-northwesterly in the eastern part of the Yaringa Metamorphic outcrop, and northwesterly in the western part. Faults trend northwest, east, and north. The 'Big Toby Granite' here is more massive than that to the south and has a distinct foliation only near major faults, and the granite contacts are irregular and truncate the foliations in the metamorphics. No bedding has been recognized within the Yaringa Metamorphics.

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The Cambrian strata that unconformably overlie the 'Big Toby Granite' and the Yaringa Metamorphics in this area are relatively undeformed. They have a gentle (2 to 5°) westerly dip except near dragfolded north-trending fault zones, where they form drag-folds and dip as steeply as 60°.

Mingera Beds area

In the west of this area the Mingera Beds and overlying Pilpah Sandstone are relatively flat-lying and form some shallow basin-and-dome structures. Dips steepen and faults are more abundant in the east, towards the May Downs Fault zone, which extends north-northwesterly from 10 km south-southeast of Monaghans Bore to beyond the northern boundary of the Sheet area. The major fault in this zone, the May Downs Fault, is up to 100 m wide, filled with quartz, and associated with many subparallel quartz veins cutting adjacent mylonitized Sybella Granite and highly deformed silicified shale and siltstone of the Mingera Beds. Tight macroscopic folds and tight to isoclinal mesoscopic folds indicate a sinistral strike-slip movement. The mesoscopic folds plunge steeply north and at moderate to shallow angles to the south-southeast, possibly indicating two phases of movement.

In the southern half of the Sheet area near Carters Bore the Mingera Beds lie in a complexly faulted zone which may be the southern continuation of the May Downs Fault zone, but has a more northerly trend. The Mingera Beds occupy tight to isoclinal synclinal structures that are downfaulted between the Yaringa Metamorphics and 'Big Toby Granite' to the west and the Sybella Granite and Judenan Beds to the east. The general northerly to north-northwesterly trend of this southern area swings west-northwest between Big Toby and Little Toby Creeks, where a tight synclinal structure containing the Mingera Beds has been folded by sinistral strike-slip movement along the possible extension of the May Downs Fault. Minor flexures occur in the faulted sequence north and south of Carters Bore.

The Sybella Granite area

The two northern phases of the Sybella Granite, Pgs_1 and Pgs_3 are separated by an area of faulted metamorphosed quartzite and basic igneous rock in the far north, and by an area covered by alluvium farther south. The northeastern microgranite phase, Pgs_3, and the southern phase, Pgs_2, are separated by a complexly folded sequence of basic volcanics and quartzite. The northwestern phase, Pgs_1, and the southern phase, Pgs_2, have faulted contacts except for some possible intrusive contacts south of the Templeton River.

The intrusion of the Sybella Granite batholith was accompanied by updoming of the surrounding metasediments and metavolcanics. These now dip steeply (more than 70^o) away from the batholith, and near the northeastern contact they are slightly overturned.

The southern phase, Egs$_2$, contains roof pendants of steeply dipping metavolcanics and metasediments enclosing lobate masses of the granite, which may represent separate intrusive bodies petrologically indistinguishable from the larger part of the phase.

Igneous lamination is rare in the granites except near contacts where elongate xenoliths are present. A strong foliation in the southern phase of the granite may be metamorphic in origin; it has a general northerly to north-northwesterly trend, except near the margins of the pluton, where it tends to be parallel to the intrusive contact. A weak northerly trending foliation occurs in parts of the northwestern phase, but both northern phases are relatively massive.

Faulting and quartz veins are extensively developed in all phases of the granite; the predominant trend is northwesterly, but some quartz veins have northerly and northeasterly trends. Dolerite dykes are rare in the batholith.

<u>Eastern contact zone of the Sybella Granite</u>

This area is tightly folded about generally north-trending axes, and some major strike faults have been recognized. Phyllite and schist are widely distributed through the area, and gneiss and amphibolite occur in zones of higher-grade metamorphism. The Mount Isa Fault forms the eastern boundary of the area. Parts of the area have been previously mapped and studied in detail by various workers.

Brooks & Shipway (1960) recognized bedding striking north-northwest to north-northeast and dipping steeply west (65^o to vertical but mostly near 75^o) southwest of Mount Isa. The beds are tightly folded and some of the fold limbs are overturned. They recognized an east-trending cross-fold near Big Beryl Mine. Heidecker (1961) noted that intense deformation had caused transposition of bedding in the quartzite units. Bennett (1965) summarized previous mapping and noted overturning and folding in the Judenan Beds to the west of the Mount Isa Fault near Mount Isa.

Doust (1967) mapped part of the Eastern Creek Volcanics northwest of Mount Isa, where he recognized folding with east-trending axes. Ramsay (1970) did further work in this area and noted the general westerly dip and a west-plunging moderately folded anticline in volcanics and pelites. He

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postulated that this anticline had been 'pinched' to the west by the intrusion of the Sybella Granite. According to the classification of Wilson (1973) the folds recognized by Ramsay are probably second generation. High-angle faults have northeasterly and less commonly northwesterly trends, and Ramsay related those filled by dolerite dykes to the intrusion of granite.

In the same stratigraphic sequence south of Mount Isa, Ramsay (1971) recognized overturning of the Mount Guide Quartzite, Eastern Creek Volcanics, and Judenan Beds, and considered that the sequence was warped by the intrusion of the Sybella Granite, which also produced complex structures such as isoclinal folds in the Mount Guide Quartzite. In this area he doubted the fundamental nature of the Mount Isa Fault and mapped other faults parallel to it to the west. A similar system of north-trending faults upthrown to the west was recognized near the northern Sheet area boundary by geologists of Anaconda Australia Inc. (Hruska, 1971). Hruska postulated that the intrusion of the Sybella Granite had superimposed a roughly concentric system of faults with sinistral horizontal movements on the earlier north-trending fault system, and he included the Mount Isa Fault in the younger system. He also recognized still younger but relatively minor sets of faults (Class C and Class D faults).

A structural and petrofabric analysis by Wilson (1973a,b) of an area west of the Mount Isa Fault, from 4 km north to 16 km south of Mount Isa, highlights the importance of faults in the area. In this work Wilson attempted to relate the faulting to three generations of folding. He recognized three major north-trending faults (Faults I, II, and III) in the Judenan Beds to the west of the Mount Isa Fault, and described in detail the fault surfaces or fault zones, with particular emphasis on the orientations of mesoscopic folds, macroscopic folds, and mineral lineations. He identified first-generation folds (F_1) only in the Judenan Beds adjacent to the Mount Isa Fault in the far south of the area studied, where they plunge about 45^o to the north-northwest. Second-generation folds (F_2) in the Mount Isa Fault zone plunge north or less frequently south at varying angles from shallow to near vertical. Third-generation folds (F_3) plunge steeply west, with less frequent moderately shallow plunges towards the north, northwest, or southwest. The Mount Isa Fault zone and Faults 1 and III are thought to accompany and postdate the second-generation folds. Other work in the Mount Isa Fault zone has been done by Powell (1963) and Lister (1969). Some cross-faults postdate these major faults and, according to Wilson (1973a), are younger that the youngest recognizable folding.

East of the Mount Isa Fault

This area has been studied by numerous company geologists because it contains the mineralized parts of the Mount Isa Group. It consists of the western limb of an extensively faulted major anticline. Many faults oblique to the bedding, and marked strike-slip displacement, differentiate this area structurally from the area to the west of the Mount Isa Fault.

The major structural features of this area were described by Blanchard & Hall (1937, 1942), who correlated the structures with three distinct movements during one structural deformation event. The first movement was major overthrusting accompanied by folding and brecciation in zones that were later silicified. During the second movement, crushing and shearing - which fractured the silicified breccia, and distorted bedding-planes in shales - was accompanied by the replacement of some earlier-formed carbonate by dolomite or ankerite, and by pyrite impregnation, silicification, and finally silver, lead and zinc sulphide mineralization. The third movement produced cross-fracturing, and was accompanied by calcite veining, and minor quartz and ankerite veining. Blanchard & Hall (op. cit.) related the first two movements to the intrusion of the Sybella Granite, and the final movement to the intrusion of the 'Mica Creek Pegmatite'. They considered the earlier movements to be 'a minor feature of a comprehensive deformation event which produced much more extensive folding in the quartzite, schist and arenaceous rocks to the south-southwest'.

Knight (1953), in his description of the area surrounding the Mount Isa Mine, noted two periods of faulting: an early set of conjugate faults trending 045° (dextral) and 130° (sinistral), and a later set of dextral strike faults. He recognized steeply north-plunging drag-folds associated with this second set of faults and 'thrust zones' near the Mount Isa Fault where beds had fractured owing to compression along strike. Major folds included a north-plunging syncline near the northern boundary of the Mount Isa Sheet area, and the rotation of strike from north-south to east-west immediately to the south (near Lake Moondarra). The complicated structural patterns in the whole of this area was attributed to extensive faulting.

Carter (1953a) examined the Mount Isa Mine area in more detail and noted minor folds that generally plunge north at 20° to 30°. He noted axial-plane folding in the 'silica dolomite', and also reported transverse tension faults, which were shown by Beresford (1953b) to displace strike faults, to trend 290° to 315°, to dip steeply south, and to be downthrown to the south.

Around Mount Isa, Murray (1961) recognized early strike faults (Mark I faults), overthrusts (Mark II faults) that developed towards the end of the major folding, later strike faults (Mark III faults), and finally minor transverse faults. Darlington (1961) presented data for folds in the shale and 'silica dolomite'. He recognized three groups of folds: (i) fully developed north-plunging folds, (ii) fully developed south-plunging folds, and (iii) flexures in various stages of development. Most folds plunge 20 to 60° at 320 to 360°, but some plunge 60° to the west and others plunge south at shallow angles. He considered that the shearing, except for bedding-plane shearing, was allied to the folding, and determined that the west blocks had moved up and north along the north to north-northwest shears.

Cordwell, Wilson, & Lord (1963) were the first to detail the structure of the upthrown blocks of volcanics to the south of Mount Isa. They recognized three main groups of faults:

(i) Cross-faults, which occur in the volcanics but extend into the Mount Isa Group owing to later movements. The north blocks have moved along these faults. Not all the faults penetrate the Mount Isa Group indicating a hiatus in deposition.

(ii) Strike faults antedating and postdating the folding: the east blocks have moved up and north along the earlier faults (Mark I of Murray, 1961) whereas the west blocks have moved up and north along the later faults (Mark II).

(iii) Low-angle faults that separate the volcanic blocks from the Mount Isa shales.

Cordwell et al. (op. cit.) considered that the discordant contact between the Mount Isa Group shales and the volcanics, or greenstone (Carter, 1953a), at the base of the Mount Isa Mine was a fault related to the third group of faults. They also noted that later movements had occurred on most faults. The concept of penecontemporaneous faults has been investigated by Smith (1969) to the east of the Mount Isa Sheet area.

McDonald (1970) studied folds within Mount Isa Mine, and concluded that differential movement had occurred within the incompetent sulphide bands during deformation; thus the silver-lead-zinc ore must have been deposited before deformation, in contrast to the views held by many of the previous workers, who favoured an epigenetic origin for the ore.

Mathias (1972) considered that the general westerly dipping strata south of Spring Creek form the western limb of a north-plunging anticline produced by Wilson's (1973) deformation F_2. Minor folds formed by Wilson's F_1 deformation have axial traces striking 345^o, and generally plunge about 40^o to the north. South-plunging minor folds occur only in northeast-trending fault zones. Minor folds plunging both north and south are open to isoclinal and asymmetric. Tighter folding in structurally higher (uplifted) blocks was caused by simultaneous faulting, especially along weaknesses such as the Mount Isa Group/Eastern Creek Volcanics contact. Mathias (op. cit.) recognized three types of faulting:

(i) Southeast-trending faults downthrown to the south, e.g., Spring Creek Fault (intersecting the Barkly Highway 3.5 km north of Hilton).

(ii) Faults trending 030^o with a strong horizontal movement.

(iii) North-trending faults upthrown to the west. e.g., Mount Isa Fault.

GEOLOGICAL HISTORY

The oldest rocks in the Sheet area are the Yaringa Metamorphics, which occur as discontinuous weathered outcrops near the western limit of exposure of the Proterozoic rocks. They are known to be older than 1760 m.y. (Page & Derrick, 1973). Originally they were probably labile arenaceous sediments, possibly equivalent to the Murphy Metamorphics 300 km to the north (Plumb, pers. comm.). Wilson (1972) states they are petrographically distinct from the Leichhardt Metamorphics, which occur 40 km to the east, but this does not preclude the two units being of similar age, and the acid volcanics in the Yaringa Metamorphics may be correlated with similar flows in the Leichhardt Metamorphics.

The 'Big Toby Granite' intruded the Yaringa Metamorphics about 1760 m.y. ago (Page & Derrick, 1973), possibly causing uplift (Fig. 29b), and contributed to the complex metamorphism of the Yaringa Metamorphics. This intrusion may be broadly contemporaneous with the Ewan Granite, to the northeast, which has been dated at 1785 m.y. (Richards, 1966), although the Ewan Granite is reported to intrude the Argylla Formation (Carter et al., 1961) which is thought to be much younger than 1760 m.y. During or after this tectonism, acid lavas of the Argylla Formation were poured out over most of the region (Fig. 29c). Further earth movements accompanied the emplacement of the Kalkadoon Granite, to the east, 1686 m.y. ago (Fig. 29c) (Page & Derrick, 1973).

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The 'Haslingden Group' was deposited on the crystalline basement of acid volcanics and Kalkadoon Granite south-east and east of the Sheet area and on the Yaringa Metamorphics/'Big Toby Granite' complex west of the Mount Isa Fault. The greatest thickness of sediment was deposited in the incipient Mount Isa Trough (Glikson, Derrick, Wilson, & Hill, 1974), a meridionally elongate basin - possibly bounded by faults - between the Leichhardt-Kalkadoon high to the east and the Yaringa/'Big Toby Granite' high to the west. As this trough developed, conglomeratic greywacke and sublabile quartzite of the lower formation of the 'Haslingdon Group', the Mount Guide Quartzite, was deposited in nearshore areas (Fig. 29d). In the Mary Kathleen Sheet area, to the east, clasts of granite and acid volcanics in the conglomerate reflect the basement source area (Derrick et al., 1974). Basic volcanic activity followed, represented by the Eastern Creek Volcanics (Fig. 29e), which accumulated mostly in the trough but some lava flows extended well to the east and west; amygdaloidal basalts with brecciated flow tops show many features of subaerial lava flows. Sandstone lenses are common between flows, especially in the upper part of the unit, and may represent fluvial deposits; they culminate in the 'Lena Quartzite Member'. On the western side of the trough however, sedimentary intercalations are pelitic, and their origin is uncertain. After the extrusion of the basic volcanics there was a renewed accumulation of basement-derived quartzo-feldspathic debris - the Myally Beds to the east of the Mount Isa Fault, and the Judenan Beds to the west (Fig. 29f). Marked thickness variations, particularly within the Myally Beds, are probably due to fault-induced irregularities in the depositional trough (Smith, 1969; Derrick et al., 1974).

West of the Mount Isa Fault the Haslingden Group was intruded by the Sybella Granite (Fig. 29g), the three major phases of which Pgs_2, Pgs_1, and Pgs_3, have been dated as 1646 ± 15 m.y., 1577 ± 13 m.y., and 1537 ± 40 m.y. respectively (Page & Derrick, 1973; Page, pers. comm., 1974). This intrusion was responsible for considerable structural deformation and uplift, and probably initiated the Mount Isa Fault. It also caused the development of a high-grade/low-pressure metamorphic aureole in which rocks up to sillimanite-grade have been recorded, especially in the 'May Downs Gneiss Member', at the base of the Mount Guide Quartzite, and was accompanied by the extrusion of 'Carters Bore Rhyolite' onto the Judenan Beds.

The 'Haslingden Group', granites, and older rocks are overlain unconformably or disconformably by the Mount Isa Group in the east and the Mingera Beds and Paradise Creek Formation in the west (Fig. 29h). The Mount Isa Group appears to have been deposited entirely within the Mount Isa Trough, which at this time was bounded by the Gorge Creek Fault to the east (Derrick et al., 1974) and the Mount Isa Fault to the west, whereas the Mingera Beds were deposited in a poorly defined basin west of the Sybella Granite. A high relief in the source area for the sediments is inferred from the presence of basal conglomerate and arenites in the two sequences, especially in the west. In both these basins the tectonic environment became increasingly quiescent, and finely laminated shales and siltstones were deposited. In the Mount Isa Trough some of these shales were dolomitic, and some thin tuff beds of great aerial extent were also deposited. Leaching of base metals from exposed basalts of the Eastern Creek Volcanics on the eastern edge of the trough may have been a source of the syngenetic (cf Croxford, 1965) silver-lead-zinc ores, and possibly of the partly syngenetic (Smith & Walker, 1971) copper ores of the Mount Isa and Hilton deposits.

Since the Mount Isa Group was deposited, considerable faulting and some associated folding has occurred (Fig. 29i), probably during a phase of deformation related to the widespread regional metamorphism that apparently accompanied the emplacement of large granitic intrusions north and south of Cloncurry, 90 km east of the Sheet area. These intrusions have been dated as between 1400 and 1500 m.y. (Page & Derrick, 1973). The north-trending fold axes, termed F_2 by Wilson (1972, 1973), are considered to belong to this phase of deformation and not to an older phase related to the intrusion of the Sybella Granite, as stated by Farquharson & Wilson.

The Pilpah Sandstone was laid down in the northwest of the Sheet area after the main structural deformation had taken place. It has been subjected only to gently basin-and-dome folding since it was deposited.

The whole area was uplifted and eroded before Middle Cambrian siltstone, slate, chert, and phosphorite was deposited in the Georgina Basin. Denudation and minor deposition occurred in the Mesozoic and again in the Cainozoic.

ECONOMIC GEOLOGY

History

Copper and gold production began in areas to the east in 1867, but did not start in the Mount Isa 1:100 000 Sheet area until about 1896, when small gold deposits were discovered in the May Downs area, 45 km northwest of Mount Isa. Small amounts of gold were mined from the May Downs goldfield early this century, during the 1930s, and since

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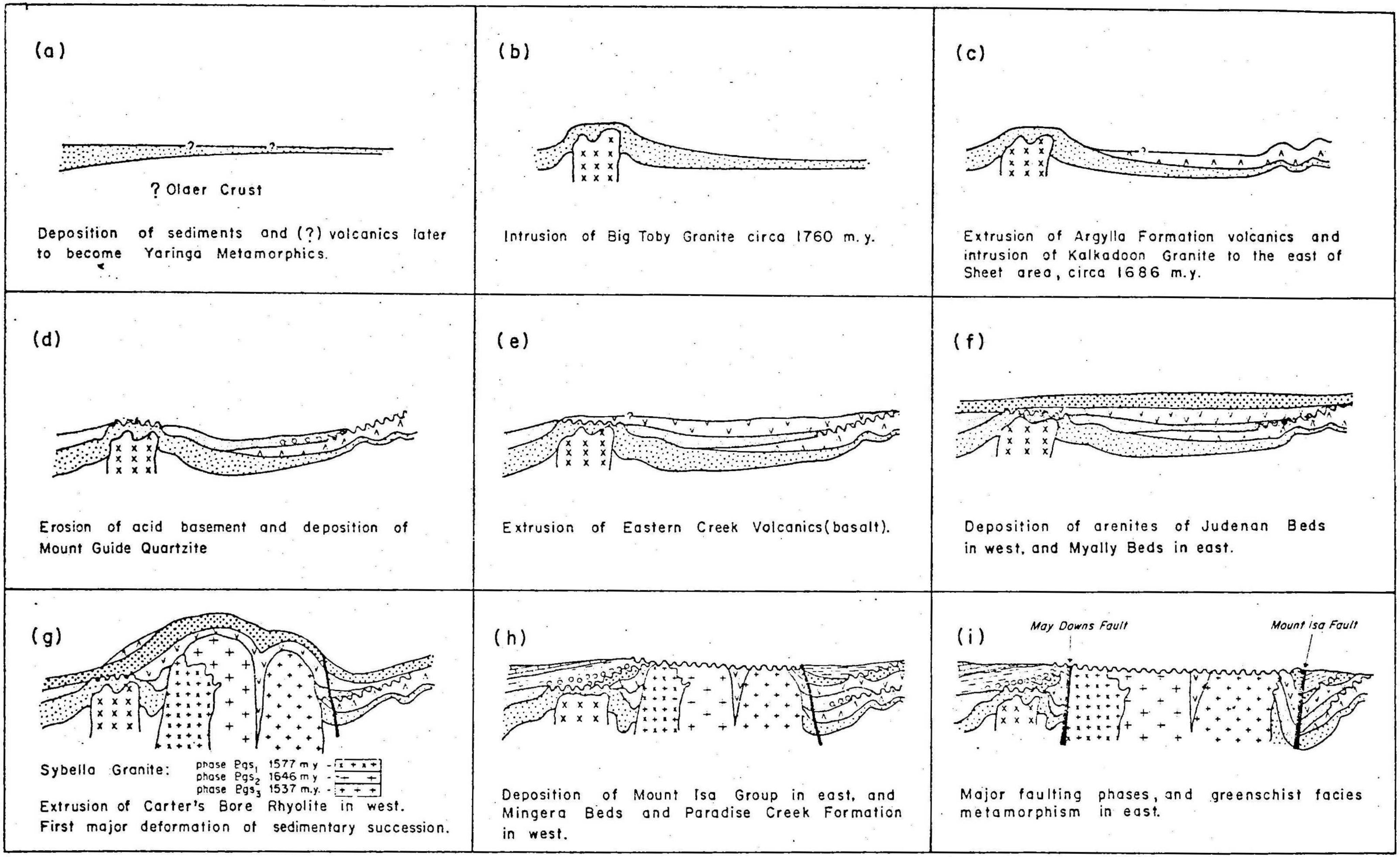

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Fig. 29 GEOLOGICAL HISTORY PRESENTED SCHEMATICALLY AS CROSS-SECTIONS.

1970. The 'Mica Creek Pegmatite' 10 km southwest of Mount Isa yielded small amounts of mica between 1922 and 1927, and beryl between 1943 and 1960. Tin has been recorded from these pegmatites (Shepherd, 1938), but has not been mined. The gold and pegmatite deposits are insignificant compared with the major lead-zinc deposits discovered at Mount Isa in 1923, and the associated major copper deposits discovered in 1927-28. Several small copper and lead-zinc deposits have since been found in the Eastern Creek Volcanics and Mount Isa Group in the eastern part of the Sheet area. After geochemical work (Debnam, 1953, 1954), Mount Isa Mines Ltd carried out a drilling program in their 'Northern Leases', this proved substantial reserves of lead-zinc ore, currently (1975) being developed at the Hilton mine. A number of small uranium prospects were discovered in the Eastern Creek Volcanics during 1954, but further exploration has indicated they have little or no economic potential.

Production of lead-zinc began on a large scale at Mount Isa in 1931, but copper ore was not mined until 1941. At the instigation of the Commonwealth Government's Mineral Production Committee, established during World War II, lead-zinc production was stopped in 1943 and only copper ore was mined between 1943 and 1946 in an attempt to increase Australian supplies of copper. From 1946 to 1953 Mount Isa Mines produced only lead-zinc, but subsequently has produced both lead-zinc and copper. More details of the history of the region can be found in Blainey (1960).

Exploration

The early prospecting in the region for gold and copper produced meagre results in the Mount Isa Sheet area. A lease-pegging rush followed the discovery of oxidized lead ore at Mount Isa, but this activity was limited to several kilometres along strike surrounding the original find. These leases were later amalgamated into a special mining lease owned by Mount Isa Mines Ltd, and exploration was restricted to proving the ore reserves within this area. In 1947 a new era in exploration began in the region when Zinc Corporation Ltd took out an Authority to Prospect surrounding the Mount Isa Mines Ltd leases. Mount Isa Mines Ltd followed this lead and took out an Authority to Prospect in the following year to expand its exploration program.

The areas that have been covered by Authorities to Prospect in the Mount Isa 1:100 000 Sheet area are indicated in Figure 30 by means of a series of outline maps. The company that held each Authority to Prospect; and a summary of the work carried out on each, is listed in Table 25, and areas that have been explored by stream-sediment geochemistry are shown in Figure 31. Soil sample geochemistry has also been applied to small areas near the Northern Leases and the Mount Novit lead-zinc deposits (Debnam 1953, 1954).

The early company activity was directed towards the discovery of extensions to the Mount Isa lode along strike to the north and south; later exploration was directed to areas containing similar rock types to the east and west. In 1954 Mount Isa Mines Ltd carried out an extensive airborne scintillometer survey as part of a search for uranium (Bennett, 1955), and a complementary survey was carried out by the BMR (Parkinson, 1956). However neither survey discovered any worthwhile deposits that had not been discovered previously. More recently, follow-up work has been done on known uranium prospects by United Uranium NL (McBride, 1958) and Queensland Mines Ltd (Thakur, 1970, 1971). Some company interest has also been shown in the 'Mica Creek Pegmatite' with a view to discovering further deposits of beryl or workable deposits of tin, tantalite, fluorite, and other minerals associated with pegmatite. Most of the recent activity in the Mount Isa region has been directed towards the discovery of base metal deposits, and the exploration for phosphate in the Cambrian strata west of Mount Isa.

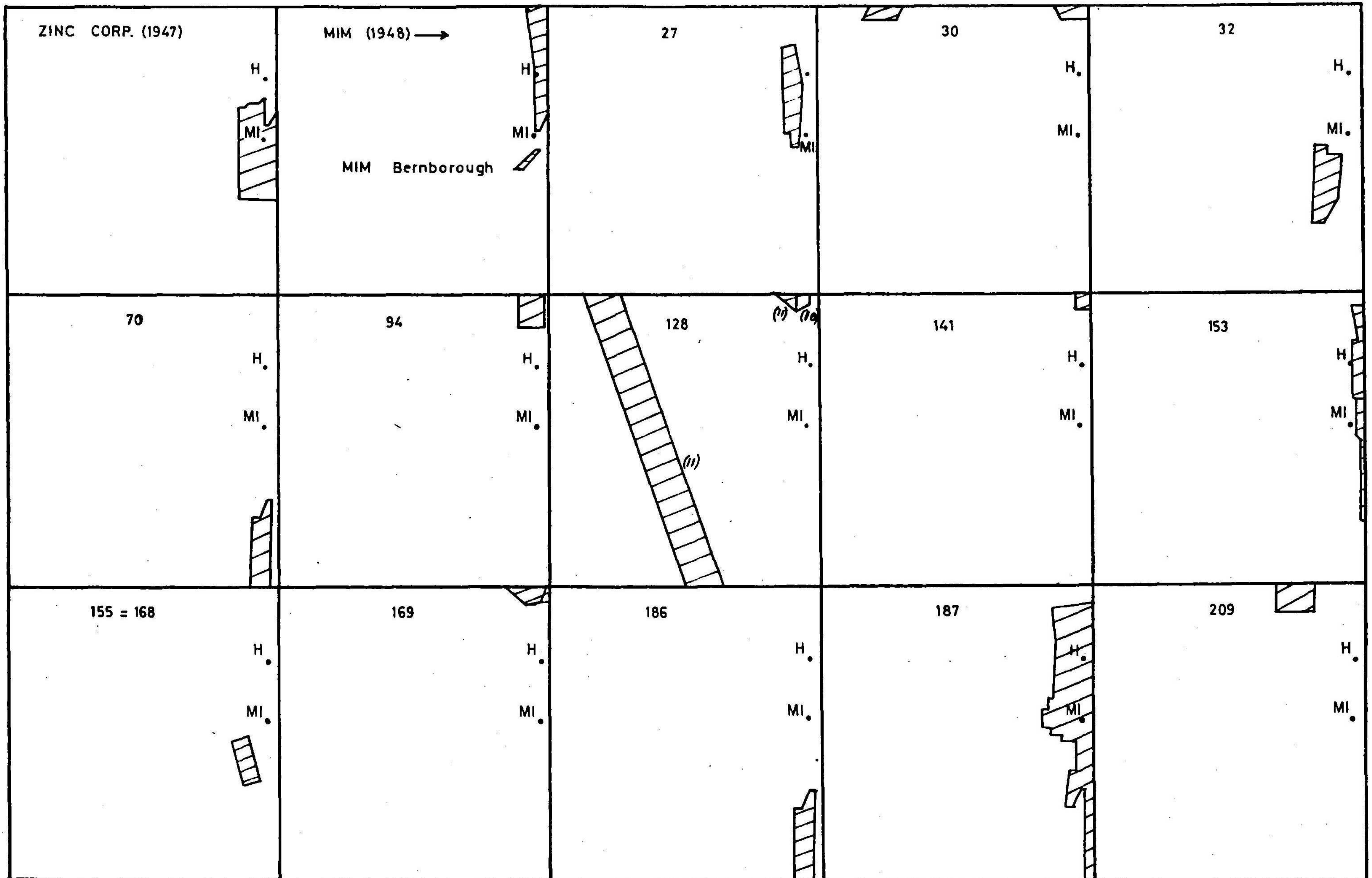
Production

Table 26 summarizes the production from mines in the Mount Isa 1:100 000 Sheet area, and shows how the Mount Isa Mine has dominated the production of base metals. The annual production of Mount Isa Mines Ltd between 1931 and 1971 is shown graphically in Figure 32.

Description of deposits

Copper

The Mount Isa copper orebodies have been described by numerous authors. A recent general description can be found in Bennett (1965, 1970a), and an earlier summary is given by Carter et al. (1961). The copper orebodies are contained in a structurally deformed part of the Urquhart Shale that is known locally as 'silica-dolomite'. In the primary ore copper occurs as chalcopyrite associated with pyrite and pyrrhotite. Secondary oxidized ore, no longer mined, was obtained from the Black Rock Open Cut before 1965. Copper mineralization is present throughout the 'silica-dolomite', but economic concentrations are restricted to an indistinct en echelon pattern of elongate bodies in both plan and section (Bennett, 1965). Smith & Walker (1971) use geochemical data to show that the copper ore bodies are most probably epigenetic, and derived from the underlying metabasalts.



MI *Mount Isa* H *Hilton* 27 *Registred number of Authority to Prospect*

Fig. 30 a. Approximate locations of Authorities to Prospect in the Mount Isa 1:100 000 Sheet area (Scale 1:1000 000)

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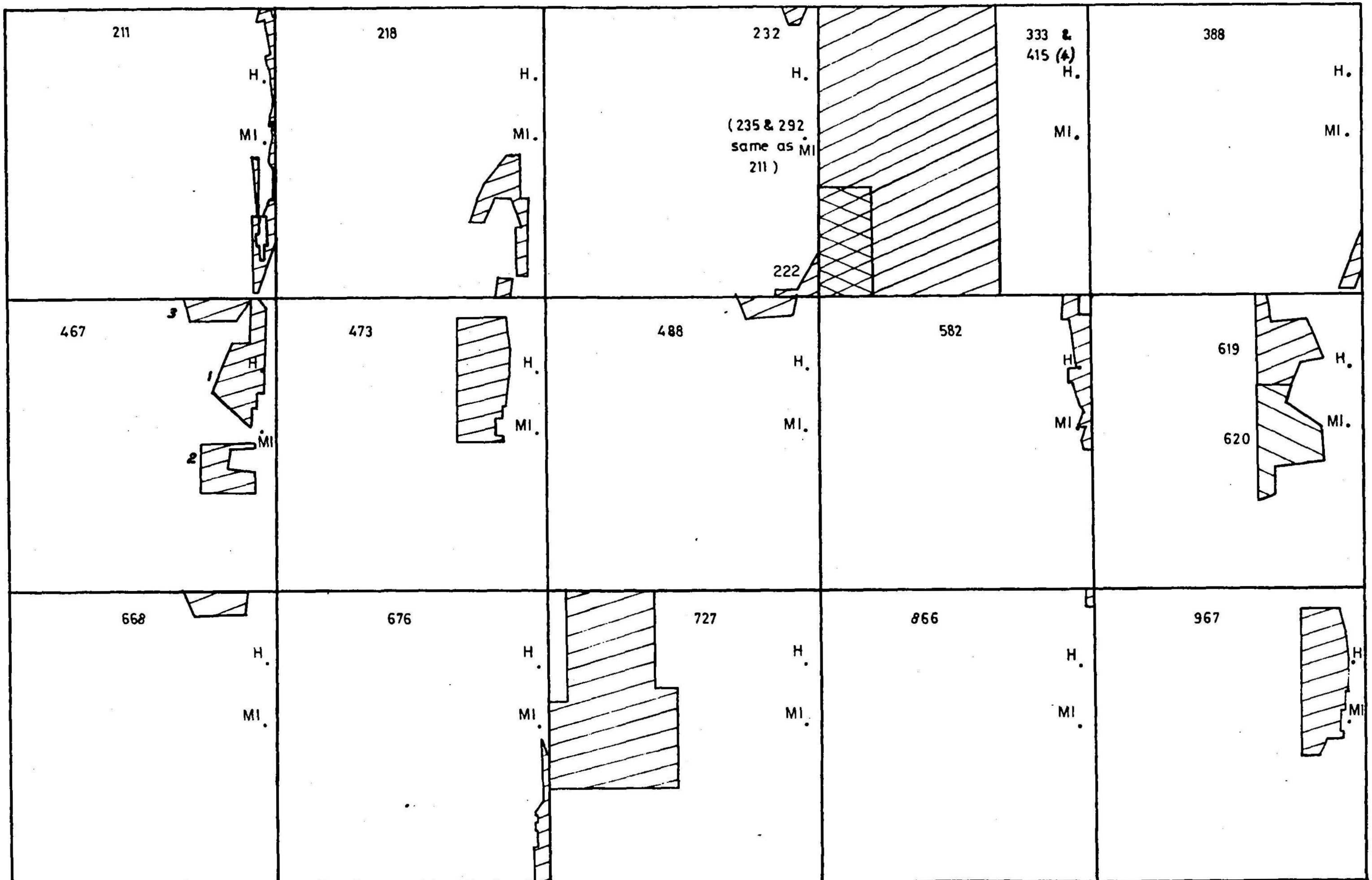

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Fig. 30b. Approximate locations of Authorities to Prospect in the Mount Isa 1:100 000 Sheet area (Scale 1: 1 000 000)

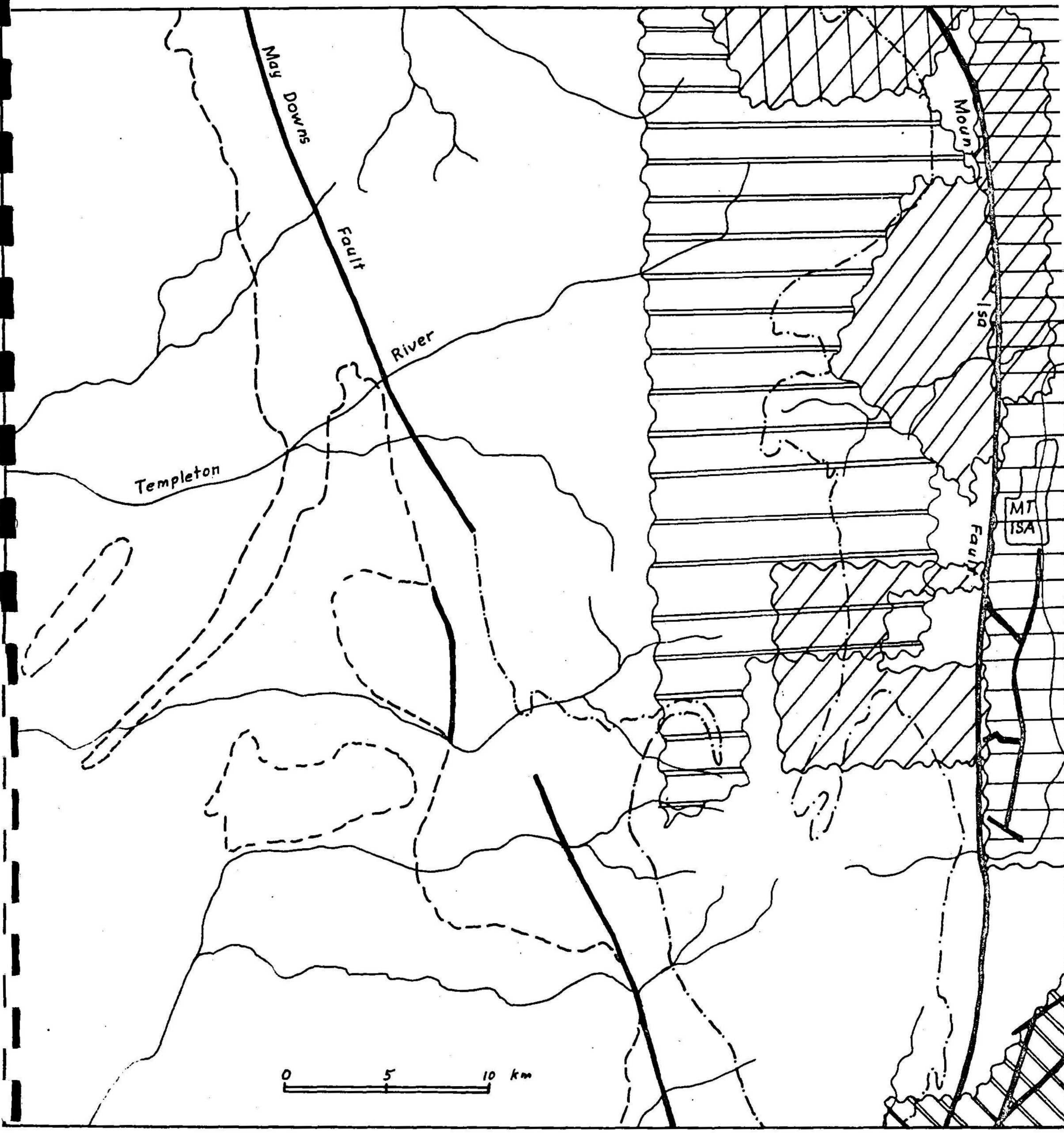
MI *Mount Isa* H *Hilton* 211 *Registred number of Authority to Prospect*

TABLE 25. WORK DONE ON AUTHORITIES TO PROSPECT IN THE MOUNT ISA SHEET AREA.
(X indicates work carried out)

A.P.No.	(1947)	(1948)	Bern-borough	27	30	32	70	94	128	141	153	155	168	169	186	187	209	211	218	222	232	235	292	333	388
Coy	Zinc Co.	MIM	MIM	MIM	MIM	MIM	Mining Corp	United Uranium	Rio Tinto	Rio Tinto	MIM	MIM	MIM	Rio Tinto	MIM	MIM	MIM	MIM	MIM	Aus-minda	CRA	MIM	MIM	Mines Ex.	Old Mines
Granted	1947	1/10/47	1/6/52	1/5/56	1/6/56	1/6/55	25/10/56	1/5/57	1/10/59	1/6/59	1/1/60	1/3/60	1/9/60	1/10/50		1/11/61	1/11/62	1/11/62	1/4/63	22/5/63	1/10/63	1/11/63	1/7/65		1/3/67
WORK DONE																									
Air Photo (scale)	1:7200	1:7200				1:7200			(1:50,000)							1:24,000			1:8000						
Photo Map	X	X																							
Geol. Map (scale)	X	X		1:24,000		1:22,000	1:24,000		1:63,360	1:63,360					1:24,000	1:24,000		1:24,000	1:8000			1:22,000			1:63,360
Detailed Geol. Map (Scale)	X	X		1:4,800			1:6,000		1:5,000						1:1,200	1:4,800			1:2,400						
Stream Sed. Geochem.																				(1203)					
Detailed Geochem.	X	X					X																		
Costean (No.)	X	X	X																9						(?)
DDH No. Holes			1	2		2	6		1																
Total Lgth			500m	1020m		1400m	2750m		102m																
Rotary Drilling No. Total Lgth																			108 300m						
Shafts							X																		
Air Mag.																									
Air E M																									
Air Scint																									
Mag.	X	?																							
E M																									
Grav	X	?																							
Resistiv.																									
I.P.														(?)											
S.P.																									
Radio act.				Berylo-meter				?				Berylo-meter	Berylo-meter												
Anomaly Evaluation																									
Petrog.						X																			
Mineralogy						X	X																		
Gen. Geol.						X	X																		
Prospect Evaluation	X					X	X																		

TABLE 25. (CONT). WORK DONE ON AUTHORITIES TO PROSPECT IN THE MOUNT ISA SHEET AREA

A.P. No.	415	467	473	488	582	588	619	620	668	676	727	866	967
Coy.	BHS	Qld Mines	Qld Mines	Qld Mines	MIM	CEC	Fraser and Associates		Anaconda	Pioneer Mining & Exp.	Pioneer Mining & Ex.	Naylor & Edsa	Esso
Granted	1/1/67		1/1/68	1/2/68		1/3/69	1/6/69	1/6/69	1/10/69	1/10/69			28/7/72
Air Photo (scale)													
Photo Map (scale)	1:50,000			X						1:120,000	1:30,000		
Geol. Map (scale)	1:24,000	1:50,000		X	1:8,500				1:24,000	1:50,000			
Detailed Geol. Map (scale)	1:600	1:600	1:600						1:4,800				
Stream Sed. Geochem		X					X	X	X		?		
Detailed Geochem										X			
Costean No.		37	X							X			
DDH No.			4		1								
Total lgth			460m		400m								
Rotary Drilling No.		7								30			
Total lgth		250m								1100m			
Shafts													
Air Mag		X			X								X
Air E M							X	X					
Air Scint		X				X	X	X					X
Mag							X	X					
E M													
Grav													
Resistiv													
I.P.									X				
S.P.													
Radioact.		X	X	X		X	X	X					X
Anomaly Evaluation													
Petrog			X		X								
Mineralogy				X					X				
Gen. Geol.	X	X	X		X		X		X	X	X		
Prospect Evaluation					X	X	X	X	X				



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A.P. 222	Asuminda Pty. Ltd.	Cu	(Bell, 1965)
A.P. 292	Mount Isa Mines Ltd.	Cu, Pb, Zn, Ni, Co	(Battey, 1965e, 1966)
A.P. 467	Qld. Mines Ltd.	—	(Thakur, 1970, 1971; Qld. Mines Ltd., 1971)
A.P. 619, 620	Fraser and Associates	—	(Mullins & Calaizlis, 1971a, b)
A.P. 668	Anaconda	Cu, Pb, Zn	(Hruska, 1970, 1971)

Fig. 31 Mount Isa 1:100 000 Sheet area - areas of streamsediment geochemistry

TABLE 26a. MINE PRODUCTION, MOUNT ISA 1:100 000 SHEET AREA to 1971

(A) COPPER

Mine	Ore	Copper (t)	Gold (gm)	Years of production
Argent?	24	1.3		pre-1958
Argyle?	86	4.9		"
Blue Bird?	216	15.8	6	"
Blue Hills?	68	24.0		1963-64
Blue Mantle?	105	8.8	2	pre-1958
Cluny	60	3.1		" and 1971
Copper Conquest	22	2.0		1967-68
Copper King?	28	4.8		pre-1958
Della Joy?	32	3.2		"
Doolan's Hope	17	2.0		"
Eagles Nest	19	1.5		"
Five to Nine?	21	1.5		"
Fortyniner?	86	5.6		"
Glance	7	0.6		1967
The John?	47	3.3		pre-1958
Lady Ellen?	41	5.9		"
Lucky Strike	87	6.7		1968
Lucky Strike No. 2	8	0.1		1968
Mavis?	27	2.3		-
Mount Burns	30	2.1		-

TABLE 26a (Contd.)

Mine	Ore (t)	Copper (t)	Gold (gm)	Years of production
Mount Isa	30 000 000	1 090 000		1943-71
Native Bee	888	77.4		-
New Bluebird?	96	7.8		-
Philice?	7	1.1		-
Red Wings	29	1.4		-
Rosina?	7	2.1		-
Top of the World?	42	3.9		-
Victoria?	19	0.7		-
Waimate?	11	1.7		-

(B) Silver-Lead-Zinc Table 26b.

Mine	Ore (t)	Silver (kg)	Lead (t)	Zinc (t)	Years of production
Bernborough	6650		1750		1947-51
Copalot	324		54		1955-57
Doolan's Hope	7		1		1950
Mount Isa	38 000 000	2200	2 330 000	1 830 000	1931-71
Mount Isa Dumps	24		6		1949
North Star	201		48		1950-51
Silver King?	89	40	48		1966
South Crystal	181		32		1949-51
Spider Ant & Reject	55		29		1930

TABLE 26a. (Cont.)

(C) Other Minerals

Mine	Type of ore	Ore	Quantity, metal or mineral	Years of production
Big Beryl	Beryl		73 t	1943-58
Hexagon, Beryl Queen, Beryl King	"		7.8 t	1958
Mica Ck area	Mica		0.6 t	1922/25/27
Crescent No. 1	Gold	246 t	3.1 kg	1927-35
Hidden Valley	Silica		22 400 t	
White Blow	"		8 000 t?	1971
Snowy	"		3 100 t	1967
Mount Isa Mines	Cadmium carbonate*		85 t	1948-1956

* Not now separated from zinc concentrates and no precise figures of recovery are available.

The small copper lodes within the Mount Isa Group to the south of Mount Isa - at the Cluny, Doolan's Hope, Eagle's Nest, and Native Bee Mines - occur as epigenetic veins containing chalcopyrite with a quartz gangue, and as disseminations of copper minerals in the wall rocks.

Numerous copper occurrences are known in the Eastern Creek Volcanics, both east and west of the Mount Isa Fault, but none of these has been of economic importance. These deposits consist of chalcopyrite in epigenetic quartz veins cutting metabasalts, and are commonly associated with traces of uranium mineralization.

Silver-lead-zinc

The silver-lead-zinc deposits at the Mount Isa Mine are described in various publications (e.g., Carter et al., 1961; Bennett, 1965; Bennett, 1970a; Stanton, 1972). They occur in the Urquhart Shale, but not in the 'silica-dolomite'. They are markedly conformable and occur discontinuously throughout a stratigraphic thickness of 1 km. The orebodies are arranged in an en echelon pattern; the largest extends for 1 km along strike, 0.6 km down dip, and has a maximum thickness of more than 50 m. They consist of discrete bands of sulphides - mainly galena, sphalerite, and pyrite - intercalated with beds of weakly metamorphosed shale. Smith & Walker (1971) consider that these deposits are probably syngenetic in origin. A summary of the theories concerning the origin of the Mount Isa ore deposits up to 1960 is presented by Fisher (1960).

The Hilton mine, situated 20 km north of Mount Isa is currently being developed for production of silver-lead-zinc ore by 1978. The deposit has been described by Bennett (1970a) and by Mathias, Clark, Morris & Russell (1973); it occurs within the Urquhart Shale, and the galena and sphalerite ore, which resembles that at the Mount Isa Mine, is restricted to concordant bands associated with pyritic shale.

Oxidized lead-zinc ores have been mined from the Mount Isa Mine and adjacent areas. Carter et al. (1961) described the Black Star, Black Rock, and Rio Grande sections of the Mount Isa orebodies, and the Bernborough orebodies immediately to the south. Several minor lead deposits have been worked, e.g., Copalot, Leichhardt King, and Doolan's Hope.

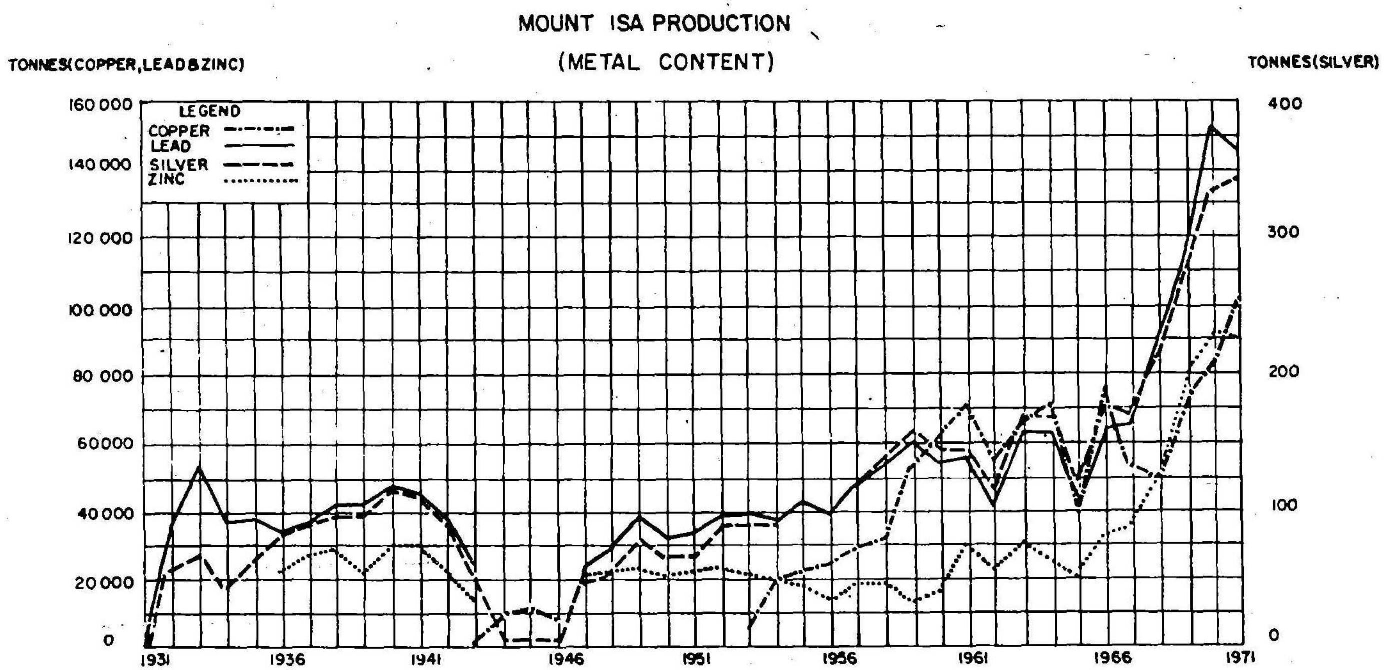

Fig. 33 ANNUAL PRODUCTION FROM MOUNT ISA MINES, 1931-1971 (AFTER MOUNT ISA MINES LTD, 1972c)

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Uranium

Almost 100 radioactive anomalies were discovered in the Mount Isa Sheet area in 1954 and the majority were later covered by leases. Subsequent more detailed investigations have failed to indicate mineable reserves at any of these prospects. The majority occur within the Eastern Creek Volcanics, and are localized by faulting in sequences of metabasalt and metasediments. Dolerite is commonly associated with the mineralization.

Beryl

Deposits of beryl occur in the 'Mica Creek Pegmatite' 7 to 15 km southwest to south-southwest of Mount Isa. The beryl-bearing pegmatites intrude hornblende schist and amphibolite of the Eastern Creek Volcanics in a narrow north-northwest-trending belt 10 km long, near the eastern contact of the Sybella Granite. The productive pegmatites are zoned from albite or albite-muscovite rock at their margins to a quartz core, and the beryl is concentrated near the quartz core, where it forms euhedral pale yellowish-green, green, blue and, amber crystals up to 30 cm across and over 1 m long. Most of the 81 tonnes of beryl produced from the area has come from the Big Beryl opencut mine. Beryl was produced discontinuously in the area between 1943 and 1958 (Carter et al., 1961).

Mica

Mica in the 'Mica Creek Pegmatite' was mined in the 1920s from small pits 12 to 14 km south-southwest of Mount Isa. Muscovite and biotite occur in imperfect sheets up to 0.1 m^2 in area (Carter et al., 1961).

Other pegmatite minerals

The complex mineralogy of the 'Mica Creek Pegmatite' has been described by Denmead (1937), Shepherd (1938), Connah (1938) and Brooks & Shipway (1960). In addition to beryl and mica, the pegmatites are known to contain monazite, feldspar, cassiterite, tantalite-columbite, quartz, tourmaline, magnetite, hematite, ilmenite, rutile, graftonite (manganese-iron-calcium phosphate), manganese oxides, rhodonite?, native bismuth, bismuth carbonate, uranium (in columbite), garnet, fluorite, apatite, epidote, and topaz, but not in mineable quantities. Fluorite is also a common accessory mineral in the Sybella Granite, but no worthwhile deposits are known.

Gold

The May Downs area contains numerous gold workings. The earliest discoveries were alluvial and were soon worked out. Subsequent work has concentrated on north-trending quartz reefs in the May Downs Fault zone cutting the Mingera Beds, and several shafts to 30 m and numerous shallower shafts have been sunk. However, production records are incomplete. The Crescent No. 1 Mine, also known as Golden Sunset, near the southern end of the auriferous belt, has a recorded production of 3.12 kg between 1927 and 1935, and work was in progress at this mine during the field mapping.

Silica

Silica is used as a flux in the copper smelters at Mount Isa. 22 000 tonnes of silica was produced from the Hidden Valley Mine, 1 km southwest of Mount Isa, before 1954. The siliceous oxidized copper ore from the Black Rock Open Cut provided sufficient silica until it ceased production in 1965. Subsequent silica requirements have come mainly from the Mount Hope Mine, to the south of the Mount Isa Sheet area, but small quantities have come from White Blow, Snowy, Gun's Knob, and White Horse Mines in the Sheet area, and from quartz-filled fault zones in the Judenan Beds and the Eastern Creek Volcanics.

Sulphur

Sulphur dioxide is presently a waste product of the copper and lead smelters at Mount Isa, but there are plans to install a sulphuric acid plant in the near future to recover the sulphur.

Construction materials

Adequate supplies of sand and gravel for local use are contained in the Leichhardt River and other large streams in the area. Quarrying for road metal is carried out near the northern limit of urbanization at Mount Isa. Waste rock from the mines also provides supplies of gravel and fill.

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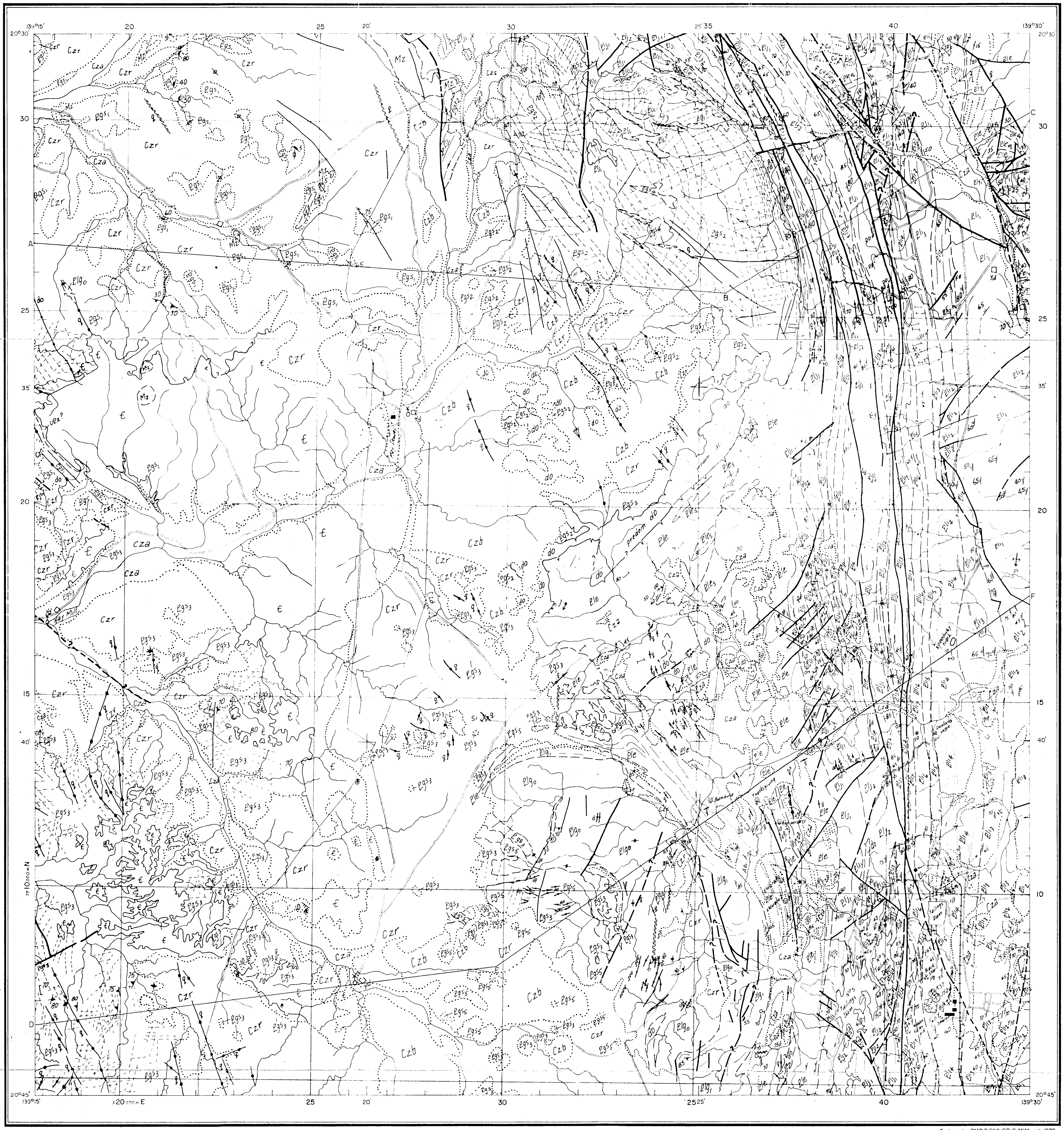

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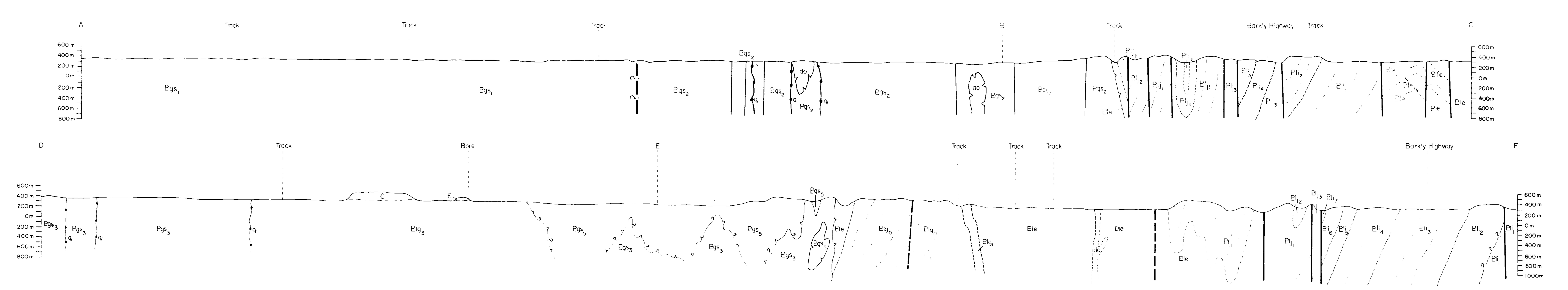

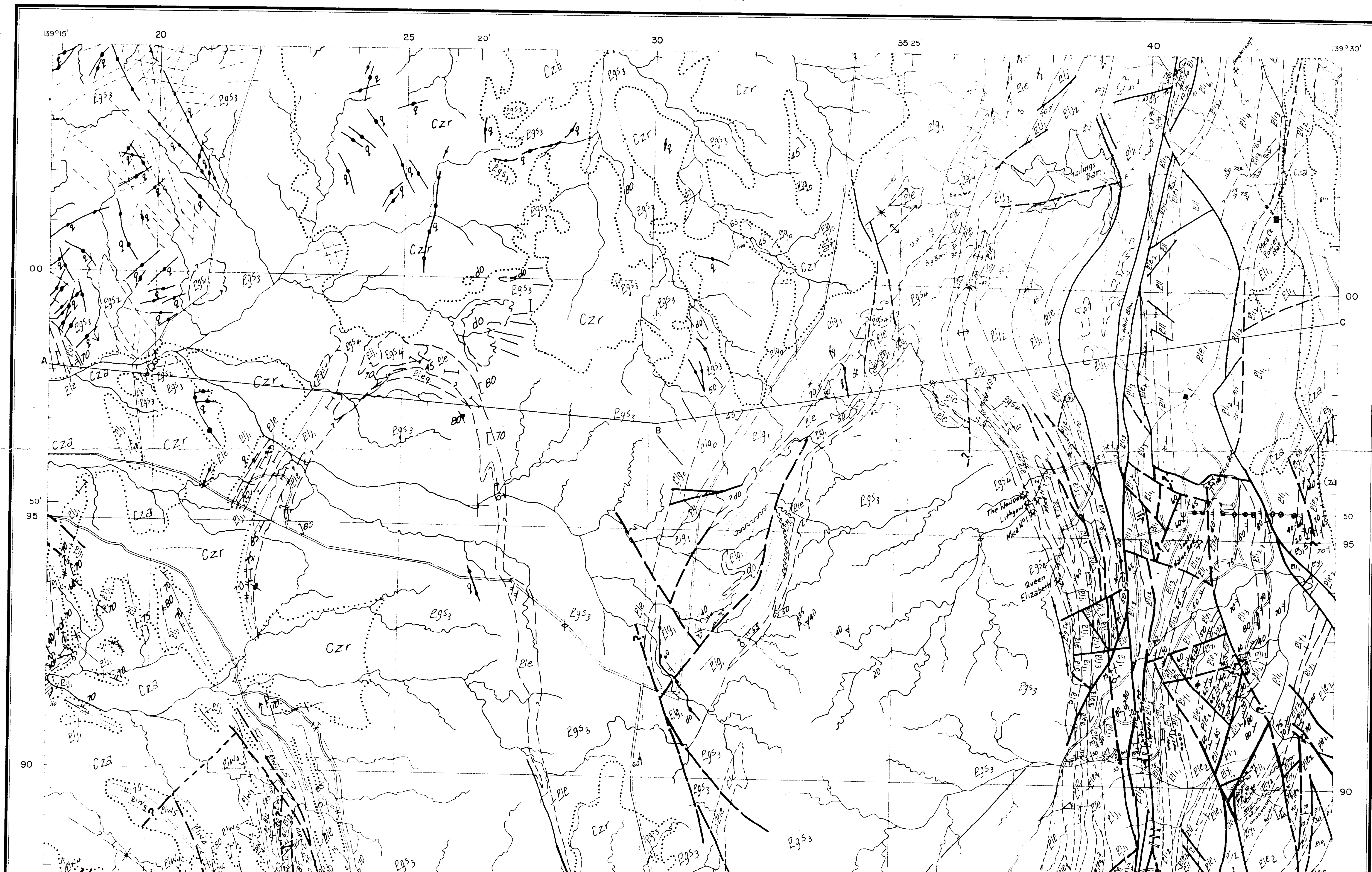

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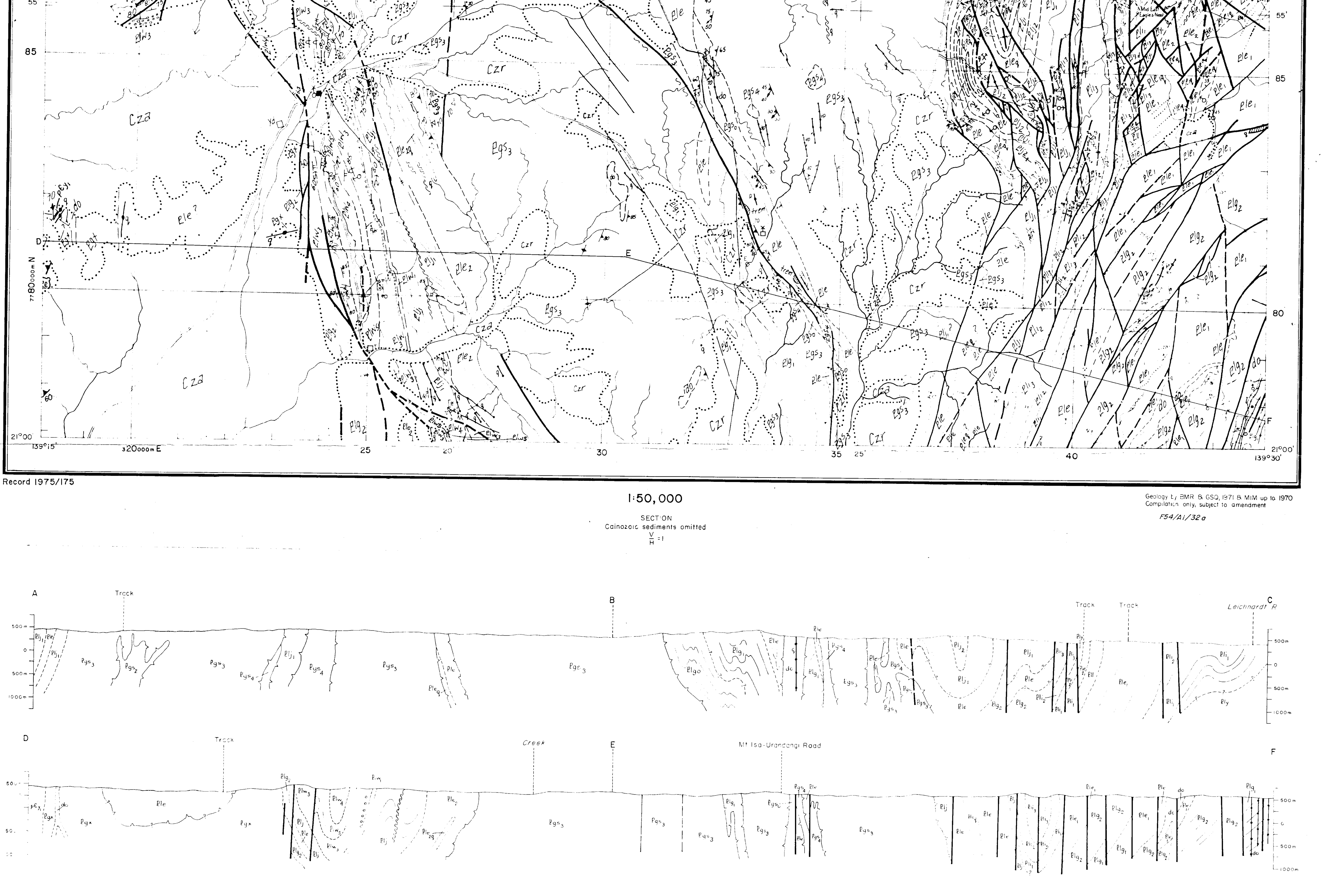

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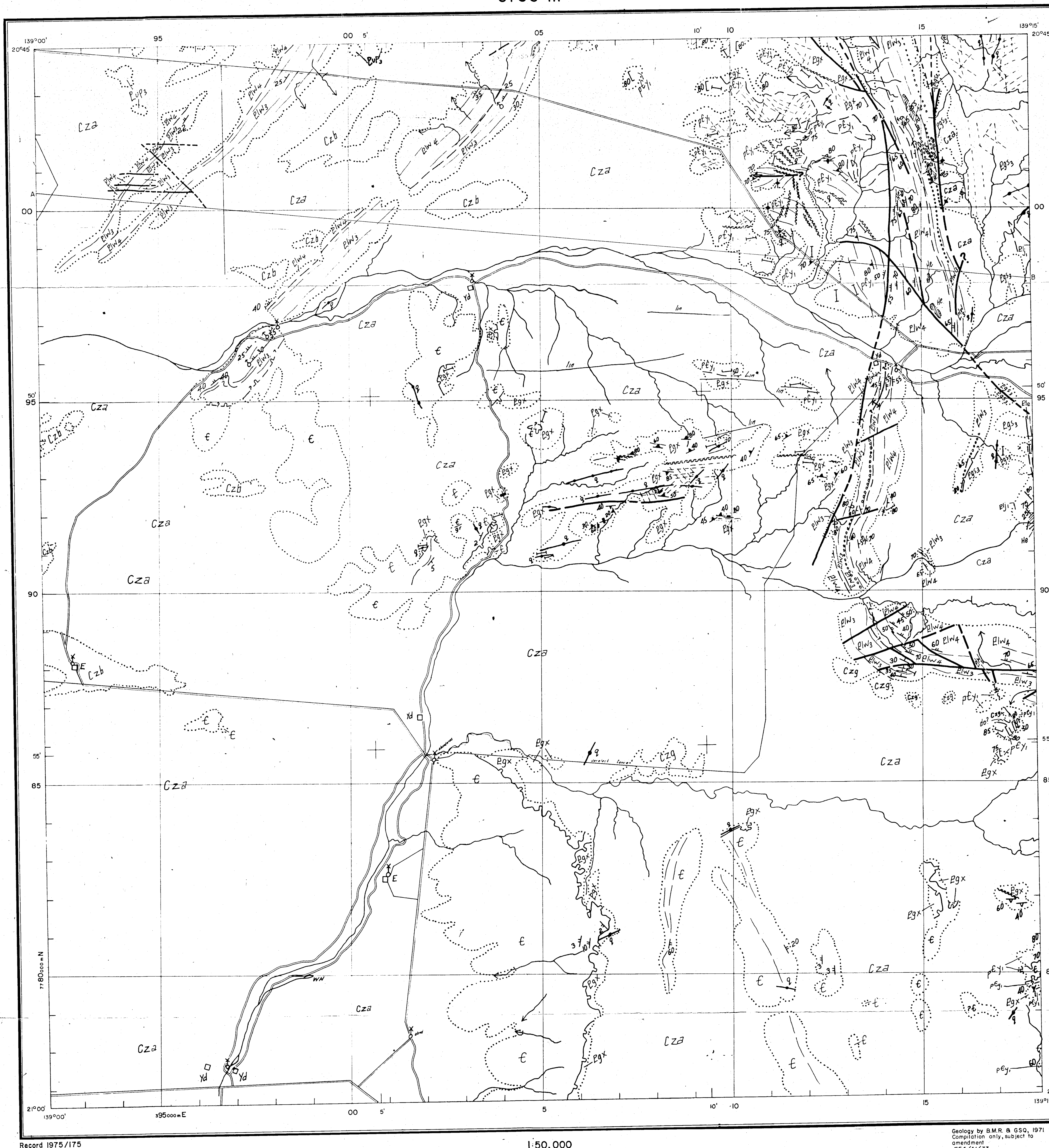

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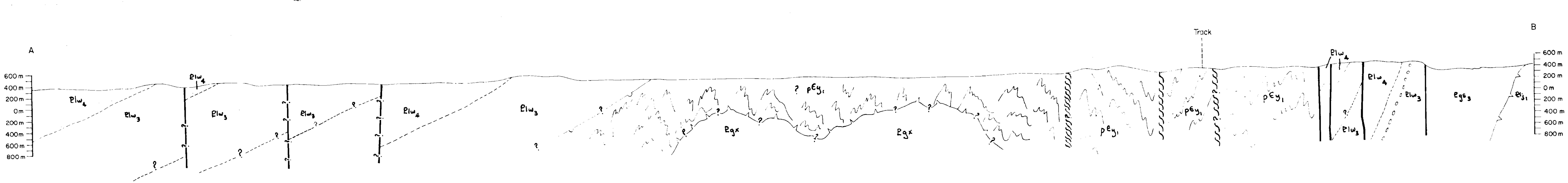

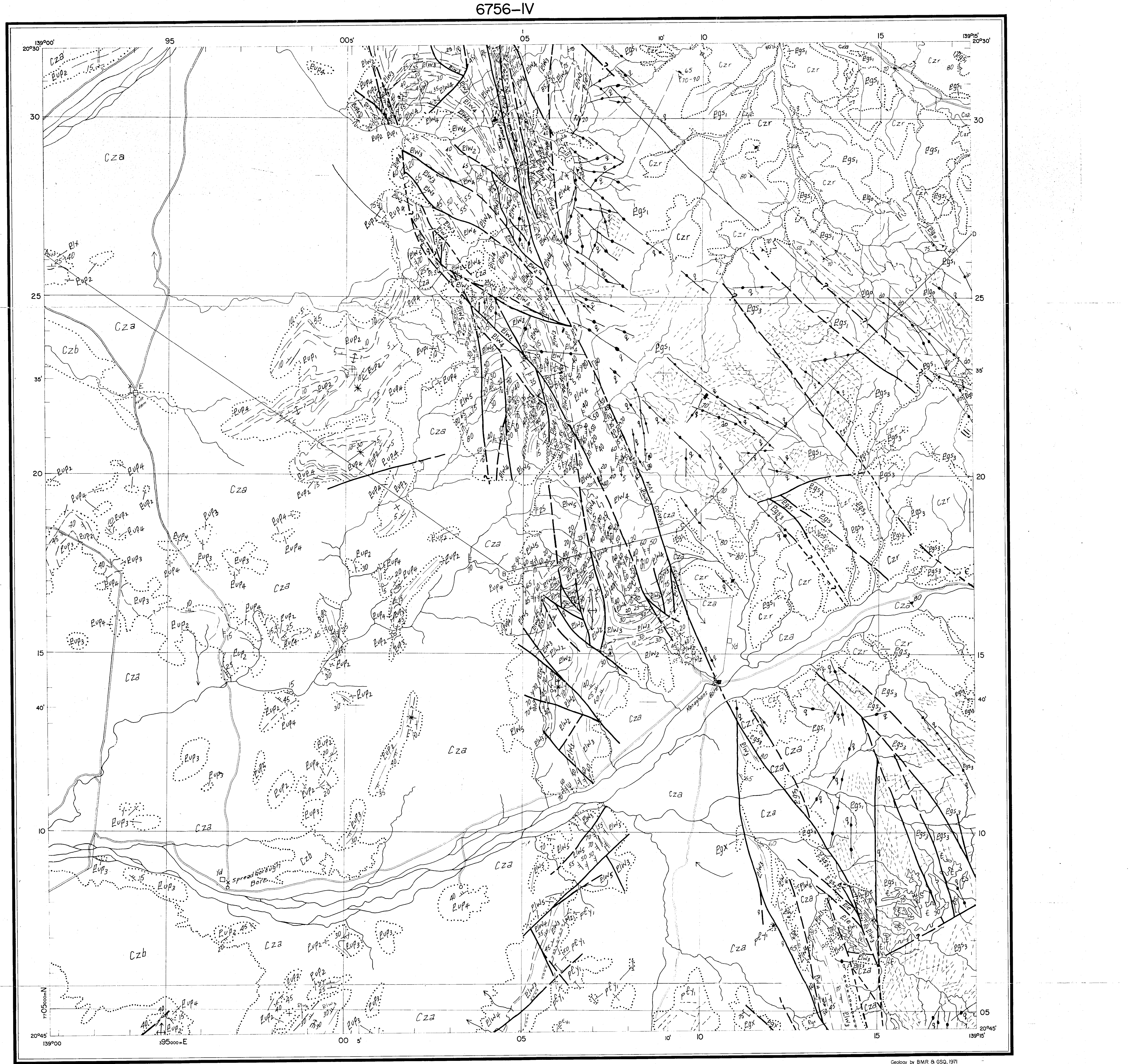

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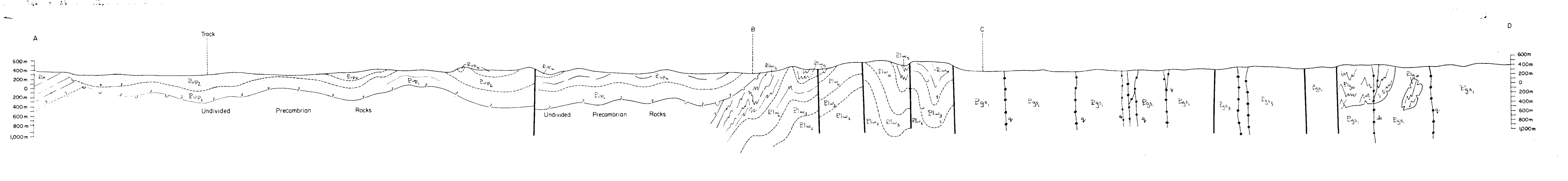
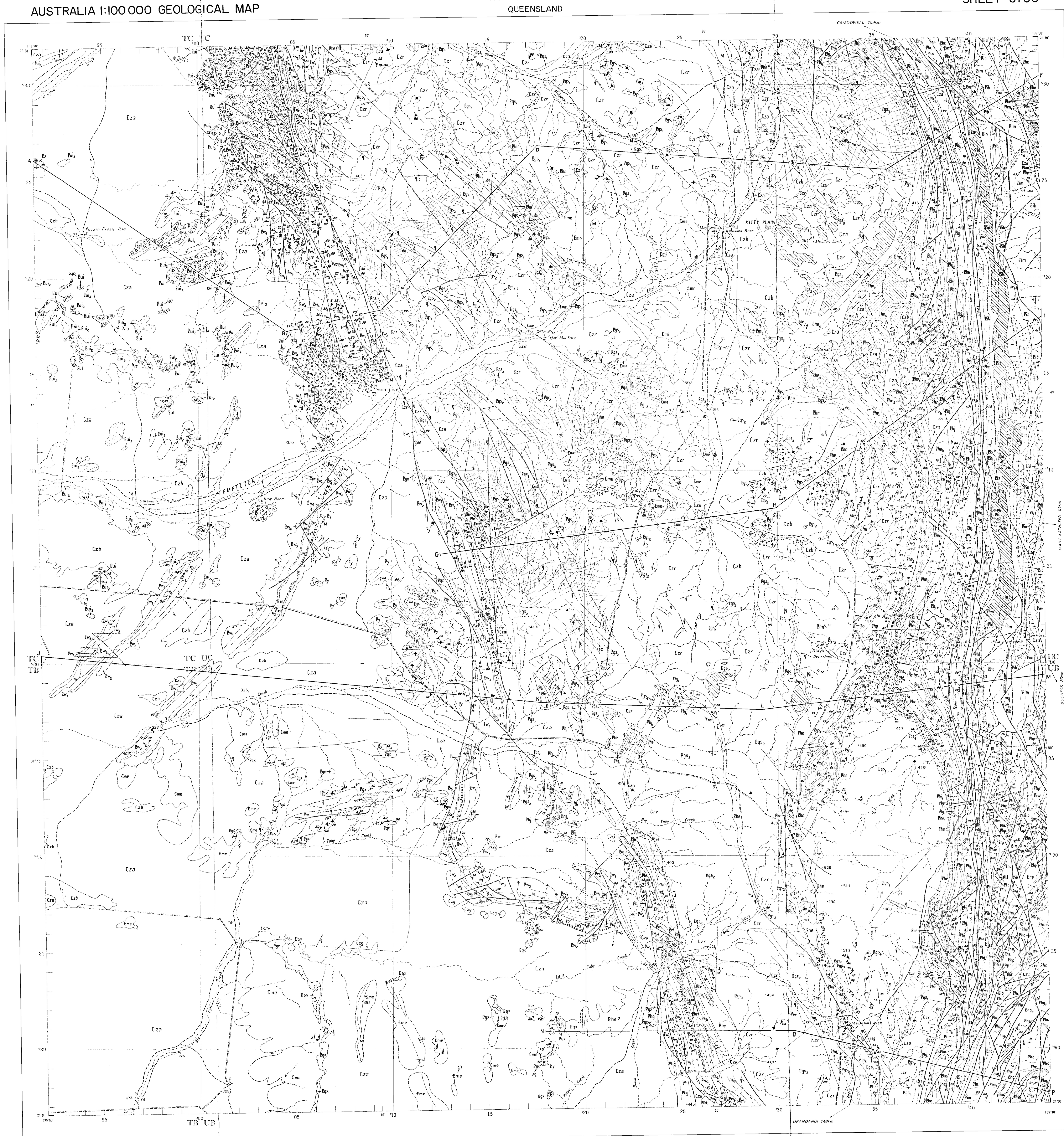


AUSTRALIA 1:100 000 GEOLOGICAL MAP

MOUNT ISA

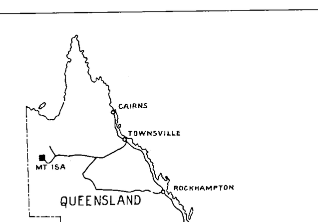
QUEENSLAND

SHEET 6756



Compiled by the Bureau of Mineral Resources, Geology and Geophysics, Department of Minerals and Energy. Issued under the authority of the Hon R.F.X. Connor M.P., Minister for Minerals and Energy.
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 A.A. Öpik, K.A. Townley, E.K. Carter, W.M.B. Roberts (BMR); B.W. Hawkins (GSQ)
To 1971 by the Geological Staff of Mount Isa Mines Limited
1972 by C.J.L. Wilson (ANU)
Detailed mapping and complete geological revision 1970-1972 by R.M. Hill, G.M. Derrick, J.E. Mitchell, S. Henley (BMR); I.H. Wilson (GSQ)
Compiled 1971-1972 by R.M. Hill, M. Little
Cartography by Geological Branch BMR
Drawn by M. Little



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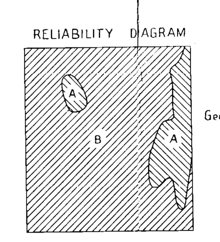


Geology A Detailed mapping

B Detailed reconnaissance: numerous traverses, and airphoto interpretation

INDEX TO ADJOINING SHEETS

Showing Magnetic Declination 1970

Reference

WEST OF MOUNT ISA FAULT

CAINOZOIC		Cza	River bed and flood plain deposits: alluvium
		Czb	Black soil plains: fine alluvium in shallow depressions
		Czg	Conglomerate, alluvial fan deposits
		Czr	Residual sand and silt
MESOZOIC		M	Ferruginous grits, ferricrete
PALAEOZOIC CAMBRIAN	Inca Formation	Єmi	Siliceous shale and chert with limestone interbeds
	Beetle Creek Formation	Єme	Basal conglomerate, chert, siliceous shale with trilobite fossils
PROTEROZOIC ADELAIDEAN?	Pilpah Sandstone	Ꝑui	Undivided: feldspathic sandstone, siltstone, shale, breccia: rock relationship diagram only
			Chert breccia, laminated chert
			Deeply weathered ferruginous sandstone
		Ꝑui₂	Feldspathic sandstone
		Ꝑui₁	Shale, fine feldspathic sandstone and siltstone, shale conglomerate
			Chert breccia, shale conglomerate
PROTEROZOIC CARPENTARIAN	Paradise Creek Formation	Ꝑx	Dolomite, siltstone, sandstone, stromatolitic dolomite
		do	Dolerite, pyroxene-bearing, ophitic texture
	Mingera Beds	Ꝑw	Undivided: conglomerate, feldspathic quartzite, siltstone, shale: rock relationship diagram only
			Ferruginous siltstone, sandstone, minor conglomerate
		Ꝑw₄	Black shale, laminated silty and micaceous shale
		Ꝑw₃	Laminated siltstone, micaceous and pyritic siltstone
		Ꝑw₂	Fine to medium feldspathic sandstone. Minor conglomerate
		Ꝑw₁	Coarse feldspathic sandstone, pebble and cobble conglomerate
			Ferruginous siltstone and fine sandstone
			Ferruginous medium sandstone
	Sybella Granite	Ꝑgs₃	Massive fine to medium even-grained granite
	* Mica Creek Pegmatite	Ꝑgs₄	Feldspar-muscovite-beryl-quartz pegmatite
		Ꝑgs₂	Coarse porphyritic foliated biotite granite
			Porphyritic quartz diorite with quartz ocelli
			Fine to medium magnetite granite and gneiss
		Ꝑgs₁	Massive medium to coarse porphyritic granite with distinctive blue quartz phenocrysts
		dc	Dolerite, metadolerite, amphibolite of pre-Sybella Granite age
	* Carters Bore Rhyolite		Porphyritic rhyolite, granite porphyry
	Judenan Beds	Ꝑhj	Undivided: quartzite, feldspathic quartzite, pelitic schist, amphibolite: rock relationship diagram only. Metabasalt, amygdaloidal metabasalt, amphibolite, chlorite and biotite schist
			Siltstone, shale, pelitic schist, quartz-muscovite schist
			White clean quartzite, feldspathic quartzite, foliated quartzite, minor schist. Minor conglomerate
	Haslingden Group: Eastern Creek Volcanics	Ꝑhe	Undivided: metabasalt, amygdaloidal metabasalt, amphibolite
			Quartzite, epidote quartzite, feldspathic quartzite
			Metabasalt, amygdaloidal metabasalt, amphibolite
			Pelitic schist, cordierite schist, quartzite
			Metabasalt, amygdaloidal metabasalt, amphibolite
	Mount Guide Quartzite	Ꝑhg	Quartzite, feldspathic and micaceous quartzite, with minor gneiss
	* May Downs Gneiss Member		Plagioclase-microcline-quartz gneiss with minor biotite, sillimanite, and muscovite
UNDIFFERENTIATED PRE-CARPENTARIAN	* Big Toby Granite	Ꝑgx	Fine to medium biotite granite, minor coarse foliated granite
	Yaringa Metamorphics	Ꝑy	Quartz-muscovite schist, quartzite, quartz-muscovite-biotite gneiss, minor migmatite
			Quartz-feldspar porphyry

* Name not yet approved

Unconformity

EAST OF MOUNT ISA FAULT

CAINOZOIC		Cza	Soil, sand: alluvium
PROTEROZOIC CARPENTARIAN		do	Dolerite, metadolerite, amphibolite, of various ages
Mount Isa Group	Magazine Shale	Ꝑig	Thin bedded calcareous sericitic shales, minor pyrite
	Kennedy Siltstone	Ꝑik	Siliceous and dolomitic siltstone, dolomitic quartzite
	Spear Siltstone	Ꝑis	Laminated dolomitic siltstone and shale
	Urquhart Shale	Ꝑiu	Ferruginous pyritic shale, tuff marker beds
	Native Bee Siltstone	Ꝑin	Bedded dolomitic siltstone, minor tuff
	Breakaway Shale	Ꝑib	Grey shale, minor siltstone
	Moondarra Siltstone	Ꝑim	Dolomitic siltstone, minor dolomite and shale
	* Warrina Park Quartzite	Ꝑiw	Quartzite, ferruginous siltstone
	Myally Beds	Ꝑhm	Undivided: quartzite, siltstone, shale, conglomerate: rock relationship diagram only
		Ꝑhm₂	Quartzite, conglomerate
		Ꝑhm₁	Feldspathic quartzite, quartzite, siltstone, mud-flake conglomerate
* Haslingden Group	Eastern Creek Volcanics	Ꝑhe	Undivided: metabasalt, amygdaloidal metabasalt, amphibolite
			Quartzite, epidote quartzite
	* Pickwick Metabasalt Member	Ꝑhp	Metabasalt, amygdaloidal metabasalt
			Quartzite, epidote quartzite
	* Lena Quartzite Member	Ꝑhl	Quartzite, feldspathic quartzite
	* Cromwell Metabasalt Member	Ꝑhc	Metabasalt, amygdaloidal metabasalt, flow-top breccia
			Quartzite, epidote quartzite
	Mount Guide Quartzite	Ꝑhg₂	Micaceous and feldspathic quartzite, silicified fine sandstone and siltstone
		Ꝑhg₁	Friable fine to medium sandstone, greywacke, siltstone

* Name not yet approved

Symbols

- Geological boundary
- Unconformity
- Unconformity, position approximate
- Anticline, showing plunge
- Syncline, showing plunge
- Fault, showing relative horizontal movement

Where location of boundaries, folds and faults is approximate, line is broken; where inferred, queried; where concealed, boundaries and folds are dotted, faults are shown by short dashes

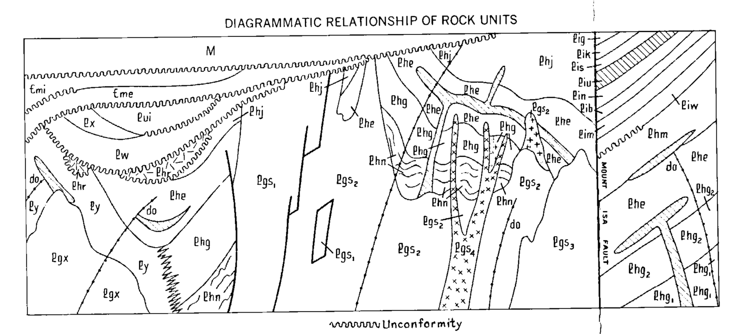
- 30 Plunge of minor anticline
- Plunge of minor anticline, unmeasured
- 30 Plunge of minor syncline
- 50 Plunge of drag-fold
- Plunge of drag-fold, unmeasured
- F.A. Fold axis
- Shear zone
- Zone of silicification, with Fe and Mn enrichment
- Breccia zone
- 75 Strike and dip of strata
- Strike and dip of strata, unmeasured
- 70 Strike and dip of strata - facing not known
- Strike and dip of strata - facing not known, unmeasured
- Vertical strata
- Horizontal strata
- Overturned strata
- 5 Dip slope
- Dip > 45° (airphoto interpretation)
- Trend line (airphoto interpretation)
- Lineament (airphoto interpretation)
- Joint pattern (airphoto interpretation)
- 70 Generalized strike and dip of undulating strata
- Generalized strike and dip of undulating strata, unmeasured
- Top of bed indicated by cleavage/bedding relationship
- Top of bed indicated by cross-bedding
- 60 Strike and dip of joints
- Strike and dip of joints, unmeasured
- Vertical joints
- 70 Strike and dip of foliation
- Strike and dip of foliation, unmeasured
- Vertical foliation
- 70 Strike and dip of cleavage
- Strike and dip of cleavage, unmeasured
- Vertical cleavage
- 75 70 Lineation on bedding, showing dip where measured
- 80 70 Lineation on cleavage
- 65 60 Foliation with plunge of lineation
- Macrofossil locality
- Dyke or vein; ap - aplite, do - dolerite, He - hematite, peg - pegmatite, q - quartz, Tr - tremolite
- • Cu Minor mineral occurrence
- Prospect
- Mine - minor
- Mine - minor, not worked
- Mine - major
- Open cut
- Open cut, not worked
- Treatment plant
- Costean
- Cu Copper
- Be Beryllium
- Au Gold
- Fe Iron
- Pb Lead
- Mn Manganese
- Mi Mica
- Si Silica
- Ag Silver
- Ta Tantalum
- U Uranium
- Zn Zinc
- Bore, pump equipped
- Bore, abandoned
- Windpump
- Water tank
- Earth tank
- Dam on stream
- Waterhole
- Rockhole
- Highway
- Road
- Vehicle Track
- Railway, siding, station with siding
- Airport
- Landing ground
- Homestead
- Building
- Yard
- Fence
- Built-up area
- Power transmission line
- Elevation in metres, accurate

Mining and Lease Index

Numbers refer to location on map

No.	Name		No.	Name	
1		Au	45	Bernborough	Pb
2		Au	46	Spinning Wheel	Be
3	Golden Sunset	Au	47		Cu
4	Kiora	Au	48	Pauline, Anne, Pamela	U
5		Au	49	Skippy Janelle	Be
6		U	50	Big Wheel	Be
7		U	51	Beryl North	Be
8		U	52	Midway, Cloudy Day, Tiny Two, Tiny	U, Cu
9		U	53	Big Beryl	Be
10		U	54		Be
11		U	55	Wishbone	U
12		Cu	56	The Crystal	Ta
13	Hilton	Ag, Pb, Zn	57	Beryl Queen	Be
14		Pb	58	Beryl King	Be
15		U?	59	White Blow	Si
16	Flat Tyre	U	60	Hexagon	Mi
17	Folderol	U	61	Beryllina	Be
18	Folderol South	U	62	Emancipation	Be
19	Snowy	Si	63	Glance	Cu
20	Mothers Day	U	64	Karlene	U
21	Never Can Tell	U	65	Mica N°3	Mi, Be?
22	Lucky Break	U	66	Lucky 29	U
23	Miami	U	67	Wonder	Be
24	Doolan's Hope	Pb	68	Lithgow	Be
25	Turpentine (Highlander)	U	69	Mica N°2	Mi, Ta
26	Mighty Glare	U	70	Mica N°1	Mi, Be
27	Mighty	U	71	Native Bee	Cu
28	Citation	U	72	Southern Native Bee	Cu
29	Exploration	U	73	Queen Elizabeth	Be
30	Bambino	U	74		Cu
31	Thanksgiving	U	75		U?
32	Anniversary	U	76	Copalot	Cu
33		Gravel	77	Copper Conquest	Cu
34	Little Beauty	U	78	Mount Novit	Pb, Zn
35	Quartz Outcrop	Si	79		Be
36		Cu	80	Eagles Nest	Cu
37	Eldorado N°1	U	81	Mid East	Cu
38	Eldorado N°2	U	82	Judy Lynn	Cu
39	Eldorado South	U	83		Cu
40	Leichhardt King	Pb	84		Cu
41	Black Star	Cu	85	Cluny	Cu
42	Mount Isa	Cu, Ag, Pb, Zn	86		Cu
43	Black Rock	Cu	87		Cu
44	Hidden Treasure	Cu			

DIAGRAMMATIC RELATIONSHIP OF ROCK UNITS



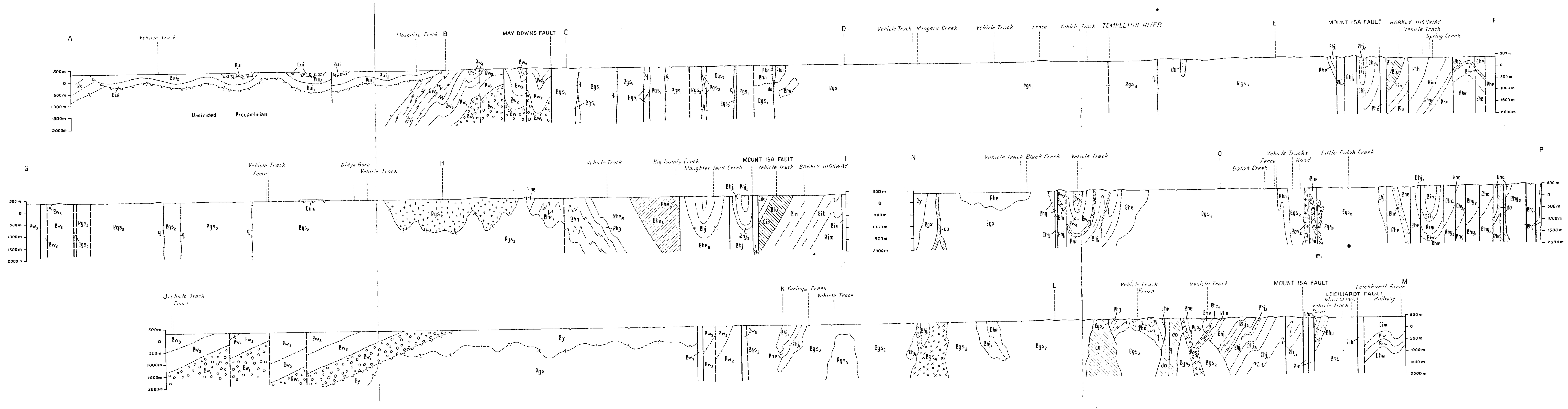
Unconformity

Facies change

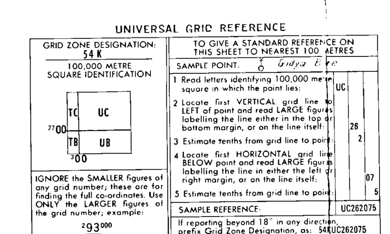
Sections

Depth in metres

Cainozoic sediments omitted



UNIVERSAL GRID REFERENCE



PRELIMINARY EDITION 1973
SUBJECT TO AMENDMENT

MOUNT ISA

SHEET 6756

MOUNT ISA
1:100,000

Age	Unit	Symbol	Description
CAINOZOIC		Cza	Alluvium, river bed and flood plain deposits.
		Czb	Black soil plains.
		Czg	Conglomerate, alluvial fan deposits.
		Czr	Residual sand and soil.
MESOZOIC		Mz	Ferriginous grits, ferricrete, ironstone rubble, laterite.
PALAEOZOIC – CAMBRIAN		€	Basal conglomerate, chert, siliceous shales, kaolinitic shales.
PROTEROZOIC – UPPER PROTEROZOIC		Pu	Undiff metasediments forming rubbley scree.
	Pilpah Sandstone	Pup_4	Silicified grey laminated shale fragments in white matrix.
		Pup_3	Highly ferruginized feldspathic quartzite rubble.
		Pup_2	Ferruginous feldspathic quartzite, friable quartzite.
		Pup_1	Laminated kaolinitic siltstone.
PROTEROZOIC – LOWER PROTEROZOIC OR CARPENTARIAN	Paradise Ck Formation	Plx	Dolomite, siltstone, and sandstone containing stromatolites.
	Mingera Beds	Plw_5	Black shale, laminated shales.
		Plw_4	Red-brown siltstones, grey laminated siltstones.
		Plw_3	Feldspathic quartzite, clean quartzite.
		Plw_2	White quartz cobble and pebble conglomerate, feldspathic grits, coarse quartzite
		Plw_1	Acid volcanics, quartz-feldspar porphyry meta-rhyolite.
	Judenan Beds	Plj_3	Metobasalt, amygdaloidal basalt, amphibolite, chlorite and biotite schist.
		Plj_2	Siltstone, shale, pelitic schist.
		Plj_1	White clean quartzite, feldspathic quartzite conglomerate.
	Mount Isa Group: Magazine Shale	Pli_7	Light grey to red-brown sericitic shales.
	Kennedy Siltstone	Pli_6	Siliceous and dolomitic siltstone, dolomitic quartzite.
	Spear Siltstone	Pli_5	Laminated dolomitic siltstone and shale.
	Urquhart Shale	Pli_4	Ferruginous, pyritic and dolomitic shale with tuff marker beds.
	Native Bee Siltstone	Pli_3	Bedded dolomitic siltstone, minor tuff.
	Breakaway Shale	Pli_2	Grey shale, minor siltstone.
	Moondarra Siltstone	Pli_1	Dolomitic siltstone, minor dolomite and shale.
	Myally Beds	Ply_2	Quartzite, conglomerate, boulder beds.
		Ply_1	Feldspathic quartzite, mud-flake conglomerate, siltstone.
	Eastern Ck Volcanics	Ple	Undiff. metabasalt, amygdaloidal metabasalt amphibolite with minor meta-sediments.
		s	Pelitic schist, cordierite rocks, meta-sediments.
		q_2	Quartzite, feldspathic quartzite.
	Pickwick Metabasalt Member	Ple_2	Metabasalt, amygdaloidal metabasalt, minor sedimentary beds.
		q_2	Quartzite, feldspathic quartzite.
	Lena Quartzite Member	Pll	Quartzite, feldspathic quartzite.
	Cromwell-Paroo Metabasalt Member	Ple_1	Metabasalt, amygdaloidal metabasalt, flow-top breccia, minor metasediments.
		q_2	Feldspathic quartzite, epidote quartzite.
	Mt Guide Quartzite	Plg_2	Feldspathic quartzite, limonitic quartzite
		Plg_1	F.-m.g. quartzite, feldspathic quartzite and siltstone.
	May Downs Gneiss	Plg_0	Quartzose gneiss with minor feldspar, sillimanite, biotite, and muscovite.
	Yaringa Metamorphics	$p€y_2$	Quartz-feldspar porphyry with euhedral feldspar phenocrysts in foliated g'mass
		$p€y_1$	Quartz-biotite-muscovite schist and gneiss, minor migmatite

Acid Intrusive Rocks

Unit	Symbol	Description
Sybella Granite	Pgs_5	Porphyritic quartz diorite with quartz ocelli.
Mica Ck Pegmatite	Pgs_4	Feldspar muscovite quartz beryl pegmatite.
	Pgs_3	C.g. porphyritic foliated biotite granite.
Sybella Microgranite	Pgs_2	Massive f.-m. even grained granite.
	Pgs_1	Massive m.-c.g. porphyritic granite with blue quartz phenocrysts.
	Pgs_0	F.-m.g. magnetite granite/gneiss.
	Pgx	F.-m. even grained biotite granite and c.g. foliated granite.

Basic Intrusive Rocks

Symbol	Description
do	Undiff. metadolerite, amphibolite, basic schist.

Note: Small numbers refer to Series 19 Derwent colour pencils; strokes refer to type of hachure
e.g. /15 = colour 15, northeast hachure.