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The Proterozoic metamorphic rocks of the Cloncurry 1:100,000 Sheet area, (Soldiers Cap Belt)

Northwestern Queensland

by

A.Y. Glikson and G.M. Derrick

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RECORDS 1970/24

Frontispiece

An auriferous quartz vein stands above a plain underlain by schists of the Weatherly Creek Quartzite near the Gilded Rose gold mine, approximately 9 miles ESE of Cloncurry (GA/2524).

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SUMMARY

This report describes a detailed geological survey of the Precambrian rocks within the Cloncurry 1:100,000 Sheet area, Cloncurry District, northwestern Queensland. The principal stratigraphic unit cropping out in the area is the Soldiers Cap Formation, which comprises a lower member consisting of meta-greywacke schists and pelitic schists, an intermediate member consisting of quartzites, pelitic meta-sediments and meta-basalts, and an upper member consisting of meta-basalts with chert intercalations. These units are respectively comparable with the Alpine flysch facies, the stable shelf orthoquartzite facies, and the eugeosynclinal volcanic facies. The Soldiers Cap Formation was isoclinally folded on north-south-trending axes, and metamorphosed within the middle greenschist-lower amphibolite facies range. These events were followed by the elevation, denudation, and resubmergence of the area. During the resubmergence, carbonates of the Corella Formation were deposited and were in turn capped by the cross-bedded sandstones of the Roxmere Quartzite. The deposition of these sediments was followed by the intrusion of granites, which may have caused the large-scale cross-folding of the Soldiers Cap Formation, and the associated deformation and brecciation of the Corella Formation. The low pressure regional metamorphism displayed by the Corella Formation is probably later than the metamorphism exhibited by the Soldiers Cap Formation. The emplacement of the granites was accompanied by the release of ore-bearing solutions, which deposited the copper and gold occurring at low to intermediate stratigraphic levels of the volcanic sequence of the Soldiers Cap Formation. In addition to their stratigraphic control, the ore deposits tend to occur as fault infillings and in fold axial zones. A compilation of copper and gold production data for individual mines in the Cloncurry 1:100,000 Sheet area is presented in this report.

I. INTRODUCTION

Aims and methods of the survey

This report is concerned with the results of a geological survey of the Cloncurry 1:100,000 Sheet area (Australia 1:100,000 Series, map no. 7056), which was carried out as a part of a Bureau of Mineral Resources-Geological Survey of Queensland detailed mapping project of the Cloncurry-Mount Isa region, northwestern Queensland. The field traverses on which this report is based were conducted between May and August, 1968. The Soldiers Cap Formation and outliers of the Corella Formation were mapped by A.Y. Glikson (BMR), the area west of the western branch of Snake Creek was mapped by G.M. Derrick (BMR), and a small area about 6 km. east of Soldiers Cap was mapped by I. Wilson (GSQ). The aims of the survey were to produce a detailed geological map of the Precambrian rock outcrops, and to study the structural, stratigraphic, and petrographic features of the rocks, with implications on their relationships to mineralization.

Four-day and five-day field trips were made from a base camp located 5 km. south of the Cloncurry township, and included vehicle and foot traverses. The latter were carried out mainly along creeks running across the strike, and were spaced approximately 6-8 km. from one another, except in areas of special geological and economic significance where more densely spaced traverses were conducted. The data were plotted on 1:48,000 aerial photos (RAAF, 1950), using transparent overlays. 1:85,000 aerial photos (National Mapping, RC9 Series, 1966) were also used, mainly for structural interpretation. The mapping of the southwesternmost part of the Sheet area was facilitated by 1:25,000 aerial photos (Adastra,1956). The compilation of the geological information was carried out using the Royal Australian Survey Corps 1:48,000 Norna and Cloncurry topographical base maps. The preliminary 1:100,000 Cloncurry Sheet was subsequently prepared through the redrafting and reduction of the compilation sheets. The mapping was combined with detailed sampling aimed at attaining a representative petrographic collection. Approximately 100 specimens were studied in thin-section (Appendix I). Amphibolites and black slates collected from the Cloncurry and Marraba 1:100,000 Sheet areas are the subject of current geochemical investigations (Appendix II).

Location and access

The Cloncurry 1:100,000 Sheet area covers approximately 1100 square miles, defined by the longitudes 140°30'-141°00' and the latitudes 20°30'S-21°00'S. The area constitutes a portion of the eastern edge of the Cloncurry-Mount Isa ranges, and is centred about 250 miles south of the Gulf of Carpentaria. The map area includes the Cloncurry township, which is the administrative centre of the District, and the junction of roads leading to Mount Isa (128 km. westward), Duchess, Longreach, Townsville (768 km. eastward), and Normanton. The principal routes passing through the Cloncurry 1:100,000 Sheet area include the Cloncurry-Julia Creek section of the Flinders Highway, the Cloncurry-McKinlay section of the Landsborough Highway, and the Cloncurry-Townsville railway. Access within the area is afforded by graded and formed tracks leading to cattle stations, water bores, and mineral workings, and which commonly can only be negotiated by 4-wheel drive vehicles. Cattle stations within the Sheet area include Roxmere, Ilkley, Napperley Park, and Fisher Creek (Fig.1).

History of Settlement and Mining

The Cloncurry District, initially occupied by the Mitakoodi tribe, was first traversed by the survivors of Burke and Wills' expedition in 1860, and subsequently visited by McKinlay in 1861. Settlement was initiated by the discovery of the Great Australia copper deposit by Ernest Henry in 1867, and the Cloncurry town grew rapidly because of the findings of alluvial and reef gold in the area (Top Camp, Pumpkin Gulley, Gilded Rose, Soldiers Cap). A coach service and a telegraph line linking Cloncurry with Townsville were established in 1883-84, and a railway from Townsville was completed in 1908. The period 1911-1920 saw the expansion of copper and gold mining in the District, followed by a decline in mining as a result of the drop in copper prices after the First World War. The important silver-lead-zinc deposit of Mount Isa was discovered in 1923, and the site rapidly became the mining and population centre of northwestern Queensland. Gold mining in the Gilded Rose and Soldiers Cap areas was briefly revived during 1933-37, and was completely abandoned in 1943. The present population of Cloncurry is about 2000, and the town remains the centre of local government. The increase in the production of silver, lead, zinc and copper at Mount Isa,

LOCALITY MAP

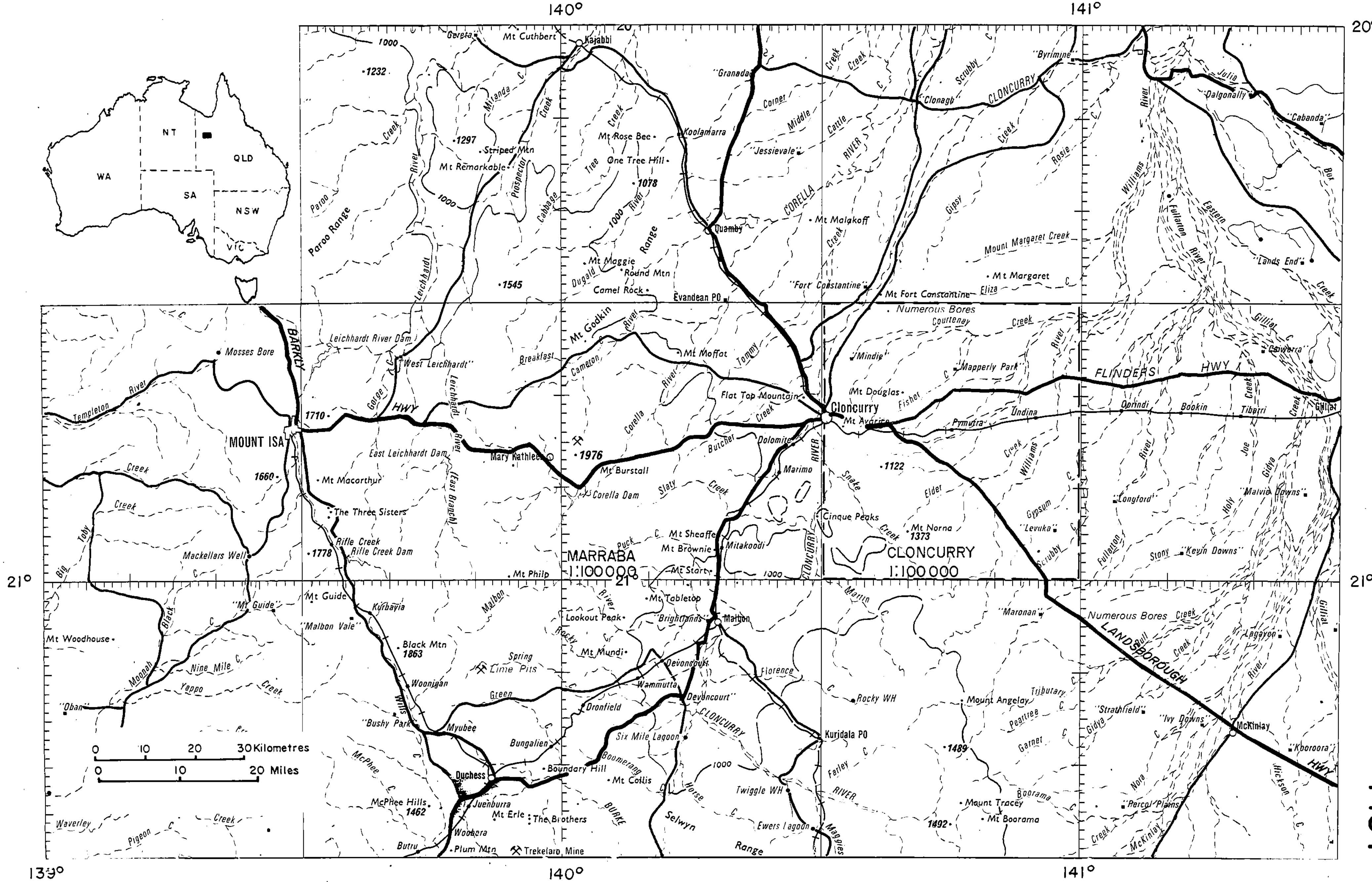

FIG 1

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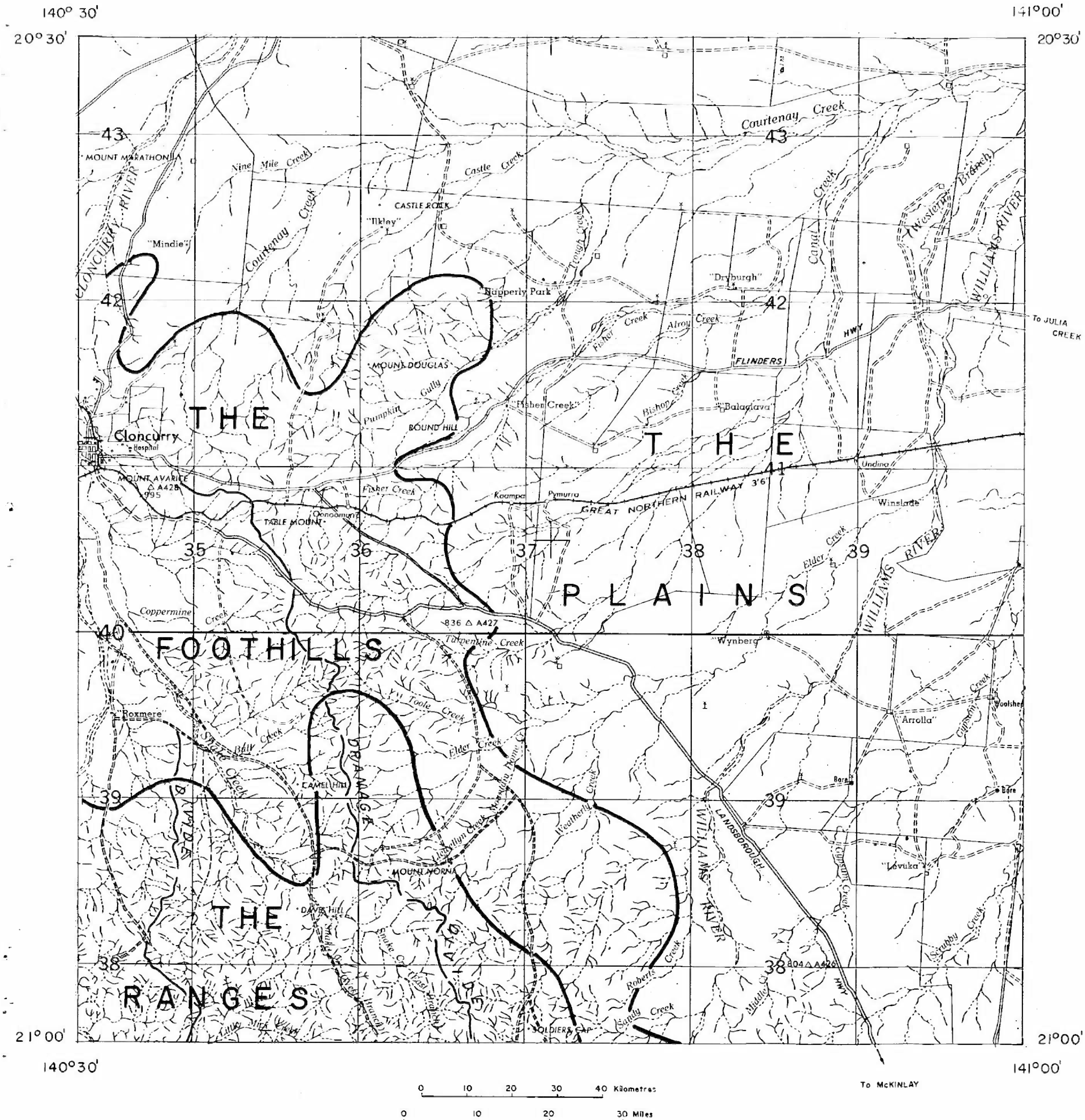
PHYSIOGRAPHIC MAP OF THE CLONCURRY SHEET FIG 2



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the discovery of uranium at Mary Kathleen (64 km. west of Cloncurry), and continuing high copper prices have resulted in a rapid expansion of exploration for base metals in the Cloncurry District in recent years.

Earlier geological investigations

The exploration and mining activities which have taken place in the Cloncurry Sheet area during the second half of the 19th century and the first half of the 20th century were in part reported in publications of the Queensland Bureau of Mines (e.g. Rands, 1895; Jack, 1898; Ball, 1908; Shepherd, 1931, 1932, 1933a, 1933b). The first systematic survey of the Soldiers Cap area was made by the Aerial, Geological and Geophysical Survey of Northern Australia (Honman, 1936a; 1936b; Honman et al., 1939) and included the photogeological mapping of the area on the scale of 1:48,000, as well as a detailed survey of the mines. The Soldiers Cap area was the first in Queensland to be mapped by the AGGSNA. Honman's work remains the most comprehensive economic survey of the area to date. The Sheet area was included in the regional 1:250,000 mapping project carried out during 1950-1954 by the BMR and the GSQ, and reported by Carter, Brooks and Walker (1961). The three-fold stratigraphic division of the Soldiers Cap sequence and its metamorphic zonation were recognized in this survey. The Soldiers Cap Formation was included in a regional geochronologic study carried out by Richards et al. (1963). The dating of biotite from schist by the K-Ar method gave an age of 1431 m.y. A geochemical prospecting survey of 35 square km. in the vicinity of Soldiers Cap was carried out by Australian Selection Pty Ltd in 1968. Reconnaissance traverses were carried out in the area by Derrick (1968). The economic interest in the Soldiers Cap belt is continuing at present, and it is hoped that the present report will be of assistance to exploration companies working in the area.

II. PHYSIOGRAPHY

The Cloncurry 1:100,000 Sheet area includes a portion of the eastern margin of the Cloncurry-Mount Isa ranges, which occupy approximately one-third of the Sheet area (Fig.2). The ranges, peaked by Mount Norna (415 metres a.s.l.), grade into the plains to the east and the north through a belt of mildly undulating foothills. The major drainage is the Cloncurry River, which runs toward the Gulf of Carpentaria 400 km. to the north. The water divide of the ranges within the Sheet area runs subparallel to the NSW-trending boundary of the foothills, separating a system of ENE and NE-flowing streams to the east, from the drainage system of Snake Creek to the west. The northeastward flowing creeks (Sandy Creek, Weatherly Creek, Mountain Home Creek, Elder Creek, Toole Creek, Turpentine Creek, Bishop Creek, Pumpkin Gully) join outside the Sheet area into a northward course which merges with the Cloncurry River. The rugged country west of the principal water divide is drained by a series of short streams (Bull Creek, Coppermine Creek), which join the northwest-flowing east and west branches of Snake Creek, which merges with the Cloncurry River near Roxmere.

The ranges and the dissected tableland

This morphological unit extends over the southwesternmost sector of the Sheet area, and includes the Soldiers Cap-Mount Norna ridges to the east, and the dissected table mountainland between Snake Creek and the Cloncurry River to the west. The orientation of the ridges is controlled by the bedding, and therefore reflect the structural trends (Fig.3). The highest peaks in the area are formed by silicified metasediments developed around the northern closure of the Snake Creek Crossfold. With the exception of Snake Creek, the major streams are incised at high angles to the strike, whereas the tributaries are often oriented parallel to the strike. The waterfalls and waterholes associated with the streams provide the most significant geological outcrops in the area. Erosion of the extensive Mesozoic cappings in and west of the Snake Creek area has formed the dissected tableland morphology of this area (Fig.4). Because of the predominance of brecciated calc-silicates west of Snake Creek (west branch), the drainage pattern in this area is little controlled by structural elements, and is subsequently very irregular. The Mesozoic cappings are progressively eroded towards the east, the easternmost mesa

Fig. 3. The lower section of the Weatherly Creek Quartzite, southwest of the Soldiers Cap mesa, which shows on the right. The picture is taken from the south. (GA/2533)

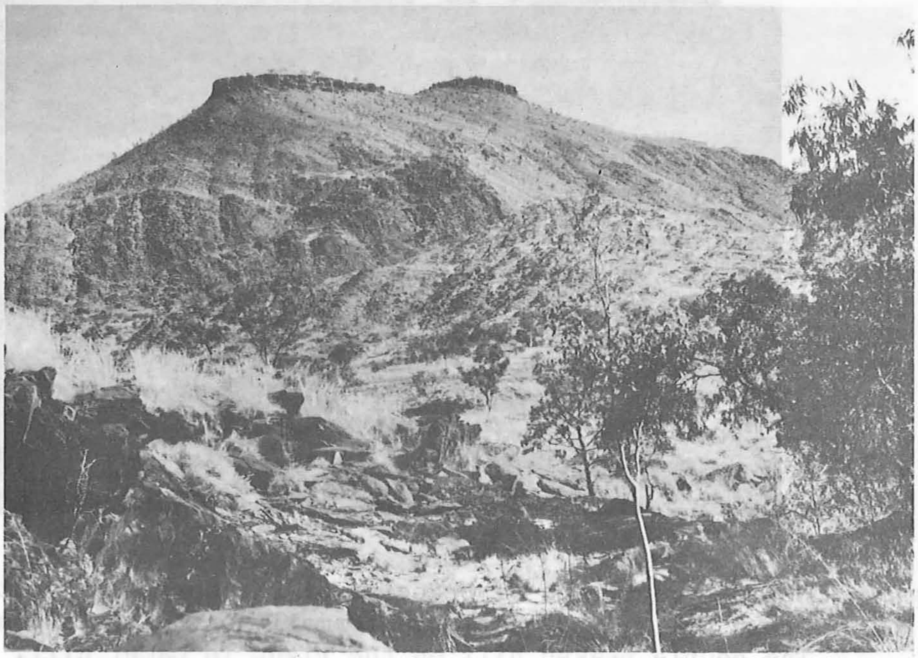


Fig. 4. Mesozoic lateritic mesas, capping schists of the Snake Creek Meta-turbidites. Snake Creek (east branch). (GA/2523)

Fig. 5. A view of schists of the Snake Creek Meta-turbidites (foreground) and silicified meta-sediments marking the northern closure of the Snake Creek Cross-fold (background). Mount Norma can be seen in the horizon on the right. (GA/2529).

Fig. 6. Bouldery outcrops of breccias of the Corella Formation form dark brown hills, and rest unconformably on the Soldiers Cap Formation. The double peaked hill on the right is Camel Hill. (GA/2531)

relic being Soldiers Cap (Fig.3). The flat-lying Mesozoic beds were unconformably laid on the Precambrian with a strong unconformity. The Mesozoic rocks consist of a basal conglomerate, grits, sandstones and siltstone, capped by silcrete and laterite, which support a relatively dense acacia shrub vegetation. The thickening of the Mesozoic cappings towards the west is associated with and probably was caused by the gentle slope of the unconformity surface in this direction.

The foothills

The ranges are flanked by a zone of mildly undulating hills and shallow rises which form a narrow zone east of Soldiers Cap, and become progressively wider toward the north, where the transition between the ranges and the foothills is very gradual (Fig.2). The country around and north of the old Cloncurry-McKinlay road is representative of the foothill topography. It consists of rounded rises of amphibolite, separated by broad valleys underlain by meta-sediments which are usually covered with quartz rubble derived from veins. Because of the difference in colour between the amphibolitic and sedimentary zones, the geology of the area is remarkably well expressed on the aerial photographs, even in areas of relatively poor exposure (Figs 28 and 29). Hills and pinnacles consisting of brecciated calc-silicate rock displaying deep brown weathering surfaces, occur isolated or in groups within the foothill zone (Figs 6 and 18). Loose rubble of calc-silicate rock is scattered on the surface throughout the northern foothills, and is believed to be derived from the Corella Formation. The main streams within the foothills run parallel or subparallel to the strike, in contrast to the streams in the ranges terrain. This variation may be explained by the prevalence of sub-latitudinal strike orientations in the northern zone, combined with the occurrence of topographically low ground northeast of the foothills (e.g., Toole Creek, Turpentine Creek, Pumpkin Gully).

The plains

Between the foothills and the alluvial plains to the east and north of the Soldiers Cap belt lie rubble-covered pediments of the elevated terrain. Because the rubble is autochthonously derived from the underlying rocks, the general geology of the pediment zone can be readily interpreted on the aerial photographs. Thus, alternating dark-coloured (amphibolitic) and light coloured (sedimentary) formation patterns persist in flat areas of little or no outcrop.

The distribution of surface deposits over the alluvial plains to the east and the north of the mapped area has been included in a regional survey by the BMR Carpentaria party, and is therefore not described in the present report. Some areas situated near the transition from the pediment into the alluvial plains show on the aerial photographs as distinct light-coloured patches. Observations on the ground indicate that intensive grazing, and possibly early bush fires, were responsible for an almost complete "shaving" of these areas. Upon their entrance into the plains, the creeks develop meandering and braiding stream patterns.

Climate, vegetation and wild life

The climate of the Cloncurry District can be classified as of the tropical low-rainfall continental type (Slatyer, 1964). The average annual rainfall at Cloncurry is 420 mm, with the bulk of the precipitation taking place during the summer. The distribution of rain may be highly uneven, because of the localized nature of the thunderstorms. The average maximum daily temperature is 90.1°F, and the average minimum daily temperature is 65.9°F. The prevailing wind directions during summer and winter are from the northwest and southeast respectively.

The ranges and the foothill terrain support a sparse to moderately dense vegetation of stunted eucalypts (snappy gum, mountain gum) reaching heights of between 3-5 metres, several varieties of acacia, tea trees, isolated groups of kurrajong trees, and the ubiquitous spinfex. Isolated bottle trees are characteristically associated with water holes. The water courses are marked with tall river gums and tea-trees. Pasture grasses are commonly associated with alluvial flats and river terraces, and are absent from the rubbly plains. The native fauna consists mainly of kangaroos, rock wallabies, rabbits and dingoes. Termite hills are very common on the plains, and less common in the foothill area. The area supports several cattle stations. Horses and goats, as well as undomesticated camels, are of minor importance. The permanent water holes may abound in small fish. No perennial streams occur in the area.

III. STRATIGRAPHY

The stratigraphic sequence exposed in the Cloncurry 1:100,000 Sheet area comprises a succession of meta-sediments and stratiform amphibolites 8000 metres thick (minimum thickness), which is unconformably overlain by brecciated calc-silicates, in turn capped by cross-bedded quartzites. The youngest sediments in the area are flat-lying Mesozoic clastics unconformably overlying the strongly deformed Precambrian rocks. Honman et al. (1939) regarded the metamorphic sequence, which they termed "Soldiers Cap Series", as of Upper Archaeozoic age, and have divided it into a Lower or Schist Stage, and an Upper or Volcanic Stage. The calc-silicate breccias were mistakenly considered by Honman et al. (1939) as volcanic agglomerates, which were correlated with the Lower Proterozoic Mount Isa Series. Carter et al. (1961) described and measured a type-section of the Soldiers Cap sequence between the core of the Snake Creek fold and Weatherly Creek. These authors redefined the unit as the "Soldiers Cap Formation", which they considered to be of probable Lower Proterozoic age. Dunn et al. (1966) assigned the Precambrian of northwest Queensland to the Carpentarian System (approximately Middle Proterozoic). The three-fold subdivision of the Soldiers Cap Formation was recognized by Carter et al. (1961) as follows (from base to top):

(1) High-grade pelitic succession.
(2) Interbedded meta-basalts and medium-grained quartzites.
(3) Interbedded meta-basalts, cherty quartzites, chert and slate.

Because of the relatively large thickness of each of the above units, as measured in the present survey (Figs 7, 8, 9), it is proposed to give them member status. The stratigraphic division used in this report corresponds to that noted by Carter et al. (1961), and is defined as follows:

(1) Snake Creek Meta-turbidites (BLs_1).
(2) Weatherly Creek Quartzite (BLs_2).
(3) Toole Creek Meta-volcanics (BLs_3).

The stratiform amphibolites which constitute between one-third and two-thirds of the two upper units, are regarded as mainly extrusive meta-basalts, and are therefore dealt with as integral primary components of these stratigraphic units. Owing to the systematic decrease in metamorphic grade with higher stratigraphic levels, the three units are characterized by mineral assemblages corresponding to the upper greenschist to lower amphibolite facies, middle to upper greenschist facies, and lower to middle greenschist facies, respectively.

The brecciated and mega-brecciated metamorphosed carbonates which unconformably overly the Soldiers Cap Formation, have been classified by Carter et al. (1961) as outliers of the Corella Formation (Blc) which underlies extensive areas west of the Cloncurry 1:100,000 Sheet area. The overlying quartzites were defined by the above authors as the Roxmere Quartzite (BLr).

The dating of a Soldiers Cap schist and a schist from the Corella Formation by Richards et al. (1963) at 1431 m.y.and 1452 m.y. respectively contrasts with the age relationships of these formations determined in the field. The dating shows, however, that the metamorphism of these rocks took place at approximately the same time.

The following is a detailed description of the stratigraphic units:-

SOLDIERS CAP FORMATION (BLs)

Snake Creek Meta-turbidites (BLs_1)

Definition and outcrop: This is a sequence of well-bedded and graded schists, phyllites, arenaceous schists (meta-greywackes), meta-siltstones, and pebble-bearing meta-sandstones. The outcrops of this unit occupy the main part of the Snake Creek Cross-fold and a small area 6 km. east of Soldiers Cap (Map 1). The sequence has been metamorphosed within the upper greenschist-lower amphibolite facies range. The base of the Snake Creek Meta-turbidites is unexposed, or is in places truncated by granites. A minimum thickness of 2000 metres has been recorded from the Weatherly Creek section (Fig.8). A thickness of 2200 metres is recorded from the Sandy Creek section, the base of which is intruded by granites (Fig.7). The Snake Creek Meta-turbidites are conformably overlain by the Weatherly Creek Quartzite.

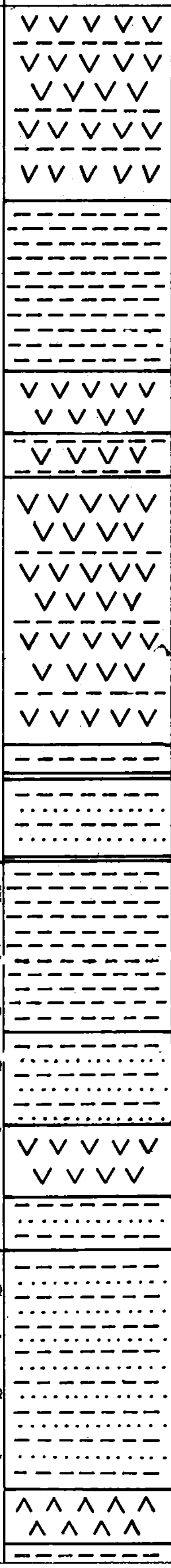
Fig. 7

GEOLOGICAL COLUMNAR SECTION

MAP: CLONCURRY 1:100.000 RUN: 15 PHOTO: 5052 POINTS: 1-64

GENERAL LOCALITY: Sandy Creek, Soldiers Cap GEOLOGIST: A.Y.Glikson DATE: 1969

AGE: Proterozoic STRATGRAPHIC UNIT/S: Soldiers Cap Fm REFERENCE: Rec. 70/



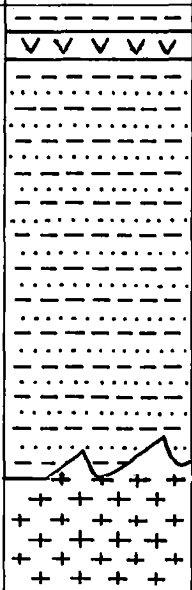
SCALE meters	AGE	GROUP	FORMATION	MEMBER	DESCRIPTION	SAMPLES
	Middle Proterozoic		Soldiers Cap Formation	Toole Creek Meta-volcanics	Ortho-amphibolites, with thin sedimentary intercalations	
					Phyllites, silicified slates, cherts, meta-siltstones	25
1000					Ortho-amphibolite	26
					Black slate, meta-siltstone, amphibolite	27
					Meta-basalt and f.g. ortho-amphibolites, thin sedimentary intercalations (pelites and cherts)	28
2000					Silicified slates and siltstones	
					Meta-dolerite	32A
					Arenaceous, pelitic and silicified meta-sediments	
					Amphibolite	
				Weatherly Creek Quartzite	Interbedded biotite-rich phyllite and meta-siltstones	33, 34
3000					Garnet-staurolite schists, quartzites, meta-siltstones	35-36
					Ortho-amphibolite	
					Biotite phyllite, meta-siltstone, meta-sandstone, quartzite	
4000				Snake Creek Meta-turbidites	Garnet-staurolite-andalusite schists, phyllites, meta-sandstone, quartzite. Intercalation of amphibolite	40,41,42
					Sill of meta-gabbro	55

Fig. 7 (cont.) GEOLOGICAL COLUMNAR SECTION

MAP: RUN: PHOTO: POINTS:

GENERAL LOCALITY: GEOLOGIST: DATE:

AGE: STRATGRAPHIC UNIT/S: REFERENCE:

SCALE meters	AGE	GROUP	FORMATION	MEMBER	GRAPHIC LOG	DESCRIPTION	SAMPLES
	Middle Proterozoic		Soldiers Cap Formation	Snake Creek Meta-turbid.		Staurolite-garnet-andalusite sch.	55
						Amphibolite	45
5000						Garnet-andalusite pelitic and quartzo-feldspathic schists. Interbedded and graded meta-greywackes.	
6000				Williams Granite		Leucocratic granite	

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X

Fig. 8 GEOLOGICAL COLUMNAR SECTION

MAP: CLONCURRY 1:100.000 RUN: 14 PHOTO: 5074 POINTS: 1-12, 34-53

GENERAL LOCALITY: Weatherly Creek, Soldiers Cap GEOLOGIST: A.Y. Glikson DATE: 1969

AGE: Proterozoic STRATGRAPHIC UNIT/S: Soldiers Cap Fm REFERENCE: Rec. 70/

SCALE meters	AGE	GROUP	FORMATION	MEMBER	GRAPHIC LOG	DESCRIPTION	SAMPLES
						Chert and pelitic meta-sediments	
						Amphibolite	
						Chert and meta-siltstone	
						Amphibolite	
						Meta-siltstone, slate, chert, quartzite	
						Meta-basalt and amphibolite	
						Meta-siltstone, slate, chert, quartzite	
						Meta-basalt and meta-dolerite	
						Meta-sediments	
						Meta-siltstone, slate, chert, meta-basalt and meta-dolerite intercalations	
						Amphibolite	
						Cross-bedded quartzite, phyllite, chert, silicified siltstone	
						Meta-basalt	
						Quartzite and phyllite	56
						Meta-basalt and quartzite intercalations	
						Cross-bedded quartzite, meta-siltstone, phyllite, meta-sandstone	57

Scale: 1000, 2000, 3-4000, 5000

Age: Middle Proterozoic

Formation: Soldiers Cap Formation

Mount Norna Quartzite

Member: Toole Creek Meta-volcanics; Weatherly Creek Quartzite

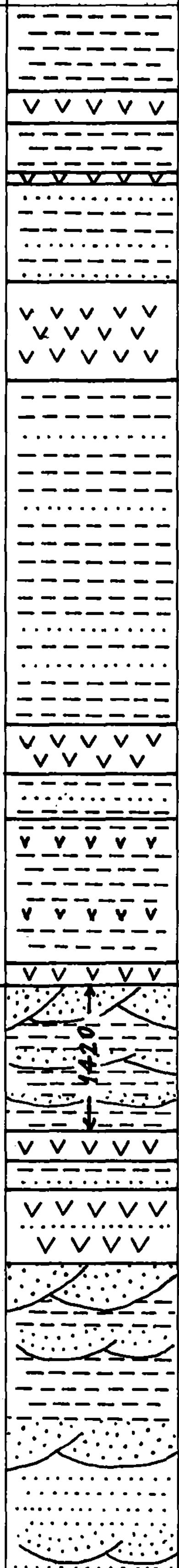


Fig. 8 (cont.)

GEOLOGICAL COLUMNAR SECTION

MAP: RUN: PHOTO: POINTS:

GENERAL LOCALITY: GEOLOGIST: DATE:

AGE: STRATGRAPHIC UNIT/S: REFERENCE:

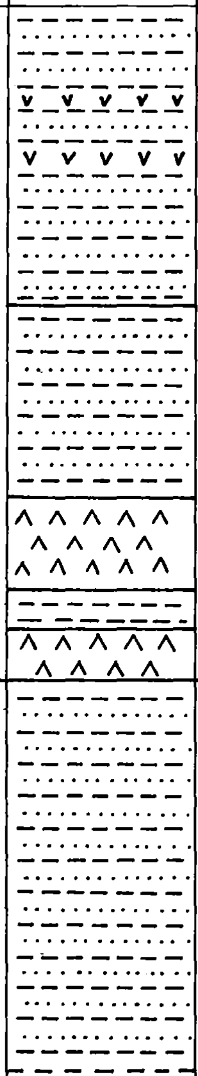
SCALE meters	AGE	GROUP	FORMATION	MEMBER	GRAPHIC LOG	DESCRIPTION	SAMPLES
6000	Middle Proterozoic		Soldiers Cap Formation	Snake Creek Meta-turbidites		Interbedded arenaceous schists, phyllite, garnet schist, and intercalations of amphibolite (meta-basalt)	58A
						Garnet schist, pelitic and arenaceous schist	
7000						Meta-gabbro and meta-dolerite	58b
						Garnet schist	
						Meta-gabbro and meta-dolerite	
				f		f Arenaceous and pelitic garnet-andalusite schists	
8000							
						base unexposed	

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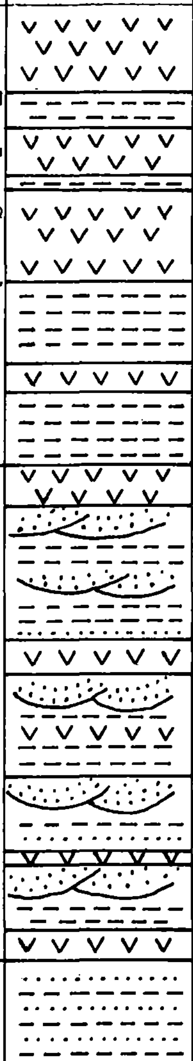
Fig. 9

GEOLOGICAL COLUMNAR SECTION

MAP: CLONCURRY 1:100.000 RUN: 13 PHOTO: 5138 POINTS: 4-19

GENERAL LOCALITY: Elder Creek, Mt Norna area GEOLOGIST: A.Y. Glikson DATE: 1969

AGE: Proterozoic STRATGRAPHIC UNIT/S: Soldiers Cap Fm REFERENCE: Rec 70/



SCALE meters	AGE	GROUP	FORMATION	MEMBER	DESCRIPTION	SAMPLES
	Middle Proterozoic		Soldiers Cap Formation	Toole Creek Meta-volcanics	Meta-basalt	
					Chert and meta-siltstone	
					Meta-basalt	
					Chert and meta-siltstone	
					Meta-basalt and meta-dolerite	
					Pelitic meta-sediments and silicified meta-sediments	
1000					Meta-basalt	
					Pelitic, arenaceous meta-sediments	
				Weatherly Creek Quartzite	Meta-basalt and meta-dolerite	
					Quartzites, biotite phyllites	
					Fine-grained amphibolite	
2000					Cross-bedded quartzites, with slate intercalations. Intercalation of amphibolite.	
					Quartzite and pelitie sediments	
					Meta-basalt	
					Quartzite and meta-siltstone	
					Meta-basalt	
				Snake Creek Meta-turbidites	Interbedded arenaceous and pelitic schists. Minor silicified meta-siltstones.	
3000						

Sedimentary structures:- Pelitic and arenaceous beds alternate with each other, the common thickness range of individual layers being about 10-100 cm. Internal lamination and fine-scale banding of individualbeds are very common (Fig.10). Although the contacts between pelitic and arenaceous beds are usually sharp, sedimentary grading within arenaceous and silty layers into pelitic and often carbonaceous tops has been observed. In higher-grade meta-sediments the compositional variations are represented by the progressive increase in the abundance of andalusite towards the top of the bed (Fig.12). The sedimentary lamination is usually retained in the garnet-staurolite schists (Fig.13), and the compositional differences between individual laminae have evidently been accentuated due to metamorphic segregation. Fine-scale cross-lamination and minor slumping occur in the meta-argillites. Pebble-bearing meta-greywackes and mud-flake-bearing meta-sandstones are minor occurrences. The meta-greywackes have commonly retained their fine clastic textures to a considerable degree. Although the proportion of arenaceous to pelitic rocks varies from outcrop to outcrop, the overall ratio is probably near to 1:1. The similarity of the greywacke-slate association to the geosynclinal flysch facies and to modern turbidites, constitutes the basis for the designation of the sediments as turbidites.

Mineral assemblages:- The mineral assemblages described in thin-section are listed below. Individual descriptions are presented in Appendix I. A discussion of the petrology is given in chapter VI.

- Garnet-staurolite-muscovite-biotite-quartz porphyroblastic schist.
- Garnet-biotite-quartz-staurolite sieve-structured schist.
- Andalusite-bearing garnet-muscovite-staurolite-quartz-biotite porphyroblastic schist.
- Garnet-staurolite-muscovite-biotite-quartz schist.
- Staurolite-andalusite-muscovite lenses in quartz-biotite schist.
- Biotite-chlorite-quartz-garnet-tremolite schist.
- Quartz-staurolite-garnet-biotite-porphyroblastic schist.
- Garnet-andalusite-muscovite-biotite-quartz porphyroblastic schist.
- Garnet-biotite-muscovite-quartz-andalusite porphyroblastic schist.
- Garnet-chlorite-biotite-muscovite-quartz-schist.
- Garnet-andalusite-sericite-clinozoisite-biotite-plagioclase-quartz schist.
- Garnet-magnetite-albite-quartz-biotite schist.

- Garnet-biotite-sericite-quartz meta-siltstone phyllite.
- Carbonaceous garnet-quartz-muscovite crenulated phyllite.
- Garnet-bearing biotite-muscovite-quartz meta-sandstone schist.
- Garnet-chlorite-biotite-tremolite-microcline-albite-quartz porphyroblastic meta-sandstone.
- Garnet-biotite-muscovite-quartz meta-greywacke semi-schist.
- Tourmaline-bearing albite-muscovite-biotite-quartz meta-greywacke semi-schist.
- Albite-biotite-muscovite-quartz meta-greywacke semi-schist.
- Chlorite-microcline-albite-quartz meta-sandstone.

Weatherly Creek Quartzite (Bls_2)

Definition and outcrop:- This stratigraphic unit consists of cross-bedded light-coloured quartzite, siliceous meta-siltstone phyllite, and feldspathic meta-sandstone, and is abundantly interspersed with stratiform meta-basalts and meta-dolerites which range from a few feet to approximately 350 metres in thickness. The alternation of resistant quartzite ridges with soft pelitic meta-sediments accounts for the ridge and valley morphology of the outcrop, which shows on the aerial photographs as distinct white bands (Fig.28). The transitions between the Weatherly Creek Quartzite and the underlying and overlying stratigraphic units are gradational. The quartzites are well developed in a 0.6-2.4 km. wide belt between Weatherly Creek and Bull Creek, where they constitute over 50 percent of the sedimentary rocks. The unit is subject to considerable variations in thickness, lithology, and abundance of incorporated amphibolites. The type-sections of the Weatherly Creek Quartzite along Weatherly Creek (Fig.8) and along an upper tributary of Elder Creek (Fig.9), are 2700 metres thick and 1300 metres thick respectively. The thickness recorded from the Sandy Creek section west of Soldiers Cap (Fig.7) is 1100 metres, and owing to a lower percentage of quartzites the unit is difficult to define in this area. Probable outcrops of the Weatherly Creek Quartzite occur between the Toole Creek Syncline and the Oonoomurra Syncline, and between the latter structure and the Pumpkin Gully Syncline (Fig.29). The definition of the unit in these areas is partly based on the occurrence of cross-bedded quartzites within the predominantly pelitic meta-sediments, and partly on structural considerations. It appears that the Weatherly Creek Quartzite, while well defined east and north of the Mount Norna area, grades into a

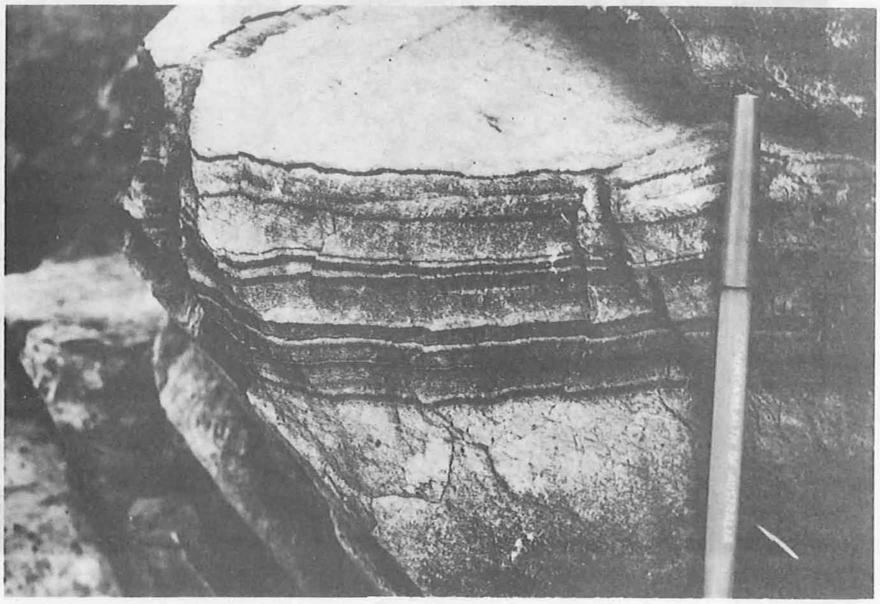


Fig.10. Fine sedimentary banding developed in garnetiferous lineated schist. The schistosity is oriented at an angle to the bedding. Upper course of Weatherly Creek, 2 miles south of Mount Norna. (GA/2331)

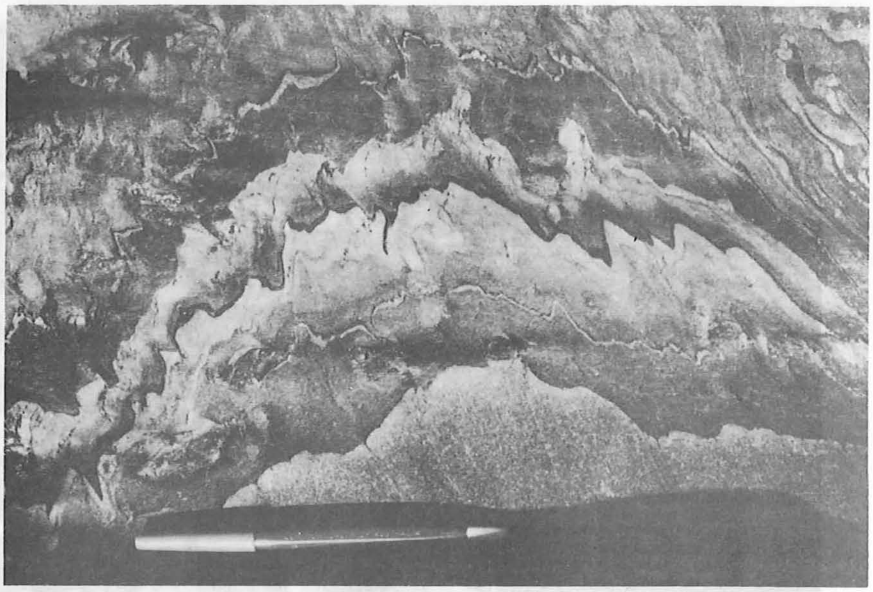


Fig.11. Graded bedding in pelitic and fine-grained quartzose garnet-andalusite schists. The downward grading indicates the strata are overturned. The folding is the result of drag and displacement along schistosity planes, oriented at a high angle to the bedding. Upper course of Snake Creek (east branch). (GA/2345)

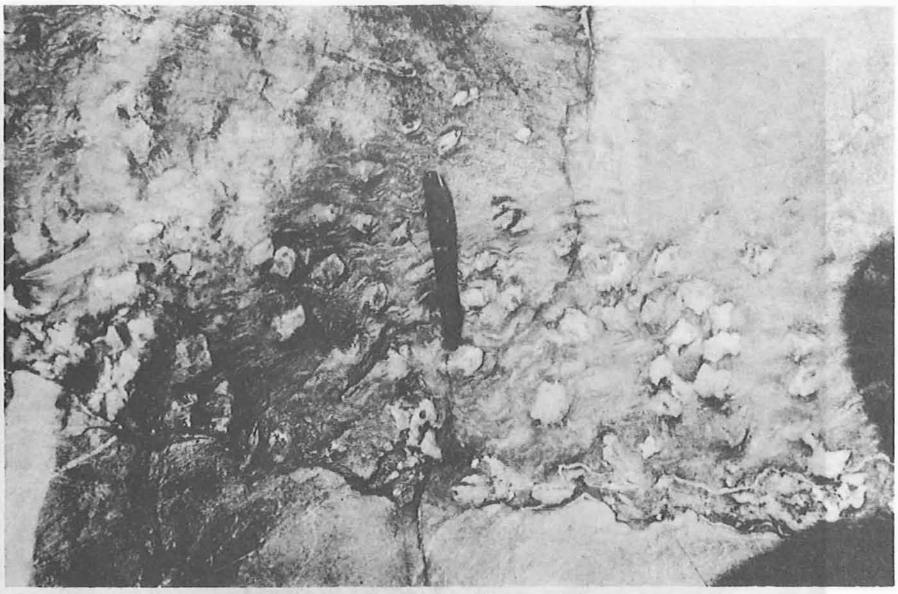


Fig.12. An overturned graded bed of andalusite schist. The increase in size and abundance of andalusite porphyroblasts downwards, indicates a corresponding increase in the pelitic component, which implies sedimentary grading and facing in the same direction. Upper course of Snake Creek (east branch). (GA/2328)

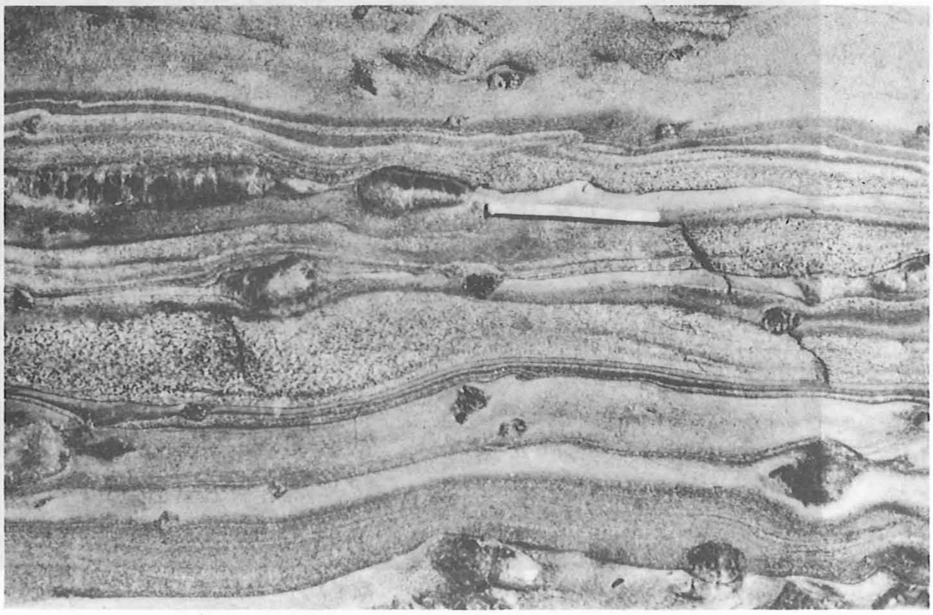


Fig.13. Andalusite-staurolite-garnet augen schist, displaying relic sedimentary lamination. Upper course of Sandy Creek. (GA/2774)

predominantly pelitic facies both northward and southward of the type area. This unit grades into the overlying Toole Creek Meta-volcanics.

Petrography:- The rocks most typical of the unit are fine-grained white to light grey, flaggy, well-bedded or massive orthoquartzites, commonly displaying foreset-bedding, ripple marks, and groove casts (Fig.14). The meta-siltstones are commonly laminated, and may display slump features (Fig.15) and sedimentary pillow structures. Cross-bedded meta-siltstones are present (Fig.16). The meta-sediments have been metamorphosed within the middle greenschist-lower amphibolite facies range. The following mineral assemblages have been described in thin-section (Appendix I):-

- Muscovite-biotite-quartz laminated meta-siltstone.
- Chlorite-veined muscovite-quartz meta-siltstone.
- Chlorite-biotite-muscovite-quartz laminated spotted phyllite.
- Chlorite-garnet-biotite-quartz-muscovite banded phyllitic meta-siltstone.
- Garnet-staurolite-muscovite-biotite-quartz schist.

The petrography of the meta-basalts and the meta-dolerites associated with the Weatherly Creek Quartzite is considered in chapter IV.

Toole Creek Meta-Volcanics (BLs$_3$)

Definition and outcrop:- This unit is a sequence of stratiform, massive, uniform fine-grained to medium-grained amphibolites, composed mainly of meta-basalts and to a lesser extent meta-dolerites. The basic meta-igneous rocks are intercalated with chert, silicified meta-siltstone, fine-grained quartzite and phyllite. Feldspathic meta-sandstone, banded iron formation (meta-jaspilite)(Fig.17), and calcsilicate rocks are minor components of the unit. The ratio of igneous to sedimentary components is about 3:1. The unit occupies most portions of the synclines in the map area. Cross-sections through the sequence have been recorded along Sandy Creek (Fig.7), Weatherly Creek (Fig.8), Elder Creek (Fig.9), and the upper tributaries of Turpentine Creek and Bishop Creek. The thicknesses of the first three sections are 2500 metres, 2800 metres, and 1200 metres respectively, whereas the thicknesses of the two latter sections are difficult to ascertain due to the extensive occurrence of small-scale folding in the cores of the Weatherly Creek-

Toole Creek Syncline. The proportion of the sedimentary intercalations decreases considerably northward, e.g. in the northwestern part of the core of the Oonoomurra Syncline, and in the Pumpkin Gully Syncline, sediments constitute no more than one to two percent of the total thickness.

The Toole Creek Meta-volcanics is the stratigraphically uppermost unit of the Soldiers Cap Formation in the Cloncurry 1:100,000 Sheet area, and is unconformably overlain by calc-silicates of the Corella Formation.

Petrography:- The mode of occurrence and the petrography of the amphibolites are discussed in chapter IV. Chert is the characteristic, but not the most common, type of sedimentary intercalation in the volcanic sequence. The intercalations usually range between about 2 metres and about 10 metres in thickness. The cherts are white, grey or black, are commonly finely laminated due to variations in the content of graphite, and may display tight small-scale folding, possibly of penecontemporaneous origin. The following cherts were described in thin-section (Appendix I):

- Clinozoisite-quartz banded meta-chert.
- Amphibole-quartz meta-chert.
- Tourmaline-veined graphitic chert.

Silicified meta-siltstones and fine-grained quartzites are also present, and are difficult to distinguish from cherts in hand-specimen. Pelitic and arenaceous meta-sediments are also common components of the unit. The following mineral assemblages were recorded in thin-section (Appendix I):

- Spotted biotite-feldspar-quartz-sericite-meta-siltstone.
- Black meta-siltstone slate.
- Rutile-bearing albite-quartz-muscovite crenulated phyllite.
- Biotite-quartz-muscovite spotted phyllite.
- Biotite-muscovite-microcline-albite-quartz phyllite.
- Biotite-muscovite-quartz crenulated phyllite.

As indicated by the above assemblages, the rocks conform to the lower to middle greenschist metamorphic facies. Calc-silicates are minor

Fig.14. Groove moulds on the base of an overturned quartzite bed of the Weatherly Creek Quartzites. Bull Creek area. (GA/2341)

Fig.15. Sedimentary slumping in laminated meta-siltstone of the Weatherly Creek Quartzite. Sandy Creek. (GA/2380)

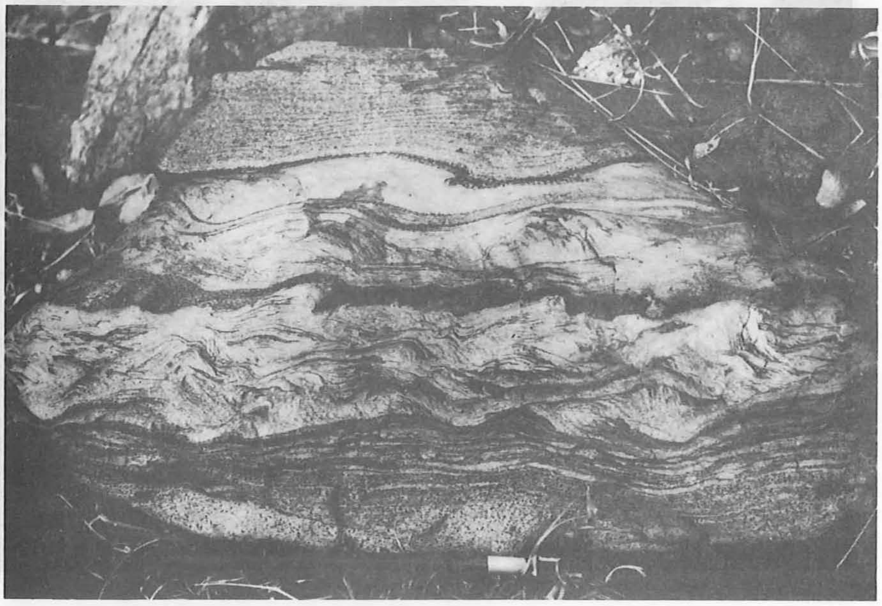


Fig.16. Laminated and cross-bedded garnetiferous meta-greywacke, meta-siltstones and biotite phyllite. The sedimentary structures are accentuated by incipient metamorphic segregation. Weatherly Creek Quartzite . Near the Gilded Rose gold mine.

Fig.17. Folded banded iron formation (hematite-quartz meta-jaspilite), occurring as an intercalation in meta-basalts. Toole Creek Volcanics. North of Pumpkin Gull y. (GA/2348)

but significant constituents of the unit. An occurrence of an edenite-dolomite intercalation containing concretions of graphitic dolomite was recorded south of the Gilded Rose gold mine area (sps. 69200065A, B and C, Appendix I). The Toole Creek Meta-volcanics is the only unit in which banded iron formation (meta-jaspilite) has been observed (Fig.17). The meta-jaspilite shows fine interbanding of quartz and hematite-magnetite layers, and is characterized by the abundance of small scale folding.

MARIMO SLATE (Blm)

The Marimo Slate occupies the far southwest corner of the Sheet area, together with calcareous breccia, dolerite plugs and flat-lying Mesozoic strata. Two distinct lithologies predominate: grey to black slate, and fine-grained sandstone and siltstone.

Slate member

Slate is best exposed along the southwestern sheet margin. It is grey to black, but locallv is brown and ochreous due to variable amounts of lateritization, particularly in areas adjacent to the mesas of Mesozoic strata. Certain zones in the slate contain abundant small holes, up to 3 mm diameter, due to weathering of small concretions, carbonaceous nodules or pyrite. Minor intercalations of fine-grained sandstone and silt occur near the Robur, Bluebell and Just Found mines, and calcareous (?dolomitic) slate occurs southeast of the Just Found mine. Greisen veins cut slate and silt southeast of the Bluebell mine, along an extension of a prominent fault-zone (see Structure).

Zones of silicification and iron and manganese enrichment are widespread. Most of these zones trend northwest and north-northwest, and represent major faults or zones of microfracturing with no obvious disruption.

Copper mineralization is present at many localities (see Economic Geology), and is mainly fault-controlled. A small radiometric anomaly occurs in the Copper Canyon area at the faulted contact of slate with coarse ferruginous sandstone.

Sandstone Member

A sequence of sandstone and siltstone overlying the slate and forming inliers in the Corella Formation has been informally named the Mick Creek Sandstone Member. The name is taken from Little Mick Creek, which flows through the southernmost outcrops of the member. This unit was termed Roxmere Quartzite by Carter et al., (1961), but detailed mapping has shown it to be older than the Corella Formation, whereas in the type area the Roxmere Quartzite is younger than the Corella Formation.

The dominant lithologies are fine-grained blocky to massive feldspathic sandstone, and coarse-grained grey siltstone. Ripple-marking and micro-cross-bedding are widespread, the latter being outlined by narrow ?hematite-rich laminae. Other lithologies include pebble conglomerate, friable medium to coarse-grained ferruginous sandstone and limestone. Limestone occurs in an anticlinal core of sandstone and silt 3 km. northwest of Davis Hill, and in sandstone near Little Mick Creek. It is well-bedded, and is associated with ripple-marked calcareous shale.

Stratigraphy and structure

Sandstone overlies slate conformably 5 km. south of Roxmere Homestead. Elsewhere relations with slate are not clear, and in the southwest they are partially obscured by Mesozoic cover. In this area a facies change is probable from sand in the Little Mick Creek area, to slate in the northwest.

Elsewhere breccia of the Corella Formation overlaps the sandstone member unconformably. In most cases the sandstone forms topographically high anteformal structures surrounded by a breccia "sea", but at one locality near Little Mick Creek breccia remnants occur overlying sandstone at the top of some low hills.

Facing in the anteformal structure cut by Little Mick Creek shows the beds are completely overturned; this indicates a zone of overfolding and/or major faulting between these outcrops and those sandstone outcrops to the northeast. This structure and other faulting will be considered in more detail in the Structure section (see Section

V(5)). The relationships between Marimo Slate and Soldiers Cap Formation are unknown.

Petrography

Samples 70200400, 406, 462, 463, 464 and 465 were examined. All are fine-grained feldspathic quartzite and siltstone except 400, which is calcareous, and 464, which is conglomeratic. The quartzites show very little recognizable sedimentary fabric; grain boundaries are anhedral and indistinct, and are corroded by opaline material. In 462 brown isotropic silica forms up to 50 percent of the rock. Feldspars are clouded, and include both plagioclase and alkali feldspar. Average grain diameter ranges from 0.06mm to 0.3mm.

Bedding is outlined by hematite layers up to 1 mm thick which also contain up to 5 percent zircon and tourmaline. In shaly bands sericite flakes are abundant, and scattered altered porphyroblasts of ?tremolite occur. Rutile, and rare clinozoisite are other accessories. In the conglomerate (464) clasts include granular quartzite, micaceous siltstone, hematite quartzite and rare plagioclase-rich volcanic rock. The groundmass is quartzofeldspathic and hematite-rich, and contains rare large (2mm) crystals of apatite and some tourmaline.

Petrogenesis

All samples show evidence of deformation, silicification and greenschist facies metamorphism, but distinct periods of deformation are not evident. The basic volcanic clasts in conglomerate suggests basic igneous sources; possibly the Marraba Volcanics and Soldiers Cap Formation were exposed during deposition of the Mick Creek Sandstone Member.

CORELLA FORMATION (Plc)

The Corella Formation in the Cloncurry Sheet area consists of brecciated bedded calc-silicate rocks, impure dolomites and limestones, and minor quartzites, meta-siltstones, and calcareous meta-siltstones. The breccias rest with strong unconformity on the Soldiers Cap Formation. The principal outcrops of the Corella Formation occur west of Snake Creek (west branch), where inliers of interbedded meta-sandstone, meta-siltstone and black slate of the Marimo Slate crop out from beneath the calc-silicates. Both brecciated and bedded calc-silicate rocks are present in this area, and they are intruded by numerous small granitic and doleritic stocks. The unbrecciated calc-silicates tend to occur at relatively high stratigraphic positions above the basal unconformity, and have not been observed in contact with the Soldiers Cap Formation. Brecciated outliers of the Corella Formation abound in the northern and western parts of the mapped area (Map 1). The largest continuous outlier is a tongue of brecciated and bedded calc-silicates extending between Oonoomurra and Ilkley. The isolated outliers are usually conspicuous in the field because of their rugged bouldery appearance (Figs 6, 18) and the deep brown colour of the weathering crusts developed over them. Calc-silicate rubble remnants of eroded Corella Formation are widely scattered over outcrops of the Soldiers Cap Formation in the northern part of the area (mostly north of the Landsborough Highway). Because of the almost completely brecciated state of the rocks, neither continuous sections nor measured thicknesses could be obtained for the Corella Formation within the Sheet area.

The Soldiers Cap Formation-Corella Formation unconformity

The Cloncurry Sheet area provides some of the best exposures of the basal unconformity of the Corella Formation in the region. A continuous outcrop of the unconformity can be traced parallel to and about 1.5 km. west of Snake Creek (west branch), where mega-brecciated calc-silicates and para-amphibolites overly schists and ortho-amphibolites of the Snake Creek Meta-turbidites (Figs 27 and 28). The trace of the unconformity is highly irregular, and in many places is topographically lower than the outcrops of the Soldiers Cap Formation. This situation is particularly well expressed where the calc-silicates overlie amphibolites, e.g. in the area between Davis Hill and the junction of Bull Creek with Snake Creek, and at Great Table Mount, southwest of Oonoomurra. However, whether this relief represents an original topography, or whether it resulted from the collapse of calc-silicate breccia into valleys in a later period of erosion is uncertain. The local occurrence of probable inliers of orthoamphibolite of the Soldiers Cap Formation under the

Corella Formation west of Snake Creek favours the first interpretation. A regional slope of the unconformity northward and westward is implied by the progressive increase in the abundance of calc-silicate rocks in these directions.

Brecciated calc-silicates

The rocks of the Corella Formation within the map area are mostly breccia and mega-breccia. The internal structure of the breccias can be described as chaotic. Individual blocks of calc-silicate range up to several hundred metres in size, and are usually angular. Rounded forms suggestive of solution are almost completely absent. The blocks are embedded in and veined by fragmental and pulverized breccias (Figs 20 and 21). The ratio of blocks to fragmental breccia varies from place to place, and mega-breccias including only a small proportion of fragmental matrix have been observed. Pipes and irregular bodies of breccia may be intruded into or rest unconformably on bedrock (Derrick, 1968). Both mega-breccias and fragmental breccias lie directly over the Soldiers Cap Formation. The sedimentary banding within the blocks may be folded (Fig.19) or deflected (Fig.20), but mostly it is undeformed. The compositions of the fragments and blocks incorporated in the breccia are generally similar to bedded calc-silicates in the area. Specimens of brecciated Corella Formation described in thin-section (Appendix I) include the following assemblages:

Calc-silicate rocks:-

- Sericitic quartz-calcite banded meta-limestone.
- Carbonate-biotite-quartz-scapolite calc-silicate.
- Biotite-quartz altered scapolite-carbonate porphyroblastic calc-silicate.
- Albite-microcline-biotite-quartz-sericite-carbonate calc-silicate.
- Biotite-albite-quartz-carbonate calc-silicate.

Amphibole-bearing calc-silicate rocks:-

- Sphene-rich tremolite-albite-calcite porphyroblastic calc-silicate.
- Tremolite-muscovite-quartz-carbonate porphyroblastic calc-silicate.

Para-amphibolites:-

- Sphene-quartz-diopside-tremolite-calcite-sodic plagioclase para amphibolite.
- Sphene-diopside-tremolite-calcite-albite porphyroblastic para-amphibolite.
- Hematite-spotted tremolite-epidote-albite para-amphibolite.
- Sulphide-rich apatite-phlogopite-quartz-tremolite-carbonate porphyroblastic para-amphibolite.
- Diopside-epidote-sphene-amphibole-plagioclase para-amphibolite.

Miscellaneous rocks:-

- Calcite-tourmaline-sericite-plagioclase-quartz meta-sediment.
- Banded carbonate-rich meta-siltstone.
- Carbonate-quartz-microcline-albite meta-siltstone.

As indicated by the occurrence of diopside in the para-amphibolites, the metamorphic grade of the rocks of the Corella Formation ranges up to the Abukuma type lower amphibolite facies.

Bedded Calc-Silicate Rocks

Well bedded calcareous sediments occur throughout the Corella Formation west of Snake Creek, as narrow synclinal belts surrounded by massive red-brown specularitic calcareous breccia (Map 1). The belts are of uniform lithology, and include grey brown flaggy limestone, calcareous silt, marl (calcareous clay), fine-grained, laminated to blocky calcareous quartzite, calc-silicate rocks and minor slate, mica schist and breccia. Near Davis Hill the calcareous beds show a coarse spotting of scapolite, up to 0.5 cm. diameter. Ripple marking, microcrossbedding and small-scale convoluted bedding are present, and generally indicate facing in the sequence, which is everywhere about 500 feet thick.

Stratigraphy: West of Davis Hill the well-bedded calcareous rocks slightly overlap the quartzite member of the Marimo Slate, and facing shows that the former are younger than the latter. Near the Duchenese mine, limestone and marl overlie slate of the Marimo slate unconformably.

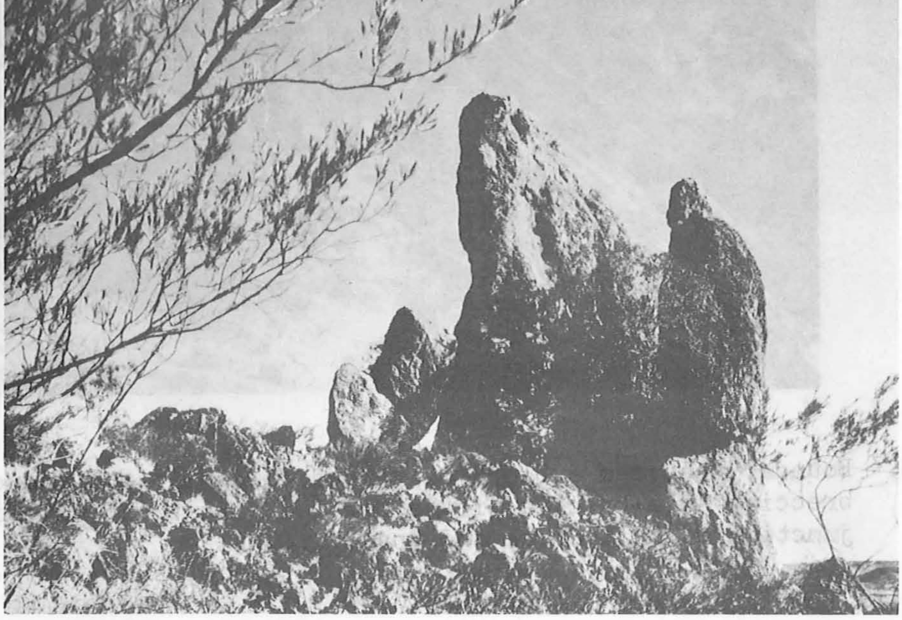


Fig.18. Columns of brecciated calc-silicates resting unconformably on amphibolites of the Soldiers Cap Formation south-west of Camel Hill. (GA/2530)

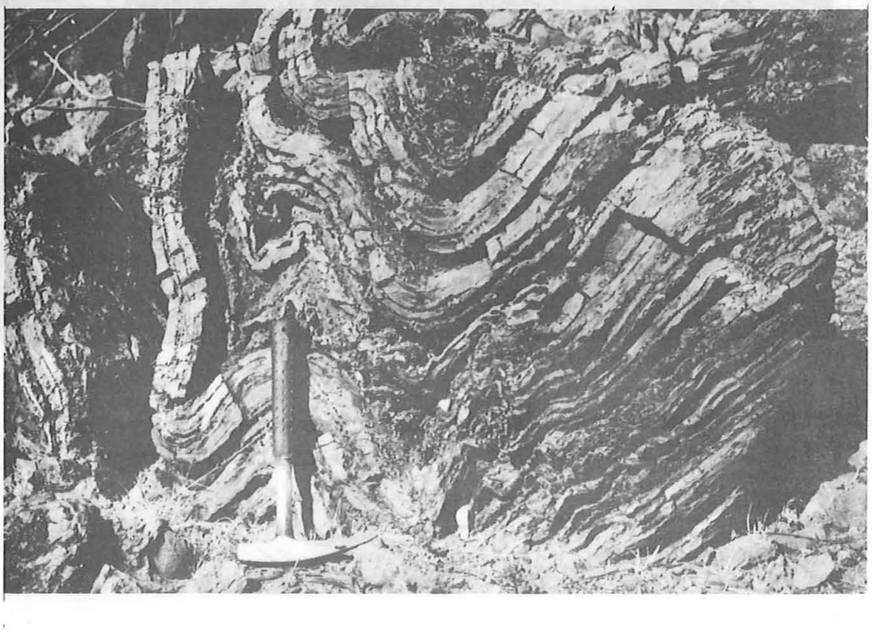


Fig.19. Contorted banded calc-silicates, limestones, and quartzites of the Corella Formation. Outcrop near Roxmere. (GA/2340)

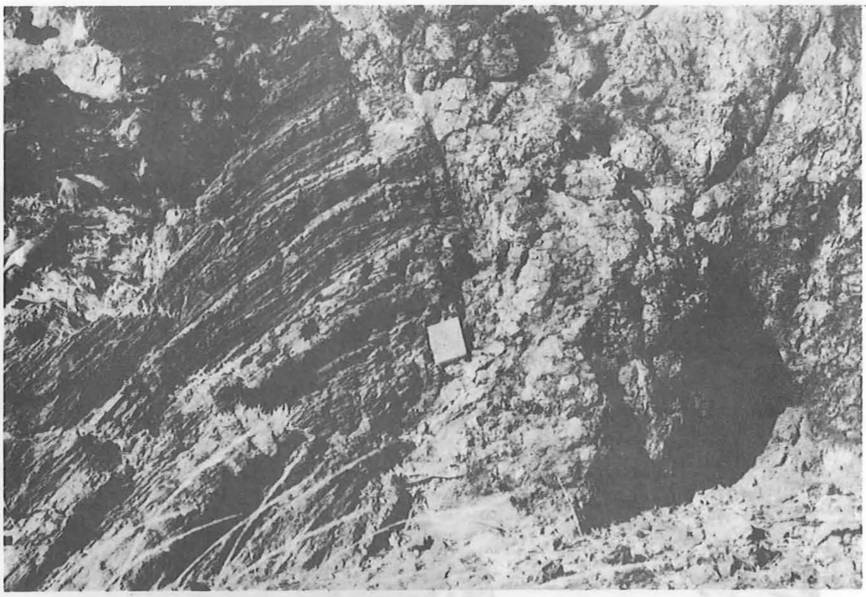


Fig.20. Boundary between a block of banded calc-silicate and calc-silicate breccia. Mega-breccia of the Corella Formation. Outcrop near the junction of Bull Creek and Snake Creek. (GA/2349)

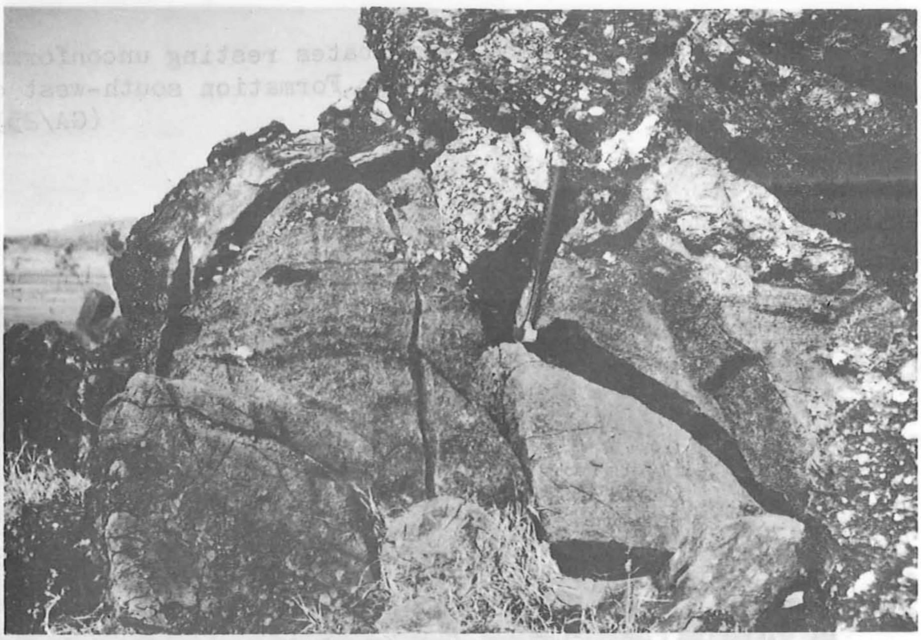


Fig. 21. Block of banded calc-silicate surrounded by breccia. Mega-breccia of the Corella Formation. Outcrop north of Pumpkin Gull y. (GA/2528)

Relations with the extensive masses of breccia are less clear; on structural grounds , the well-bedded synclinal belts appear younger than the underlying breccia. They possibly represent outliers of a folded carbonate sequence, the base of which has been preferentially brecciated (see Fig.33). In a number of localities the boundary between bedded and brecciated carbonate rock is marked by a transitional zone up to 16 metres thick of intraformational breccia, in which the original bedding is still apparent.

There is good stratigraphic evidence to show that some breccia is younger than or contemporaneous with the well-bedded sequences. Near Copper Canyon dyke-like masses of breccia cut well-bedded limestone; in the Little Mick Creek area bedded sequences are sharply transgressed by breccia, which in all cases is similar to breccia apparently underlying the bedded material elsewhere; northwest of Davis Hill zones of breccia up to a few metres thick are concordant with bedded material.

In the Little Mick Creek area fragments of calcareous quartzite and breccia in marl are suggestive of some brecciation before and possibly during deposition.

The origin of the breccia is considered in Section V(4).

Petrography: The samples examined include three groups of rocks: spotted calcareous schist and marl, limestone and quartzite, and metaigneous rocks.

a. Spotted calcareous rocks (70200395, 401, 402)

Scapolite (10% to 40%) forms porphyroblasts 1 to 3 mm diameter. They are well-rounded, and contain abundant fine-grained inclusions, mainly of biotite, sericite, iron ore, quartz and rare tourmaline and apatite. Inclusions are abundant in the porphyroblast cores, but less so near the grain margins. The matrix (60% to 90%) is a fine-grained foliated aggregate of biotite, quartz, microcline, calcite (15% to 25%), muscovite, chlorite and specularite. Banding is outlined by variations in calcite grain size and hematite concentrations.

Two cleavages are present. The older cleavage is parallel to bedding, and the other is a crenulation cleavage at right angles to the bedding.

b. Limestone and quartzite (70200403, 427)

These rocks are generally laminated and fine-grained with an average grain diameter from 0.2mm to 0.5mm. All gradations exist between bands of pure limestone (calcite with some dolomite) and bands of calcareous feldspathic quartzite. In limestone bands rare large grains of alkali feldspar and polygonal aggregates of quartz occur; the feldspathic quartzites contain calcite interstitially. Accessory minerals include tourmaline, zircon, muscovite, hematite and chloritized biotite; in 427 rare large (2mm) altered porphyroblasts of tremolite are present.

c. Meta-igneous rocks (70200404, 409)

These are concordant with calcareous sediments; sample 404 contains a clouded quartz-feldspar aggregate with scattered blebs of chlorite and calcite. Rutile, iron ore and zircon are accessory. This could be a fine-grained recrystallized acid volcanic. Sample 409 is a spotted orthoamphibolite. The spots are extensively sericitized plagioclase porphyroblasts, contained in a matrix of green-brown amphibole (60 percent) and quartz-plagioclase lenticles (40 percent). Sphene and iron ore are accessories.

Petrogenesis: Inclusions in scapolite are continuously oriented with the matrix foliation (flow cleavage), which suggests the scapolite grains are syn or post-tectonic (first phase). A second phase of deformation is indicated by the crenulation cleavage, which deforms the matrix and the oriented inclusions in scapolite. The assemblages calcite-quartz-tremolite and quartz-muscovite-biotite in various parts of the Corella Formation west of Snake Creek indicate high greenschist facies metamorphism. Diopside occurs in calc-silicate rocks south of Davis Hill, and indicates amphibolite facies metamorphism there. Similarly orthoamphibolite near Roxmere homestead indicates amphibolite facies metamorphism in that area. Thus an isograd between greenschist and amphibolite facies probably occurs in the vicinity of Snake Creek, and roughly parallel to it. This is represented in Fig. 26.

ROXMERE QUARTZITE (Plr)

The Roxmere Quartzite constitutes the uppermost Precambrian formation exposed in the Cloncurry 1:100,000 Sheet area. In this report only quartzite younger than the Corella Formation, (in the Coppermine Creek area) is described as Roxmere Quartzite. Quartzite west and south of Davis Hill, originally named Roxmere Quartzite by Carter et al. (1961), is older than the Corella Formation, and now considered to be part of the Marimo Slate (see Mick Creek Sandstone Member). The unit consists of laminated, cross-bedded, and ripple-marked orthoquartzites and feldspathic quartzites, characterized by light-brown colours. The type outcrop of the unit occurs as a synclinal core, centred approximately 5 km. northeast of the Roxmere Homestead (Map 1). A small outcrop occurs at Mount Avarice, approximately 3 km. southeast of Cloncurry. In both localities the quartzites overlie brecciated calc-silicates of the Corella Formation, the transition horizon being a thin zone of brecciated quartzite. This unit is highly jointed and cut by thin veinlets of pink calcite and quartz. Preferential weathering of calcite has emphasized the brecciated appearance of the quartzite. At a small quarry located about 1.6 km. southeast of the Cloncurry hospital, however, the quartzite directly overlies meta-basalts of the Soldiers Cap Formation. The minimum thickness of the unit in the Coppermine Creek area is 2000 metres. In thin-section (Appendix I, sp. 69200095), a specimen from the Roxmere Quartzite has been defined as tourmaline-bearing feldspathic quartzite. Specimen 70200407 is a feldspathic quartzite containing abundant biotite, calcite and rare tremolite, indicating greenschist facies metamorphism.

The Roxmere Quartzite in the Cloncurry Sheet area can be correlated with well-bedded feldspathic quartzites and sandstones which crop-out west of the Cloncurry River in the Marraba 1:100,000 Sheet area (Derrick et al., 1970).

IV. META-IGNEOUS AND IGNEOUS ROCKS

The most characteristic feature of upper stratigraphic levels of the Soldiers Cap Formation is the predominance of stratiform meta-basalts and fine-grained meta-dolerites. Sills of meta-gabbro and meta-dolerite occur at high stratigraphic levels and near the top of the Snake Creek Meta-turbidites and the Weatherly Creek Quartzite respectively. Dykes of meta-dolerite strike at low angle to the trace of the axial plane of the Snake Creek Cross-fold. Large granitic intrusions occur north and south of the Sheet area, which includes only small granitic stocks. The latter are particularly common in the Corella Formation west of Snake Creek. In the following, each igneous rock group is individually considered.

Stratiform meta-basalts and meta-dolerites (db)

The stratigraphically lowermost metabasites in the Soldiers Cap Formation are multiple sills of meta-gabbro intruded into upper levels of the Snake Creek Meta-turbidites. The abundance of stratiform metabasites increases progressively upwards above these sills. The Weatherly Creek Quartzite contains stratiform meta-basalts, fine-grained meta-dolerites and orthoamphibolites, constituting between one quarter and one half of its thickness. Individual metabasite bodies range from less than 1 metre to several hundred metres in thickness, and can be followed over considerable distances along the strike (Map 1). As a rule, the thicker the body, the greater its length along the strike. Basic meta-igneous rocks predominate in the Toole Creek Meta-volcanics, and include numerous thin intercalations of chert, meta-argillite, and other sedimentary rock types. The ratio of meta-igneous rocks to meta-sedimentary rocks in this unit appears to increase northward.

In outcrop the metabasites occur as massive to weakly cleaved and fractured aphanitic to fine-grained dark green rocks, almost completely devoid of features diagnostic of extrusive origin. The meta-dolerites display fine-grained megascopic blastophitic textures. The only locality where pillow structures have been observed is near the track between Mount Norna and the Lady Michelle copper workings (Fig.

23). The pillows display fine-grained doleritic cores, basaltic shells, and leucocratic mesostases. The origin of some stratiform meta-dolerites through multiple intrusion is suggested by the occurrence of intraformational chilled contacts (Fig.24). Bands of coarse-grained glomeroporphyritic meta-dolerite have been observed within stratiform meta-dolerite (sp. 69200030). In some instances, the boundary zone of thin stratiform metabasites contains fine leucocratic globules.

Thin-section descriptions of meta-basalts, fine-grained meta-dolerites, and ortho-amphibolites, are given in Appendix I. The following mineral assemblages were recorded:

Meta-basalts:

- Sphene-rich labradorite-amphibole porphyritic meta-basalt.
- Leucoxene-quartz-albite-epidote-tremolite blastophitic meta-basalt.
- Leucoxene-albite-quartz-amphibole-epidote meta-basalt.
- Scapolite-albite-amphibole meta-basalt.

Meta-dolerites:

- Ilmenite-bearing andesine-amphibole blasto-glomeroporphyritic meta-dolerite.
- Ilmenite-bearing amphibole-andesine meta-dolerite.
- Biotite-amphibole-andesine fine-grained sheared meta-dolerite.
- Iron-rich plagioclase-amphibole meta-dolerite.
- Leucoxene-epidote-saussurite-albite-sericite-amphibole meta-dolerite.
- Sphene-bearing altered amphibole-tremolite-plagioclase meta-dolerite.

Ortho-amphibolites (showing no relict igneous textures):

- Andesine-tremolite banded metabasite.
- Ilmenite-rich quartz-plagioclase-amphibole metabasite.
- Tremolite-andesine-hornblende metabasite.
- Sphene-rich labradorite-amphibole metabasite.
- Iron-rich quartz-plagioclase-biotite metabasite.

The presence of hornblende in some of the basic meta-igneous rocks indicates the upper greenschist facies. The geochemistry and mineralogy of these rocks are subject to current investigations (Appendix II).

The mode of emplacement of the stratiform meta-basalts and fine-grained meta-dolerites is not entirely clear. The perfect conformity of the stratiform bodies, the scarcity of transgressive contacts, the usually fine-grained textures, and the abundance of intercalations of sediments of aqueous origin (e.g. cherts, pelites), suggest an intrusive origin is unlikely. On the other hand, the almost complete absence of structures and textures suggestive of a volcanic origin does not support an extrusive mode of emplacement. It is quite likely, however, that the lack of amygdales and variolites in the meta-basalts can be explained in terms of a low volatile content of the basic magmas. It is tentatively concluded, therefore, that the bulk of the meta-basalts and the associated meta-dolerites (which occur mainly in the cores of meta-basalt sheets) is of volcanic origin.

Meta-gabbro sills (dl)

Two principal occurrences of sills of meta-gabbro and associated meta-dolerite have been encountered in the Cloncurry 1:100,000 Sheet area. A sill complex is located at high stratigraphic levels of the Snake Creek Meta-turbidites, and is deflected by the Snake Creek Cross-fold (Fig.27). The sill complex is best developed in the section between Weatherly Creek and Snake Creek (east branch), where it includes up to three individual sills, the combined maximum thickness of which is approximately 600 metres. South of Weatherly Creek and Snake Creek the sills become thinner and wedge out gradually. Only one sill is present in the Sandy Creek section, where the thickness of the meta-gabbro is approximately 170 metres. The second meta-gabbro sill occurring in the Sheet area is intruded into schists of the Weatherly Creek Quartzite southeast of Mount Avarice. The sill has been strongly folded and displaced by faulting. It consists of a single stratiform body, the maximum thickness of which is 250 metres.

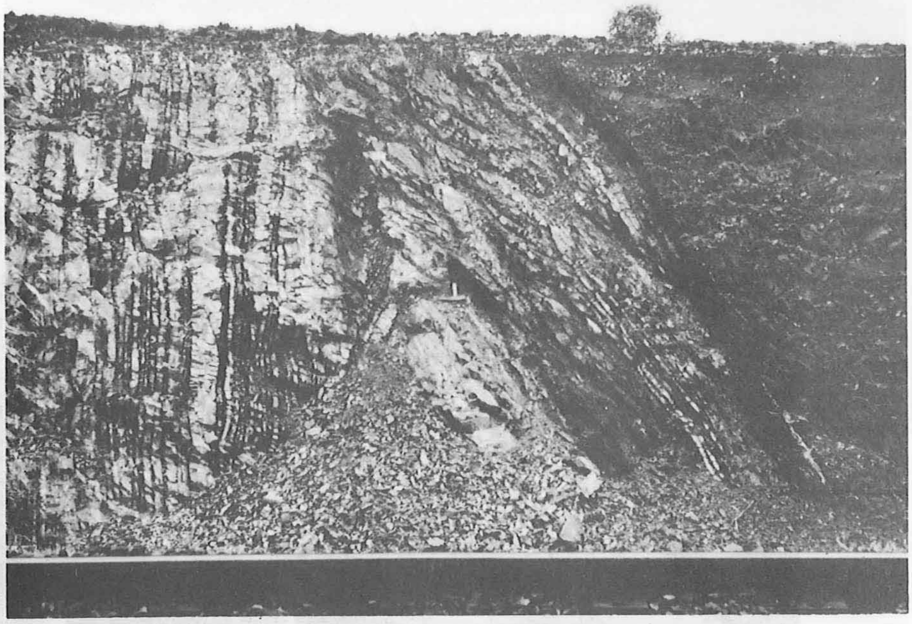


Fig. 22. A flow of meta-basalt (on the right) intercalated in deformed banded meta-siltstones of the Weatherly Creek Quartzite. Exposure on the Cloncurry-Townsville railway, 5 miles east of Cloncurry. (GA/2527).

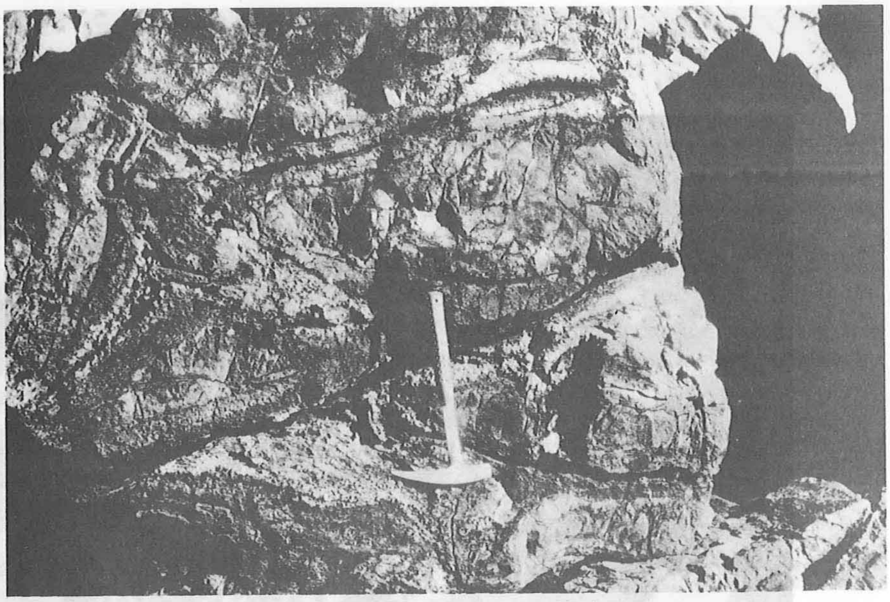


Fig. 23. Pillowed meta-basalts with cores of meta-dolerite, basaltic shells and siliceous mesostasis. Outcrop on the track between Mt Norna and the Elder (Lady Michelle) copper mine. (GA/2336).

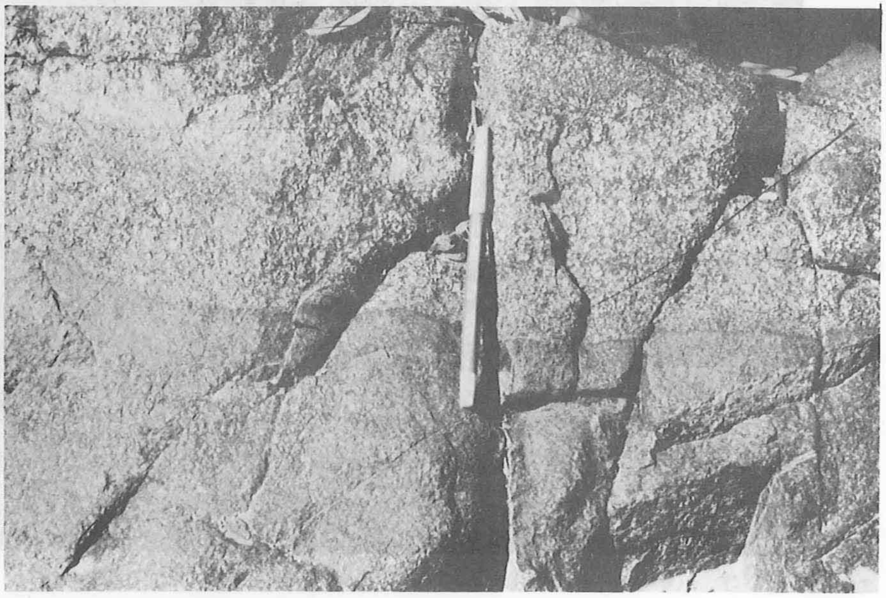


Fig.24. Chilled contact of meta-dolerite sill intruded into an earlier stratiform meta-dolerite. Toole Creek Meta-volcanics. Sandy Creek. (GA/2343)

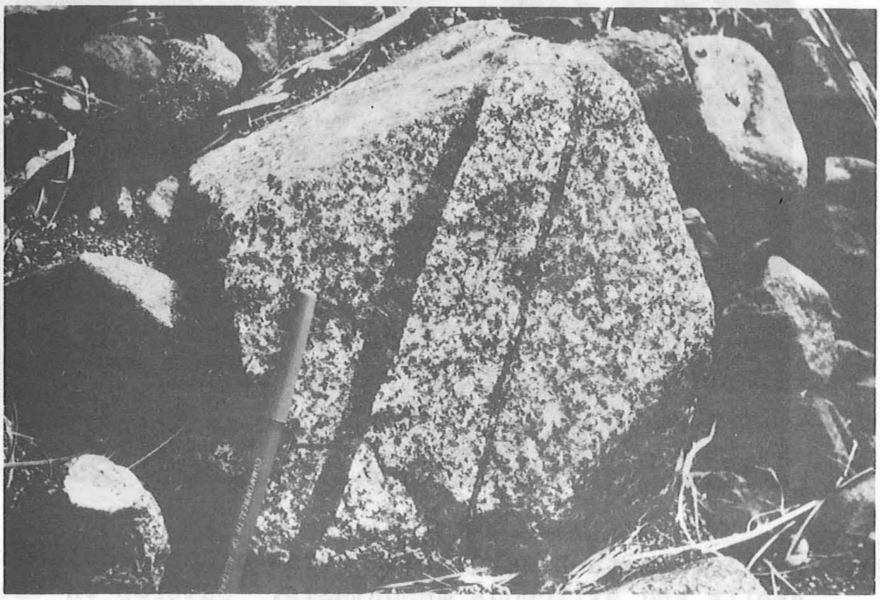


Fig.25. Thin veins of meta-basalt intruded into meta-gabbro sill south of the Elder (Lady Michelle) copper mine. (GA/2334)

In outcrop the meta-gabbros are massive uniform rocks, containing medium- to coarse-grained laths of plagioclase, and medium- to coarse-grained amphibole. Thin dykes of meta-basalt (Fig.25), irregular masses of granophyre, basic pegmatite, and veins and masses of carbonate are commonly associated with the sills. The marginal facies usually consists of meta-dolerite up to 30 metres thick. The adjacent sedimentary wall rocks may show contact effects, mainly silicification and the development of chlorite. Meta-gabbro and meta-dolerite specimens from the sills are described in Appendix I, and comprise the following assemblages:

- Ilmenite-bearing amphibole-plagioclase blasto-porphyritic meta-gabbro.
- Andesine-amphibole meta-gabbro.
- Ilmenite-sphene-quartz-epidote-saussurite-amphibole meta-gabbro.
- Epidote-sericite-amphibole-tremolite blastophitic meta-gabbro.
- Biotite-sericite amphibole-plagioclase meta-gabbro.
- Ilmenite-quartz-epidote-plagioclase-amphibole blastophitic meta-dolerite.
- Sphene-rich oligoclase-amphibole porphyroblastic metabasite.
- Talc-veined quartz-plagioclase-amphibole metabasite.
- Sphene-rich quartz-amphibole-epidote-oligoclase metabasite.
- Scapolite-bearing epidote-quartz-plagioclase amphibole metabasite.

The mineral assemblages of the meta-gabbros are similar to those of the stratiform meta-basalts and meta-dolerites of the Soldiers Cap Formation, which indicates that both the intrusive and the extrusive basic igneous rocks were affected by similar metamorphic conditions, and probably resulted from one and the same episode of regional metamorphism. The conformity between the sills and the bedding of the associated meta-sediments implies their emplacement prior to the cross-folding. It is unlikely that the swarm of meta-dolerite dykes (described below) which cut through the Snake Creek Cross-fold represents the feeders of the sills, because the dykes are discordant to the structure and younger than the cross-folding. Furthermore, the dykes cut through rather than terminate against the sills. It is concluded that the dykes represent a younger igneous episode than the sills.

Meta-dolerite dykes (dd)

A swarm of meta-dolerite dykes composed of at least six separate intrusions is associated with the axial zone of the Snake Creek Cross-fold. The dykes run subparallel to the trace of the axial plane in the southern part of the fold, and diverge in the northern part of the fold, possibly reflecting a fracture pattern genetically related to the folding. In one case a meta-dolerite dyke forks northward into two branches. The dykes cut through the meta-gabbro sills in the Weatherly Creek-Snake Creek section, as well as through the structural trends of the cross-folds north of the sills. The longest dyke within the Sheet area can be traced over 12 km. along the strike. The thickest section measured across a dyke is 15 metres. In no case have the dykes been observed to merge into the stratiform basic meta-igneous bodies incorporated in the Soldier Cap Formation.

The basic dykes are represented on the aerial photographs as thin black lineaments (Fig.27). In the field the dykes crop-out as narrow elevated ridges wherever they transgress through pelitic and arenaceous meta-sediments. They are dense, dark green to black rocks in hand-specimen, and usually display megascopic blastophitic texture. The chilled contacts consist of meta-basalt. The following assemblages were identified in thin-section (Appendix I):

- Ilmenite-bearing plagioclase-amphibole (sub-ophitic meta-dolerite),
- Sphene- and ilmenite-bearing quartz-plagioclase-amphibole (metabasite).

The independent field relationships between the dykes and the stratiform basic bodies, and the transgressive relationships between the dykes and regional structure, imply a post cross-folding origin of the dykes. Because the cross-folding is considered to have post-dated the principal phase of regional metamorphism in the area, the metamorphic state of the dykes must be ascribed to a younger metamor phic stage, possibly the same stage which accounted for the metamorphism of the Corella Formation (chapter VI).

Dolerite pipes in the Corella Formation

Small dolerite pipes are scattered throughout the Corella Formation and parts of the Marimo Slate. They occur in a narrow north-trending belt near the Robur mine, near the junction of Snake and Bull Creeks, near the Duchenese mine in the southwest of the Sheet, and in soil plains north of Roxmere, e.g. Home Mountain. The pipes are generally circular in outline, and show sharp contacts with the country rock, which in most cases is breccia of the Corella Formation. Minor copper mineralization is present in quartz-carbonate veinlets in some plugs; dolerite near the Duchenese mine is associated with massive pyritic quartz veining. Economic copper mineralization associated with fine-grained dolerite occurs at the Great Australia mine.

All the plugs are structureless, medium to coarse-grained, even-grained dolerite with a well-displayed ophitic texture.

Age Relationships: The dolerite is younger than all sedimentary units in the area except possibly the Roxmere Quartzite. It is probably older than the plugs of Naraku Granite in the same area, since in one plug along Snake Creek the dolerite was veined by leucocratic granite. The close spatial relationships between the granite and dolerite plugs suggests the two periods of intrusion were nearly contemporaneous. Near the junction of the east and south branches of Snake Creek some local contamination of dolerite by granite is present.

Petrography: Four dolerites were studied, samples 70200408, 431, 434 and 435. All show a well-preserved ophitic texture. Clinopyroxene, a colourless augite, is present in all samples, forming unaltered 2 to 3 mm crystals or relict cores in grains of amphibole. The amphibole derived from original clinopyroxene is a pale green ?actinolite, bordered in most cases by a narrow rim of green-brown hornblende. Plagioclase forms variably clouded laths 1 to 3 mm long intergrown with mafic minerals. Complex twinning is present, and compositions range from An 48 to An 60. In most cases plagioclase shows a pronounced pink coloration, probably due to finely dispersed ?hematite. Quartz occurs interstitially, or as graphic intergrowths with plagioclase. Iron ore is abundant, and in two samples grains have sphene coronas. Accessories include sericite, epidote, biotite and scapolite; the latter occurs in sample 408, replacing plagioclase.

An average estimated modal analysis of the dolerites is as follows:-

Amphibole	40%
Plagioclase	37%
Clinopyroxene	17%
Iron ore	3%
Quartz	2%
Accessories	1%
	100%

Rock name: Dolerite

Petrogenesis: The preservation of ophitic texture and fresh plagioclase and clinopyroxene grains suggests the dolerite intrusions postdate the first phase of metamorphism, and have possibly been affected by the second metamorphism (Section VI); deuteric alteration is suggested by alteration of clinopyroxene to amphibole and scapolitization of plagioclase. The concentration of both dolerite and granite plugs in the broad belt extending from Little Mick Creek to Coppermine Creek is possibly due to greater tectonic activity than elsewhere; such activity could provide a focus for magma generation and intrusion.

Granites

Granitic intrusions, while common and predominant south and north of the Cloncurry 1:100,000 Sheet area, are only of minor importance within the mapped area. Numerous small stocks of medium-grained leucocratic granite are emplaced in the Corella Formation, which is contrasted with the scarcity of granites in the Soldiers Cup Formation, where only three small stocks of leucocratic granites have been encountered. The characteristic features of the small granitic stocks are their small size (up to approximately 1300 metres in diameter), rounded form, white colour of the feldspar, and a very low content of ferromagnesian minerals. Sodic plagioclase constitutes over sixty percent, and quartz about thirty percent of the rocks, whereas microcline is generally a minor constituent (Appendix I, sps. 6900068, 69200079A and samples 70200394, 397, 429, 430). In contrast, the granites which intrude the Soldiers Cap Formation south of the map area (Fig.26) contain more microcline than sodic plagioclase, and have a slightly higher ferromagnesian mineral content (Appendix I, sps. 69200038, 69200109B). Neither the sodic granites nor the potassic granites show any evidence of metamorphism. The contacts of the granites with the country rocks are very sharply defined, and with the exception of silicification, little evidence of contact metamorphism has been disclosed.

The apparent preferential occurrence of granites within the Corella Formation has also been observed in the Marraba Sheet area to the west, where small granites and abundant aplite and micropegmatite (hematite-bearing) veins occur within the Corella Formation, but not within the Marimo Slate, the Marraba Volcanics, or the Argylla Formation (Derrick et al., 1970).

Petrography: Most samples of granite intruding the Corella Formation (394, 397, 429, 430) are highly leucocratic and microporphyritic. In some larger plugs the central parts of the intrusion show an even-grained, typically granitic texture. Clouded plagioclase phenocrysts are abundant (25-50%), and typically are euhedral, simply twinned laths of albite-oligoclase, An5 to An28. Some grains are slightly antiperthitic. Quartz phenocrysts (5-30%) are clear and unstrained, with some embayment by the groundmass in certain samples. In one sample (394) the quartz is a beta variety.

The groundmass in all samples is a fine-grained aggregate of plagioclase, quartz and potash feldspar. The latter has been reliably identified only by staining, and forms up to 30% of the rock in samples 429 and 430. Graphic quartz-plagioclase intergrowths occur in 429. Green-brown biotite flakes form 4% of sample 394, but in most cases mafic minerals are rare or absent. Accessory minerals are iron ore, rare zircon and sphene, calcite, chlorite, rutile and sericite.

Rock names: All the samples studied are plagioclase-rich granite, with an average modal composition Q(quartz) = 20, A (alkali feldspar) = 25, and P (plagioclase) = 55.

The thin-section studies confirm that the granite plugs are post-metamorphic and relatively high-level, rapidly cooled intrusions; they are similar to parts of the Naraku Granite near Cloncurry township.

V. STRUCTURE

The structure of the Precambrian rocks in the Cloncurry 1:100,000 Sheet area is determined by the following elements:

Isoclinal folds
Steep-axial cross-folds
Faults
Breccias in the Corella Formation.

A structural map of the Sheet area is presented (Fig.26). Aerial photographs and geological maps of selected areas are given in Figs. 27, 28 and 29. In the following, the structure and tectonics of the map area are discussed according to the above elements.

Isoclinal folds

The isoclinal folds represent the earliest identifiable tectonic phase which affected the Soldiers Cap Formation. Within the Sheet area these folds are extensively deflected by later cross-folding, the effects of which decrease toward the southern part of the map area, where the predominant fold axial trend is north-south. No cross-folding appears to affect the Soldiers Cap Formation in the Duchess 1:250,000 Sheet area to the south (Carter et al., 1961). The only fold segment which appears to represent the original orientation of the isoclinal folds in the Cloncurry 1:100,000 Sheet area, is the southern part of the Weatherly Creek-Toole Creek Syncline, south of Mountain Home Creek. The axial zone of this syncline in this area plunges mildly to the north, and consists of a series of parallel minor folds. Although the shapes of the isoclinal folds in the northern part of the area have been modified by the superimposed cross-folding, the original structural detail of the isoclinal folds can be readily recognized. Thus, the minor fold pattern in the axial zone of the Weatherly Creek-Toole Creek Syncline persists in the cross-folded northwestern part of this structure in the Toole Creek area. A structural feature peculiar to the central and northern zone of the Sheet area is the frequent development of minor synclines in the cores of the major synclines. The minor intervening anticlines on the other hand are considerably less well expressed than the synclines. Similarly, the anticlines separating

Fig 26

STRUCTURE AND METAMORPHIC ZONATION OF THE SOLDIERS CAP BELT, CLONCURRY DISTRICT QUEENSLAND

the Weatherly Creek-Toole Creek Syncline from the Oonoomurra Syncline, and the Oonoomurra Syncline from the Pumpkin Gully Syncline, are very narrow when compared with the synclines (Fig.26). The explanation of these contrasts appears to be the differential lithology of the synclinal and anticlinal zones, which consist mainly of greenstones and meta-sediments respectively. Because of their higher plasticity, the meta-sediments have been folded and sheared in between the more rigid and consequently broader synclinal zones.

Cross-folds

The Soldiers Cap Formation in the Cloncurry Sheet area displays classic cross-fold patterns, resulting from the refolding of the isoclinal folds about subvertical axes. The major cross-fold within the Sheet area is the Snake Creek structure, the centre of which is drained by the eastern branch of this creek. Contrary to Honman et al's (1939) view, the fold cannot be regarded as a mildly plunging anticline, but constitutes a subvertically plunging cross-fold, referred to here as the Snake Creek Cross-fold (Fig.26). The axial plane of the structure dips steeply eastward, as suggested by the overturned western limb. That the structure constitutes a cross-fold rather than a northward plunging anticline is evident from the structural pattern between the eastern and the western branch of Snake Creek near the bottom of the Sheet area, and from the occurrence of minor cross-folds north of the meta-gabbro sill complex. These features cannot be interpreted in terms of isoclinal folding only. The cross-folds account for the deflection of the beds and the isoclinal folds in the general area between Mount Norna and near the northern boundary of the Precambrian outcrops into northwest and eastwest trends. The cross-folding in the structural belt along Snake Creek resulted in lateral flexuring exceeding 180°. The structure of this belt is complex, and is partly obscured by alluvial deposits and by outliers of the Corella Formation. Rotation of synclinal axes over 250° is displayed by the nose of the Pumpkin Gully Syncline. The box-like shape of the northwestern part of the Weatherly Creek-Toole Creek Syncline and the Oonoomurra Syncline southeast of Oonoomurra Siding, may have originated by modification of the isoclinal folding by cross-folding, i.e. by lateral pressures operating at high angles to the isoclinal fold axes.

The origin of the cross-folds may have been related to lateral pressures exerted by the intrusion of the granitic batholith to the north. This possibility is supported by a southward lessening of the cross-folding. The cross-folding has clearly post-dated regional metamorphism, as indicated by the deflection of the flow-cleavage and fracture-cleavage systems by the cross-folds. The effects of the cross-folding on the Corella Formation are discussed later.

Faulting

The role of faulting in the deformation of the Soldiers Cap Formation is relatively minor when compared with that of folding. Only a few major faults have been observed. The following is a list of faults where the strike slip could be ascertained (refer to Map 1).

- At the upper course of Weatherly Creek	Displacement: 1600m
- Between Toole Creek and west of Oonoomurra.	" 900m
- Across the Oonoomurra Syncline, east of Mt. Avarice.	" 2300m
- Along the upper tributary of Bull Creek.	" 350m
- 3 miles ENE of Cloncurry.	" 650m
- Northeast of Mt. Douglas.	" 850m

Several faults cut through the Corella Formation west of Snake Creek. Apart from the measured faults listed above, the Precambrian rocks include numerous minor faults and veins with little or no displacement. The majority of these lineaments strike at high angles to the bedding. Swarms of quartz-filled veins and small-scale faults occur along the hinges of cross-folds in the Elder Creek area and the Snake Creek area. These lineaments, when truncating favourable stratigraphic horizons, provide some of the loci of copper and gold mineralization in the area (Chapter VII).

No evidence of faulting along the western margin of the outcrops of the Soldiers Cap Formation was found. The contact with the Corella Formation appears to be a well-defined unconformity (Chapter III).

Fig. 27A. Aerial photograph of the Weatherly Creek-Toole Creek syncline, the Snake Creek Cross-fold, and the southern granites. For interpretation, refer to Fig. 27B. RC9 1:85.000 series, Run 8, photo 76.

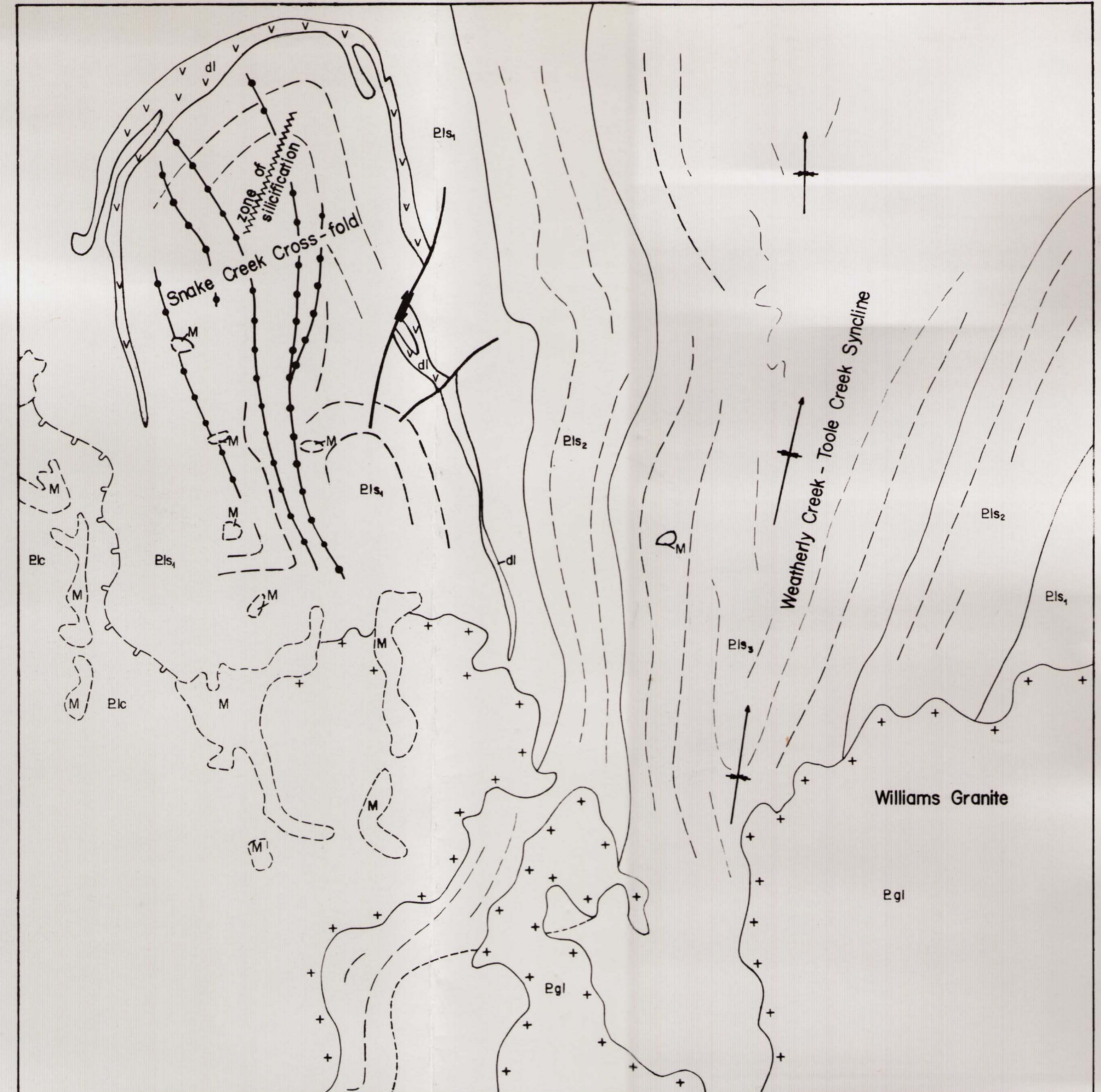


FIG. 27b GEOLOGICAL SKETCH MAP, CLONCURRY AREA, BASED ON PHOTO 8/76 (RC9 SERIES)
For explanation of symbols refer to Map I

To accompany Record 1970/24

F54/A2/19

Fig. 28A. Aerial photograph of the Snake Creek Cross-fold, and of the northwestern part of the Weatherly Creek-Toole Creek Syncline. For interpretation, refer to Fig. 28B. RC9 1:85.000 series, Run 7, photo 150.

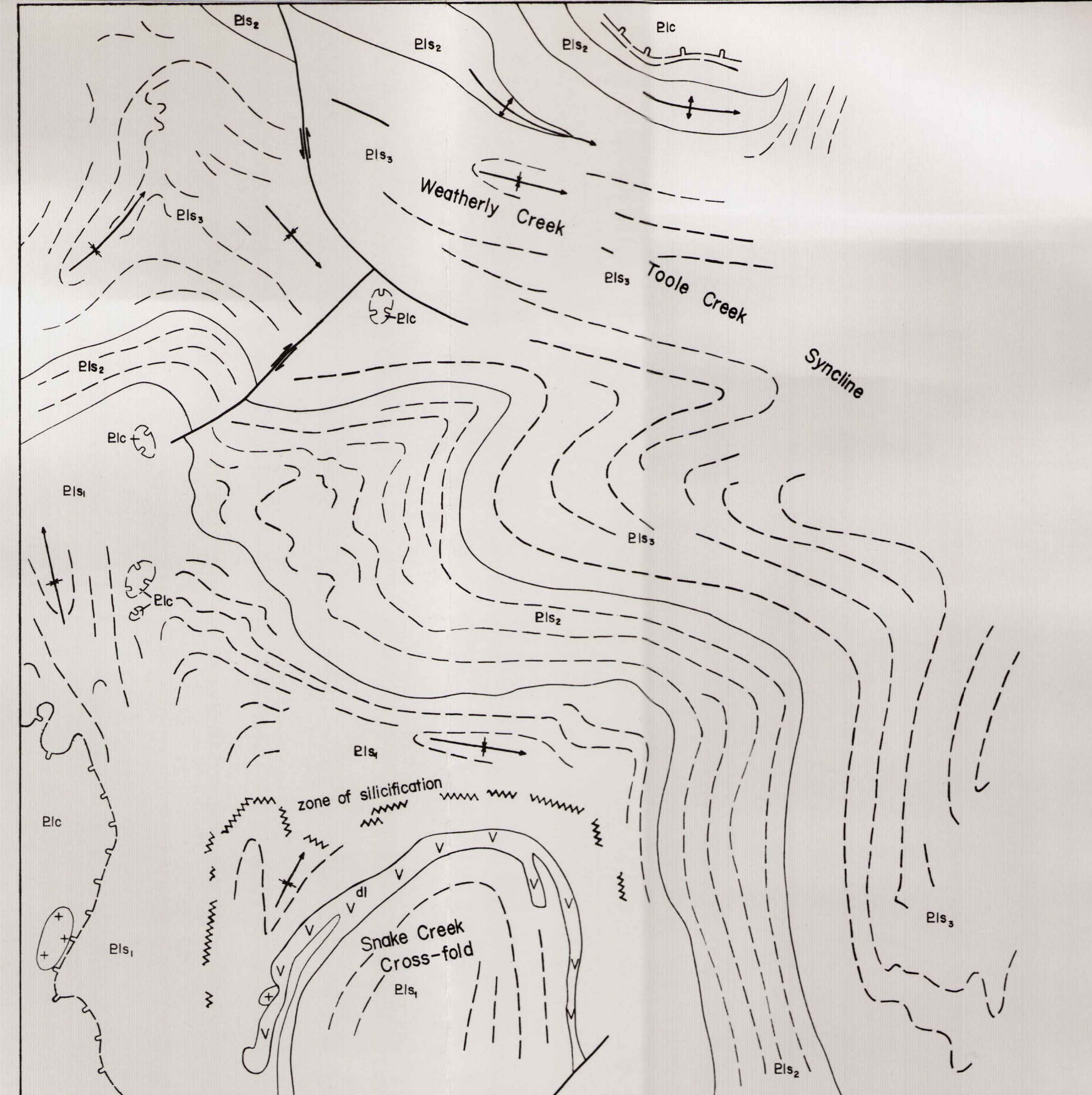
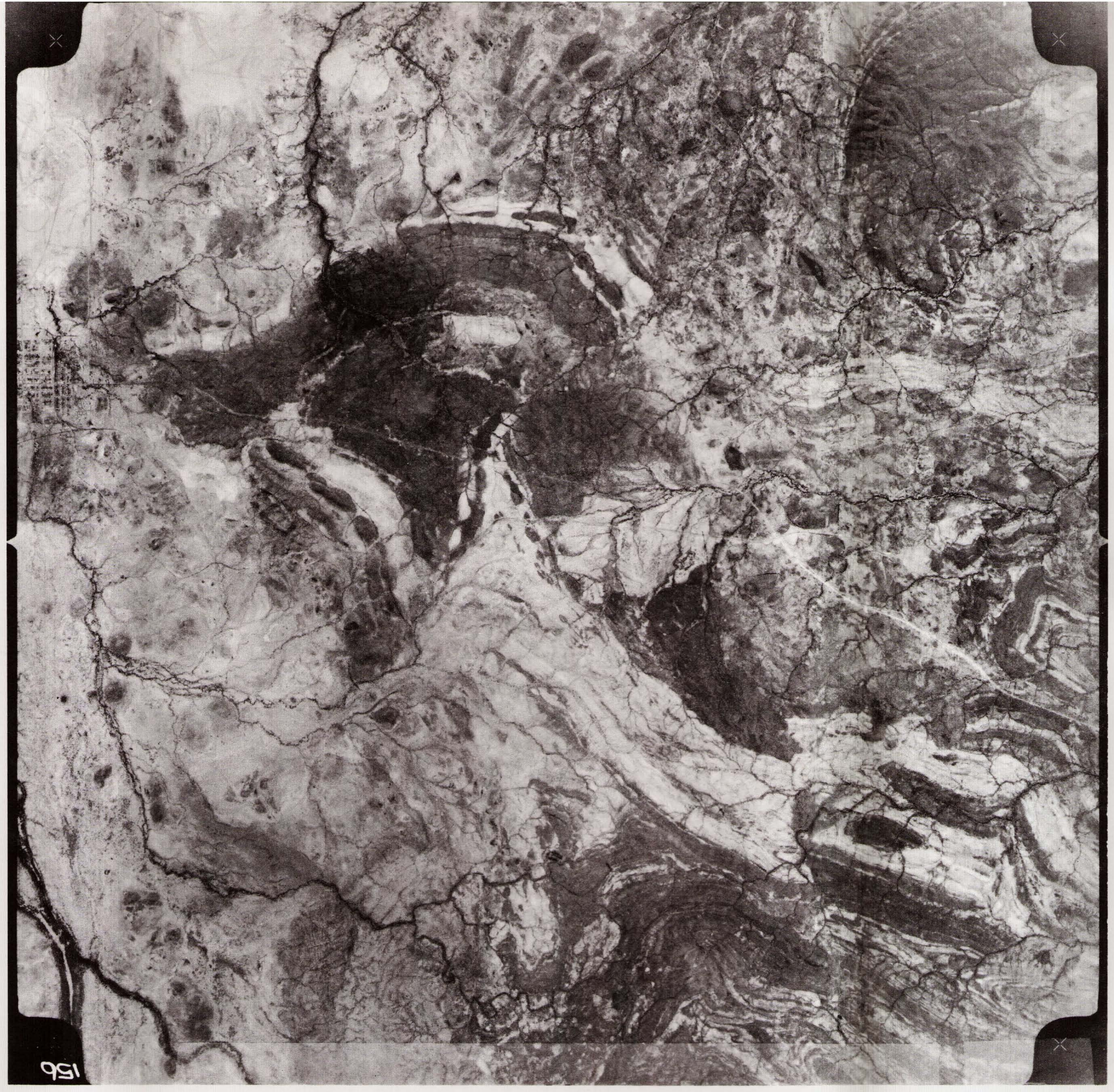


FIG. 28b GEOLOGICAL SKETCH MAP, CLONCURRY AREA, BASED ON PHOTO 7/150 (RC9 SERIES)

For an explanation of symbols refer to Map I

To accompany Record 1970/24

F54/A2/20



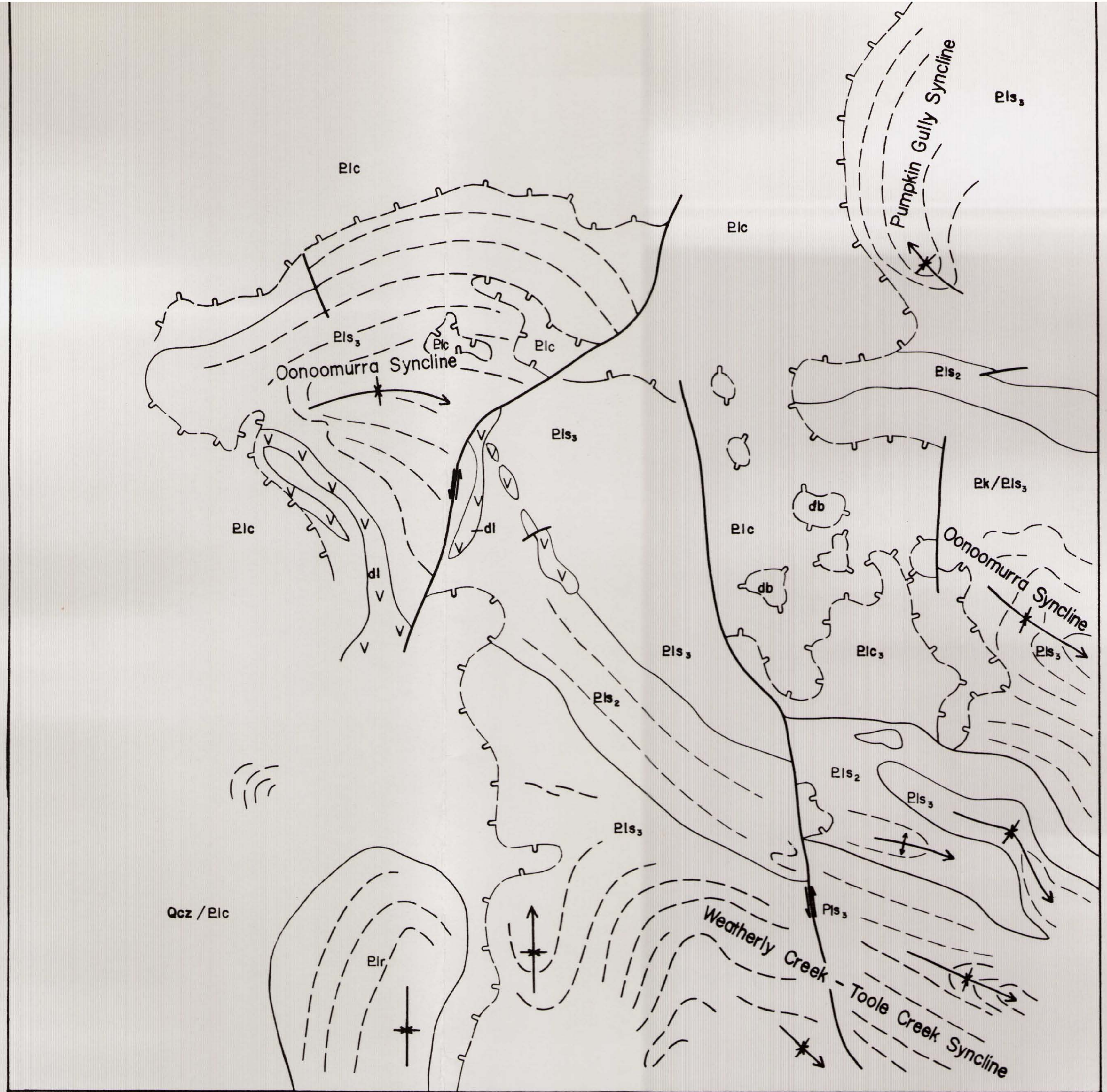


FIG 29b GEOLOGICAL SKETCH MAP, CLONCURRY AREA, BASED ON PHOTO 6/156 (RC9 SERIES)
For an explanation of symbols refer to Map I

Fig. 29A. Aerial photograph of the northwestern part of the Weatherly Creek-Toole Creek Syncline and of the Oonoomura Syncline. For interpretation refer to Fig. 29B. RC9 1:85.000 series, Run 6, photo 156.

To accompany Record 1970/24

F54/A2/21

Structure and brecciation of the Corella Formation

The style of deformation of the Corella Formation appears to be distinct from that of the underlying Soldiers Cap Formation. The most striking feature displayed by the Corella Formation within the Sheet area is the extensive brecciation and mega-brecciation of the calc-silicate rocks (Chapter III). Outliers of the Corella Formation resting unconformably on the Soldiers Cap Formation are almost invariably brecciated. The continuous tract of Corella Formation west of Snake Creek includes both brecciated and non-brecciated rocks, the latter usually occurring as synclinal keels above the breccias. The occurrence of bedded calc-silicates at stratigraphically higher positions than the breccias is a consistent feature, although some breccia is almost certainly younger than the bedded sequences. The significance of this is discussed below. The structural trends of the non-brecciated parts of the Corella Formation are usually subparallel to those of the Soldiers Cap Formation in adjacent areas, although this comparison could only be carried out in a few areas (e.g. west of Camel Hill and north of Oonoomurra siding).

In considering the origin of the brecciation of the Corella Formation, three alternative interpretations will be discussed:

The breccia may represent coarse reef debris.

The breccia may have originated through karstic solution of the carbonates and/or solution of evaporite beds, followed by subsequent collapses.

The breccia may be of tectonic origin.

There is no evidence to support the first possibility. The size of the blocks of the mega-breccia exceeds that of blocks in fore-reef breccias by several orders of magnitude. No fossil stromatolites or any other biogenetic elements have been recorded from the calc-silicates. Furthermore, a distribution of forereef breccias over an area as extensive as that covered by the breccias would imply transportation of the blocks, some of which are several hundred feet across. The apparent absence of basal sediments which could facilitate the downslope slumping of large blocks render this possibility even less likely.

A karstic origin of the breccias is contrasted with the absence of features suggestive of solution, e.g., rounded blocks, sink holes, etc. The possible pre-existence of evaporite beds, on the other hand, is supported by the extensive occurrence of scapolite in the calc-silicate rocks, suggesting the release of chlorine, and by the "residual" nature of some of the dolomitic fragmental breccias which include a large proportion of fine-grained material. In only a few cases, however, have these breccias been observed to be stratigraphically controlled, and their common occurrence in veins, fissures, pipes and lumps associated with the mega-breccias (see also Derrick, 1968) suggests they are not a result of evaporite bed solutions.

There are good reasons to regard tectonic deformation as the major factor involved in the brecciation of the Corella Formation. Because the Corella Formation overlies the Soldiers Cap Formation with strong unconformity, it is evident that its deposition post-dated a major tectonic phase which affected the Soldiers Cap Formation, probably the isoclinal folding phase. It is suggested that during the cross-folding of the Soldiers Cap Formation, the flat-lying carbonates of the Corella Formation could not react to the lateral tectonic stresses through folding because of the rigidity of the underlying basement, as well as lack of a basal decollement horizon, and consequently shattered and brecciated (Fig.33). This hypothesis explains the upward decreases in brecciation, because the intensity of shattering could be expected to be strongest at basal levels above the unconformity. A genetic relationship between the brecciation and the cross-folding is also suggested by the relatively minor role of brecciation in the Corella Formation in those parts of the Marraba Sheet area in which cross-folding is less commonly developed. A tectonic origin of the breccia also readily explains the huge sizes of blocks in the mega-breccia. It is concluded that an origin of the breccia in conjunction with the cross-folding phase accounts for the features associated with the breccias of the Corella Formation better than the two other interpretations.

The cross-folding phase was apparently not the last tectonic movement which affected the Precambrian rocks. The Roxmere Quartzite which overlies the breccias of the Corella Formation was strongly folded and faulted in both the Cloncurry and the Marraba 1:100,000 Sheet areas. Since the Roxmere Quartzite does not display brecciation except at its base, its folding may represent a younger phase than the cross-folding. Alternatively, the quartzites were deformed during the cross-folding phase, but were brecciated because of their lithologic properties and high stratigraphic position above the basal unconformity of the Corella Formation.

Structure of the Corella Formation and Marimo Slate west of Snake Creek

The structure of this area is shown in Fig.26.

Folding: Tight to isoclinal folding is widespread in both slate and sandstone members of the Marimo Slate. In slate along the western margins of the Sheet fold axes plunges are steep (60-70°) to north and south; in the Mick Creek Sandstone member fold axes trend northwest and north but plunge at only 30 to 40 degrees. The variable plunge directions to north and south indicate crossfolding about northeast and east-northeast-trending axes; the plunge of these crossfold axes in many cases appears horizontal or only shallow-plunging, and the rotated, steeply plunging box-fold structures occurring in the Soldiers Cap area do not appear to be present.

Cross-bedding in the southernmost anteform of the Mick Creek Sandstone member suggests the structure is completely overturned. The axis of the proposed overfolding trends northwest; the normal limb is represented by the Robur sandstone block, and the overturned limb by the Little Mick Creek block (Map 1). Prominent major faulting occurs parallel to the proposed overfold axis.

Well-bedded sequences of Corella Formation limestone and marl, which generally overlie calcareous breccia, form tight to isoclinally folded synclinal belts, with some local overturning. Fold axes plunge to the north, except near Little Mick Creek, where they trend northeast.

Faulting: Faulting is prominent in the areas of Marimo Slate, but less so in the Corella Formation. The Mick Creek Sandstone member is fault-bounded in a number of localities; most of these faults trend north and northwest and extend for at least 13 to 16 km. The zone believed to be overfolded and faulted in the Bluebell mine area is marked by massive quartz veining and iron and manganese enrichment. The fault plane dips at 70° to the northeast, and is probably a moderately high angle reverse fault. A block of Mick Creek Sandstone member is faulted against a syncline of Corella Formation just east of Copper Canyon; slickensliding and grooving along this fault line suggests low angle reverse movement in a northwest-southeast direction.

Zones of silicification are common in slate, and represent major faults or zones of microfracturing with no major disruption. These zones could represent reactivated lines of weakness in older basement rocks.

The Problem of the Cloncurry Overthrust: This structure was first described by Honman (1939), who postulated upward movement of the Soldiers Cap Formation and consequent removal of the Corella Formation from it. The "Overthrust" was described by Carter et al. (1961) as a high-angle east-dipping reverse fault, and the contact between the Corella Formation and Soldiers Cap Formation has been shown by them as faulted in the area immediately west of Snake Creek.

The present mapping suggests there is a rapid increase in the thickness of breccia across the "Overthrust" zone from east to west; there is also no suggestion of a faulted contact between basalt of the Soldiers Cap Formation and breccia of the Corella Formation. These features are possibly best explained by monoclinal flexuring (in the sense east flank up) along a hinge line coincident with the present-day course of Snake Creek. Movement along this zone appears to decrease northwards and increase southwards in the Duchess Sheet area.

Some high-angle reverse faulting, overfolding and local low-angle reverse faulting does occur in the Little Mick Creek-Copper Canyon area, about 1 to 2 km. west of the "Overthrust" zone. Most of these faults etc. trend north and northwest, and could be related to the "Overthrust" marked by Carter et al. (1961) in the far southwest of the Cloncurry Sheet and in the Duchess Sheet.

It is hoped that further mapping in these areas during 1970 will elucidate the nature of the contact between the Corella Formation and Soldiers Cap Formation, and establish the existence or otherwise of the Cloncurry Overthrust. It is suggested that the term "Overthrust" be discarded in favour of "Reverse Fault" or "Flexure" wherever these structures are established.

VI. METAMORPHISM

Metamorphic facies zones

The Precambrian outcrops in the Cloncurry 1:100,000 Sheet area afford the study of well-defined metamorphic zones ranging from the middle greenschist facies to the lower amphibolite facies. The transition between the various facies zones takes place across the strike, and the isograds are consequently subparallel to the structural trends (Fig.26). The metamorphic assemblages of the pelitic meta-sediments within the Soldiers Cap Formation define the following facies zones:

- Middle greenschist facies:- This zone is defined by the occurrence of biotite-muscovite parageneses in the pelitic and arenaceous meta-sediments, albite-tremolite assemblages in the calc-silicates, and actinolite-sodic plagioclase assemblages in the metabasites. The distribution of these rocks is confined to the two upper units of the Soldiers Cap Formation, and broadly coincides with the synclinal zones (Fig.26).

- Upper greenschist facies:- This zone is usually very narrow, and occurs between the garnet isograd and staurolite isograd. It is defined by the garnet-biotite assemblage in pelitic meta-sediments. Because of its narrowness, this zone was not plotted on the metamorphic facies map (Fig.26).

- Lower amphibolite facies (staurolite-almandine subfacies of the amphibolite facies, Fyfe, Turner and Verhoogen, 1958):- This facies zone comprises staurolite-garnet assemblages, andalusite-garnet assemblages, and less commonly staurolite-garnet-andalusite assemblages. Biotite, muscovite, sodic to intermediate plagioclase, and quartz are ubiquitous major constituents. The distribution of this facies zone is confined to the Snake Creek Meta-turbidites and to the uppermost part of the Weatherly Creek Quartzites.

The staurolite-almandine subfacies represents the highest metamorphic grade in the Cloncurry Sheet area. The grain size of the porphyroblasts displays a progressive increase towards the core of the Snake Creek Cross-fold (Figs 30, 31) where the meta-sediments are extensively veined by quartz. The greenschist-lower amphibolite facies

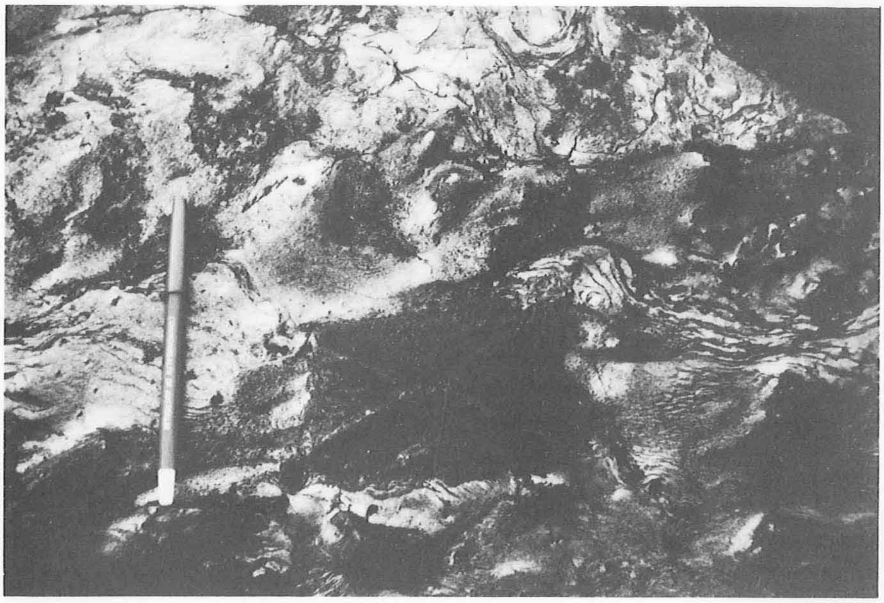


Fig. 30. A coarse-grained andalusite porphyroblasts in garnet andalusite schist of the Snake Creek Meta-turbidites. Sandy Creek section. (GA/2329)

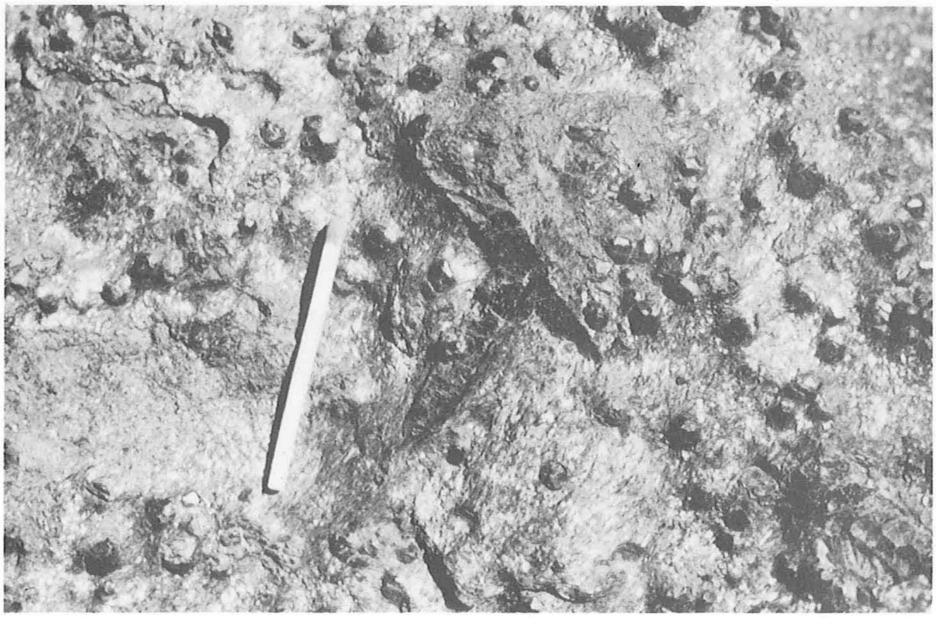


Fig.31. Staurolite-garnet schist of the Snake Creek Meta-turbidites, Sandy Creek section. (GA/2778)

range is also represented by the calc-silicates and the para-amphibolites of the Corella Formation, mainly by the transition from tremolite-bearing assemblages to diopside- and hornblende-bearing assemblages. The rise in the metamorphic grade of the basic meta-igneous rocks is reflected by the development of hornblende instead of actinolite, and by the increasing anorthite content of the plagioclase.

The lower amphibolite facies zone can be divided into two subzones, characterized by the staurolite-garnet and andalusite-garnet assemblages respectively (Fig.26). The significance of this division to the metamorphic conditions will be discussed later.

Metamorphism of the pelitic rocks

The sequence of crystallization upon prograde metamorphism of the pelitic assemblages, as suggested by the textural relationships, is as follows:

(1) Muscovite and biotite. In many instances the muscovite appears to have crystallized after the biotite.

(2) Garnet.

(3) Staurolite and andalusite.

(4) Chlorite, representing retrogressive metamorphism.

The usually independent occurrence of staurolite and andalusite may possibly reflect their dependence on different host-rock compositions. Staurolite is typical of iron-rich and potash-poor aluminous assemblages (Turner and Verhoogen, 1960, p.545), and occurs within a rather restricted pressure/temperature range (Deer et al., 1962, p.158) conditions which do not apply to andalusite. The development of staurolite requires slightly higher pressures than those for andalusite, which may provide yet another explanation for the relative scarcity of staurolite compared with andalusite in the Cloncurry Sheet area (Fig.26). The presence of staurolite, almandine, and andalusite, and the apparent absence of phases such as kyanite, cordierite and anthophyllite, which are consistent with the temperature conditions of the lower amphibolite facies, indicate the pressure conditions under which the rocks were metamorphosed. Thus, following the classification of metamorphic facies belts by Zwart et al., (1967), the occurrence of andalusite and the absence of kyanite define the metamorphism as of the low pressure type. Miyashiro (1961) did not consider staurolite as a possible component of low-pressure metamorphic facies series. However, Turner (1968, p.211) described the occurrence of staurolite in the hornblende hornfels contact aureole of the Santa Rosa granodiorite, Nevada. The stability field of the almandine-staurolite-andalusite paragenesis on the PT diagram is plotted after Hoschek (1969, p.214) in Fig.32, from which a temperature range of approximately 550°-$640^{\circ}C$, and a pressure range of approximately 2-6 kb can be deduced.

The prograde metamorphism of the sediments involved metamorphic reactions such as the following:

3 Muscovite + 5 prochlorite $\rightleftharpoons$ 3 biotite + 4 aluminous chlorite + $7SiO_2$ + $4H_2O$ ... (1)

Muscovite + silica $\rightleftharpoons$ K-feldspar + andalusite + water ... (2)

5 chloritoid + 2 quartz $\rightleftharpoons$ 2 staurolite + 1 almandine + $3H_2O$ ... (3)

Chlorite + muscovite + garnet $\rightleftharpoons$ staurolite + biotite + quartz + vapour ... (4)

The applicability of reaction (3) to the rocks of the Soldiers Cap Formation, however, is doubtful because of the complete absence of relic chloritoid, which could be expected to be present, had the staurolite developed at its expense. Another problem is posed by the common replacement of biotite by garnet and staurolite, which does not conform to the above reactions, as well as by the replacement of biotite by muscovite.

Retrogressive metamorphism is evidenced by the development of chlorite flakes with their (001) planes at high angles to the schistosity, or parallel to the fracture cleavage which is clearly younger than the flow-cleavage (e.g., sps 69200056, 69200057, 69200075). Little or no alteration of the almandine or the staurolite is apparent. It is concluded therefore that retrogressive metamorphism was of a local significance only, and was presumably associated with restricted shearing effects.

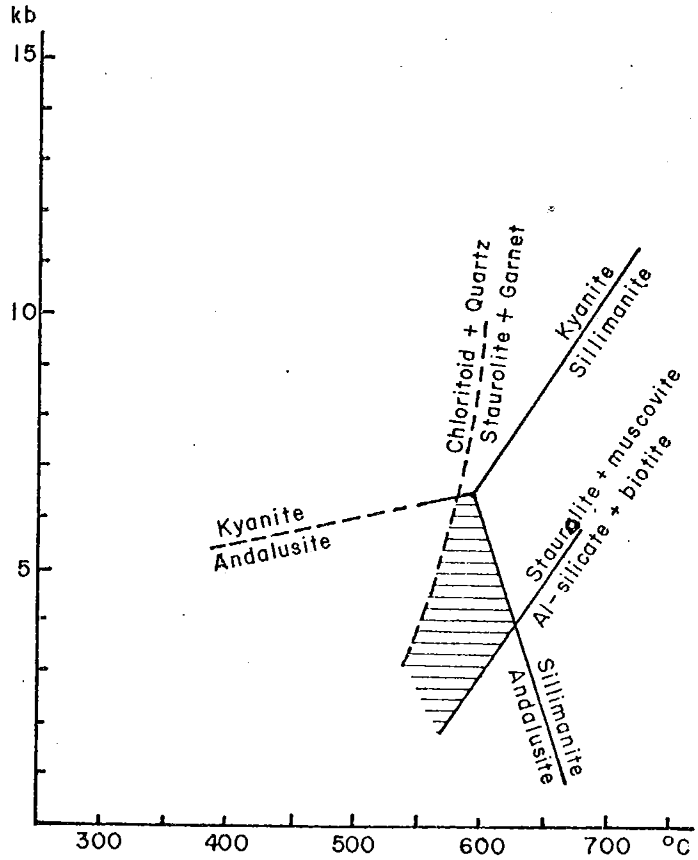


Fig. 32. Pressure-temperature diagram for aluminosilicates common in medium-grade metamorphic terrains (after Hoschek, 1969). The dashed area represents the stability field of garnet-staurolite-andalusite assemblages.

Metamorphism of the Corella Formation

The principal constituents of the calc-silicate rocks of the Corella Formation are calcite, dolomite, quartz, sodic plagioclase, tremolite, diopside, biotite, sphene, microcline, muscovite, epidote and scapolite. The original sediments from which the calc-silicates have been derived were probably siliceous dolomites and limestones, marls, and limey silts, including calcite, dolomite, quartz and clay minerals (including magnesian clay minerals, e.g. montmorillonite). The diopside-tremolite-albite assemblages (para-amphibolites) which abound in the Corella Formation presumably represent soda and magnesia-rich aluminous marls. The formation of the present assemblages probably involved reactions such as:-

5 dolomite + 8 quartz + $H_2O \rightleftharpoons$ tremolite + 3 calcite + $7CO_2$ ... (5)

Tremolite + 3 calcite $\rightleftharpoons$ dolomite + 4 diopside + CO_2 + H_2O ... (6)

Tremolite + 3 calcite + 2 quartz $\rightleftharpoons$ 5 diopside + $3CO_2$ + H_2O ... (7)

The tremolite-albite para-amphibolites were probably formed from clay minerals through transitional phase minerals such as paragonite and chlorite. The occurrence of rims of blue-green hornblende around the tremolite, as well as the partial replacement of tremolite by diopside, indicate a transition from the greenschist facies to the amphibolite facies. Although no mineralogical pressure indicators occur in the calc-silicate rocks, the apparent lack of cleavage and evidence of shearing indicates low-pressure metamorphism. Evidence of this form of metamorphism is indirectly supported by the absence of garnet and the scarcity of epidote. The abundant sphene present in the calc-silicate rocks and the para-amphibolites, probably formed through reaction of original detrital ilmenite with calcite and quartz.

Metamorphism of the basic igneous rocks

Basic meta-igneous rocks occur within the middle greenschist, upper greenschist, and lower amphibolite facies zones of the Soldiers Cap Formation, and rarely in the Corella Formation. They provide, therefore, suitable material for the study of mineralogical changes with rising metamorphic grade, a subject to be dealt with separately (Appendix II). The basic meta-igneous assemblages consist mainly of amphibole (actinolite and/or hornblende), plagioclase (composition range between albite and labradorite), minor quartz, sphene, ilmenite, and magnetite; epidote is an important constituent of metabasites within the middle greenschist facies zone, but is rather uncommon within the higher grade zones. In the Soldiers Cap Formation no relics of original pyroxene or olivine are present, and the calcic plagioclase grains are clearly recrystallized and clouded remnants of the original feldspar. By contrast the dolerite plugs in the Corella Formation contain abundant clinopyroxene relics. Igneous textures are usually well preserved in the meta-gabbros and the meta-dolerites, but are normally obliterated to varying degrees in the meta-basalts, suggesting a relationship between grain size and the degree of retention of original texture. The metamorphic reactions which affected the original basic rocks are of the following types:-

$$5 \text{ pyroxene} + \text{water} \rightleftharpoons \text{actinolite} + 3CaO + 2 \text{ quartz} \quad \ldots (8)$$

$$4 \text{ Pyroxene} + Al_2O_3 + H_2O \rightleftharpoons \text{hornblende} + 2CaO + \text{quartz} \quad (9)$$

$$4 \text{ actinolite} + 5 \text{ anorthite} + H_2O \rightleftharpoons 5 \text{ hornblende} + 3CaO + 7 \text{ quartz} \quad (10)$$

$$8 \text{ anorthite} + 4 \text{ albite} + H_2O \rightleftharpoons 4 \text{ anorthite} + 4 \text{ albite} + 2 \text{ zoisite} + 2 \text{ quartz} + Al_2O_3 \quad \ldots (11)$$

$$\text{Ilmenite} + CaO + SiO_2 \rightleftharpoons \text{Sphene} + FeO \quad \ldots (12)$$

Reaction (10) represents the transition from the greenschist facies to the amphibolite facies, and is represented in the actual assemblages by the occurrence of rims of hornblende around cores of actinolite.

Cleavage systems and metamorphic phases

The relationships between the metamorphic minerals, metamorphic cleavages and structural elements throw light on the structural and metamorphic evolution of the Precambrian series. Both flow-cleavage (schistosity) and fracture-cleavage (strain-slip cleavage) are present in the Soldiers Cap Formation, and calcareous schist of the Corella Formation. The flow-cleavage system, defined by the lepidoblastic fabric of the mica and the aligned fabric of the amphiboles, as well as by the elongation and flattening of the granular components, is usually subvertical and subparallel to the bedding. It may be concluded that the flow-cleavage developed after the isoclinal folding, but prior to the cross-folding which caused the deflection of the flow-cleavage along with the bedding. The flow-cleavage is only rarely associated with b-axis lineation of contemporaneous origin. Such a lineation set is developed near the Gilded Rose mine, where the flow-cleavage is microfolded on subhorizontal axes. Lineations resulting from the intersection of the flow-cleavage by the fracture-cleavage set are almost ubiquitous in the Soldiers Cap Formation, and are characterized by steep plunges. The orientation of this lineation set throughout the Soldiers Cap Formation indicates an original steep northerly dip of the fracture cleavage set. The fracture cleavage set usually strikes at high angles to the bedding, and is deflected by the cross-folding. The observed growth of chlorite along fracture cleavage planes associates this cleavage with retrogressive metamorphism, which must have preceded the cross-folding. A second episode of prograde metamorphism, which post-dated the cross-folding, is implied by the metamorphosed state of dykes of dolerite which cut across the Snake Creek Cross-fold (section V). It is very likely that this phase was also responsible for the metamorphism of the Corella Formation, the metamorphic assemblages of which indicate the lower amphibolite facies. The low pressure type of the second phase of prograde metamorphism is indicated by the very weak development of cleavage in the Corella Formation within the Sheet area.

In summarizing the metamorphic history of the Precambrian rocks, the following phases can be defined:-

(1) Prograde low-pressure metamorphism reaching the lower amphibolite facies, and associated with the development of a flow-cleavage set.

(2) Weak retrogressive metamorphism associated with the development of a fracture cleavage set.

(3) Prograde low-pressure metamorphism, reaching the lower amphibolite facies and affecting the Corella Formation.

(4) Retrograde metamorphism and alteration of parts of Corella Formation.

The relationships between metamorphic grade, stratigraphy and structure, as outlined earlier, clearly point to the control of metamorphic grade by depth of burial. Consequently, in as much as metamorphic grade can be used as an approximate indicator of stratigraphic depth, it follows that the Snake Creek Meta-turbidites are not only the stratigraphically lowermost rocks in the Cloncurry 1:100,000 Sheet area, but also in relation to the wider region covering the eastern part of the Marraba 1:100,000 Sheet area.

VII. MINERALIZATION

The Cloncurry 1:100,000 Sheet area ranked as the main gold producer in the Cloncurry District during the late part of the 19th century and the early part of the 20th Century. Both alluvial placer deposits and vein ores are present in the area. Reported ore production up to 1968 amount to 7384 tons, from which 7396 oz. of gold were recovered (Table 1). The area is also a minor producer of copper, which in several prospects includes gold as a by-product. Small deposits of tungsten, cobalt, silver-lead, and bismuth are known in the area. The distribution of the more important mines in the area is shown in Map 1. A comprehensive survey of the mineral occurrences, as they were developed in the forties, was conducted by officers of the Aerial, Geological and Geophysical Survey of Northern Australia (Honman, 1936b; Honman et al., 1939). The survey included detail mapping of the mine areas, assays, and geophysical measurements. Because of the emphasis of the present survey on regional mapping, as well as the inaccessibility of the underground sections of the abandoned mineral workings, little can be added to Honman's observations. The purpose of this section is to review the geological features with which the mineralization is associated, and to discuss the relationships between mineralization and the structural and stratigraphic features. A review of the past mineral production of the area, based on reports included in the Annual Reports of the Queensland Department of Mines (Tables 1 and 2) is provided.

Gold mineralization

Auriferous ores in the Cloncurry 1:100,000 Sheet area have been discovered in two principal zones, namely the Soldiers Cap area and the Gilded Rose belt, which are situated in the Toole Creek Metavolcanics and the Weatherly Creek Quartzites respectively (Map 1). Other centres of gold mineralization are the Bull Creek area and the Pinnacles (Map 1). Important alluvial gold deposits have been worked at Pumpkin Gully, and to a much lesser extent at Blacks Gully (Map 1). The major source of alluvial gold in the early days was Top Camp, situated in the northern part of the Duchess 1:250,000 Sheet area, near the junction of Two Mile Creek with the Cloncurry River. The following description is based largely on work by Honman et al., (1939), with additional observations by the authors.

Soldiers Cap area.

Mt. Freda: A detailed survey of this reef was conducted by Honman (1936a). This lode occurs within a vein of quartz and quartz-hematite breccia 400 metres long and up to 10 metres wide emplaced along a fault. The fault displaces amphibolites, slates and quartzites of the Toole Creek Meta-volcanics, the maximum displacement being 130 metres. The strike of the country rocks is between N10°E-N20°E, and the dip between 65°-85° east. The lode strikes between EW and S75°W, and dips south at 70°. The richest ore occurs where the lode is truncated by a cross-fault at a low angle. The cross-fault is associated with carbonates. The finely disseminated gold has been mined mainly in the oxidized zone. The primary ore in depth consists of quartz, calcite, and minor pyrite. The maximum depth of the workings is 40 metres, and the gold content in the main shoot averages 7 dwt per ton.

The Canteen: The prospect consists of quartz veins with vugs filled with iron oxide, forming a crescent-shaped zone 270 metres long and 3 to 10 metres wide which is conformable with the bedding of the surrounding rocks. The country rocks consist of amphibolites and silicified slates of the Toole Creek Meta-volcanics. Malachite staining is common in the reef. Carbonate rocks abound north of the mineralized zone.

Comstock: The prospect consists of lenses of quartz with iron oxide inclusions and emplaced in joints and fissures in quartzite near the boundary of a concordant amphibolite. Stratigraphically the prospect is situated near the boundary of the Weatherly Creek Quartzites and the Toole Creek Meta-volcanics. The bedding strikes N15°E and dips 75° east. Faults oriented at high angles to the strike occur north and south of the reef respectively.

Falcon (formerly Rose and Thistle): This lode has been described by Rands (1895), Ball (1908), and Honman et al., (1939). The reef consists of lenses of quartz located in altered quartzite near its contact with stratiform amphibolite of the Toole Creek Meta-volcanics. The strike of the lode is NS and the dip 75° west. The main ore shoot runs approximately 100 metres along the strike, and its average width

TABLE 1

REPORTED GOLD PRODUCTION OF INDIVIDUAL REEFS AND MINES IN THE CLONCURRY SHEET AREA.
(Information derived from the Qld. Min. Dept. Ann. Reports)

Year	1943** Ore(tons)	1943** Yield(oz)	1942 Ore(tons)	1942 Yield(oz)	1941 Ore(tons)	1941 Yield(oz)	1940 Ore(tons)	1940 Yield(oz)	1939 Ore(tons)	1939 Yield(oz)	1938 Ore(tons)	1938 Yield(oz)	Prior to 1938 Ore(tons)	Prior to 1938 Yield(oz)	Period	Total Production Total Ore (tons)	Total Production Total Yield (oz)	Average Grade (dwt/ton)
Brilliant	—		—		—		—		—		—		148.8600	92.7400	1935-6	148.8600	92.7400	12.5
British Lion	—		—		—		—		—		—		5.0000	2.5000	-	5.0000	2.5000	10.0
Chance	—		9.0585	0.5219	—		6.7320	7.7418	—		—		20.7500	19.0900	-	36.5405	27.3537	15.0
Comstock(Australian)	—		—		—		—		—		—		109.0700	209.1300	1905 + 1932-35	109.0700	209.1300	10.4
Falcon	—		—		—		—		19.1587	15.1000	—		178.8100	225.5700	1933-6	197.9687	240.6700	16.5
Glengarrie	—		—		—		—		—		—		2.0000	1.8000	-	2.0000	1.8000	22.2
Golden Stone	—		—		—		—		—		—		7.600	2.5000	-	7.0000	2.5000	7.1
Gilded Rose Area	—		—		140.2425	203.7189	136.2924	147.1792	203.2436	190.0829	—		5136.8100	5932.10000	1875-1936	5616.5885	5473.0810	23.1
Great Australia	—		238.6663	11.0808	8.0704	2.2691	—		—		32.5600	2.2834	—	—	—	279.2967	15.6333	1.1
Little Andy	—		—		—		—		—		—		197.0000	24.0000	1905	197.0000	24.0000	2.4
Mt Freda	—		—		—		106.4138	21.3658	335.0000	53.6151	—		24.5100	20.8100	1934	465.9238	95.7909	4.1
Mountains Home	36.6164	0.2607	—		—		—		—		—		—	—	—	36.6164	0.2607	0.1
Mugs for Luck	—		—		—		—		—		—		10.0000	0.4700	1934	10.0000	0.4700	0.9
Princess	—		—		—		—		—		—		17.0000	19.4000		17.0000	19.4000	22.8
Rose & Thistle South	—		—		—		—		—		—		114.0000	28.5000	Prior 1895	114.0000	28.5000	5.0
Rose of Tralee	—		—		—		—		—		—		3.5000	2.1000	—	3.5000	2.1000	12.0
Ruthren	—		—		—		—		—		—		16.0000	6.9000	—	16.0000	6.9000	8.6
Scottish Chief	—		—		—		—		—		—		28.0000	4.0500	—	28.0000	4.0500	2.8
Toole Creek	—		—		—		8.3061	1.6936	2.0000	0.3942	—		—	—	—	10.3061	2.0878	5.6
Union Jack	—		—		—		—		—		—		5.0000	1.5000	—	5.0000	1.5000	5.0
Urundula	—		—		—		—		—		—		80.0000	140.0000	Prior 1895	80.0000	140.0000	35.0
Wakeful	—		—		—		—		—		—		5.0000	6.5000	—	5.0000	6.5000	26.0
TOTAL	36.6164	0.2607	247.7248	11.6027	148.3129	205.9880	257.7443	177.9804	559.4023	259.1922	32.5600	2.2834	6108.3100	6731.6600		7384.6707	7396.9674	

* Only reported production figures are given in this table.   ** No gold production has been reported later than 1943.

is 0.7 metres. The oxidized ore consists of quartz, iron oxides, carbonate, tourmaline, scheelite and mica. Sulphides occur at a depth of approximately 27 metres. An adjacent reef (Shamrock reef) occurring NE of the Falcon reef is emplaced in amphibolites.

Castle Hill Reefs: This reef occurs 2.4 km. ESE of the Falcon. It consists of weakly auriferous quartz veins emplaced in and folded with slates of the Toole Creek Meta-volcanics. The reefs occur in a tight synclinal axial zone. They consist of quartz and gossanous vugs. A limited amount of work has been carried out on this reef, and because of its size Clappison (in Honman, 1939) recommended further prospecting.

Quartz reef west of the Bosca lode: The quartz reef is emplaced in a line of weakness in slates of the Toole Creek Meta-volcanics. Amphibolites crop out about 40 metres east of the reef.

Prospect 1 mile south of Weatherly Trig Station: The lode is emplaced along an EW fault in the Toole Creek Meta-volcanics, with slates and cherts forming the northern wall and amphibolites forming the southern wall. These rocks are situated in a synclinal axial zone, and are highly contorted.

Iron Duke: The quartz lode is conformable with the NS strike of the country rocks, which consist of amphibolites and slate intercalations of the Toole Creek Meta-volcanics.

The Jewel: The reef consists of quartz, calcite and ilmenite and is emplaced along a contact of quartzite and amphibolite of the Toole Creek Meta-volcanics. Traces of chalcopyrite are present in the reef.

The Brilliant reefs (Bull Creek Group)

These reefs are located 17 km. SE of Cloncurry. They consist of conformable quartz veins emplaced in amphibolite near an amphibolite-quartzite-boundary in the Weatherly Creek Quartzites. The bedding strikes approximately EW and dips 53° south. A NS-striking fault occurs 217 metres west of the reefs. The reefs include a pocket of scheelite. Siderite, malachite, ilmenite, wolfram and bismuthinite are minor constituents of the reef. The two principal reefs in the area strike EW and dip 30°-45° northward. Both gold and copper have been derived from these lodes.

The Pinnacles

The reefs occur south of the Pinnacles; a group of rugged hills of breccia of the Corella Formation. The reefs consist of lenses of quartz with seams of iron oxide, and are conformably emplaced in schists of the Toole Creek Meta-volcanics, striking N55°E and dipping steeply northward.

The Gilded Rose

The Gilded Rose reef has been the most important producer of gold in the Cloncurry District up to the thirties, by which time a total of 5136 tons of ore had been mined, to yield 5932 ounces of gold (Honman, et al., 1939). Surveys of the mines were carried out by Jack (1898), Rands (1895), Shepherd (1931, 1932), and Honman (1936b). The prospect consists of a parallel set of auriferous quartz veins with a maximum width of 1.3 metres, emplaced conformably in garnetiferous pelitic and arenaceous schists a short distance north of a stratiform amphibolite. The reef strikes approximately S75°E for about 1000 metres, and dips 75° south. At upper levels of the lode the gold is associated with iron oxides, which grade into sulphides in depth. The richest parts of the lodes are at the junction with transverse faults which strike N70°E. The Gilded Rose reef was worked at numerous localities along the strike, the deepest shaft descending to a depth of 50 metres.

Copper mineralization

Copper is the single mineral mined in the Cloncurry Sheet area at the present time, and although the area as a whole ranked as a minor copper producer, the great number of small shows and the association of many of the copper deposits with auriferous mineralization, account for the interest taken by earlier workers (mainly Honman et al., 1939) in the distribution of copper mineralization in the area. The Great Australia copper deposit discovered by Ernest Henry in 1867 was the first major mineral occurrence found in the Cloncurry District. Subsequently, numerous small copper and copper-gold ores were worked in the

TABLE 2.

REPORTED COPPER PRODUCTION OF INDIVIDUAL MINES IN THE CLONCURRY 1:100,000 SHEET AREA.
(Information derived from the Qld. Min. Dept. Ann Reports) *

Name of Mine	1968		1967		1966		1963		1962		1957		1956	
	Ore(tons)	Yield(tons.Cu)	Ore(tons)	Yield(tons.Cu)	Ore(tons)	Yield(tons.Cu)	Ore(tons)	Yield(tons.Cu)	Ore(tons)	Yield(tons.Cu)	Ore(tons)	Yield(tons.Cu)	Ore(tons)	Yield(tons.Cu)
Alpine	58.8759	5.6480												
Blue Bell	224.9255	7.4192												
Bosca														
Brilliant														
Chance														
Eagle Hawke	11.5597	0.8470												
Elder Lady Michelle														
Gar	25.7226	2.1769			17.3842	1.7413								
Glory Hole	30.5761	2.0223												
Great Australian	1482.4269	80.6121			918.8821	35.7523								
Iron Duke	76.4471	6.3953	393.4449	26.8326	547.2933	32.1947								
I.X.L.	267.4255	13.3165	115.7483	6.7354	3.9933	0.3814					6.0960	0.4023	59.3614	7.2380
Jacky Jacky														
Jasper	7.3880	1.1503	132,7608	5.3988										
Joker (Old Joker)	110.3441	5.4793	267,7533	13.4918										
Jubilee	389.9372	31.7591	440.9643	38.2464	136.5773	18.0399	120.1071	9.2045	276.9946	24.7001				
Kangaroo Rat									9.4459	2.2805				
Kingfisher														
Llomas														
Margaret														
Maria Dell	29,9914	1.3952	12.2168	0.8678										
Mata														
May Graham														
McKinlay														
Meteor														
Mount Dorothy	48.9064	2.0470												
Mount Norman	73.2435	6.5960												
Mountain Home Laird														
Mountain Queen														
New Moon													3.5571	0.2134
Pinnacle	7.5919	0.9072												
Raggedy	53.7413	1.4165												
Robur	25.7648	1.8706												
Three Johns														
Toole Creek														
Trough														
Victory									26.9821	2.1331	44.4707	2.4900	34.9845	1.9017
TOTAL	2930.8679	171.0525	1362.8884	91.5738	1624.1302	88.1096	120.1071	9.2045	313.4226	29.1137	50.5661	2.8323	97.9030	9.3531

* Only reported production figures are given in this table.

Table 2.

Name of Mine	1955 Ore(tons)	1955 Yield(tons.Cu)	1954 Ore(tons)	1954 Yield(tons.Cu)	1953 Ore(tons)	1953 Yield(tons.Cu)	1952 Ore(tons)	1952 Yield(tons.Cu)	1938 - 1948 (inc.) Ore(tons)	1938 - 1948 (inc.) Yield(tons.Cu)	Prior to 1938 Ore(tons)	Prior to 1938 Yield(tons.Cu)	Prior to 1938 Period	TOTAL PRODUCTION Ore(tons)	TOTAL PRODUCTION Yield(tons.Cu)	%Cu
Alpine														58.8759	5.6480	9.6
Blue Bell			9.2855	0.8450	5.4725	0.6786	8.2917	0.8706						247.9752	9.8134	4.0
Bosca											31.3092	7.1449	1929-30	31.3092	7.1449	22.8
Brilliant											140.6796	11.3819	1935-36	140.6796	11.3819	8.1
Chance	4.2536	0.4509							46.4732	6.5245				50.7268	6.9754	13.8
Eagle Hawk														11.5597	0.8470	7.3
Elder Lady Michelle											36.8355	10.7599	1905-34	36.8355	10.7599	29.2
Gar														43.1068	3.9182	9.1
Glory Hole									1015.4484	138.6738				30.5761	2.0223	6.6
Great Australian					8.0360	0.5911								3425.0934	255.7293	6.6
Iron Duke														1017.1853	65.4226	6.4
I.X.L.	66.0770	4.1715	63.8800	7.2607	5.3622	0.6327					88.8109	18.7491	1929-31	677.2886	58.8886	8.7
Jacky Jacky											5.000	0.5575	1935	5.000	0.5575	11.1
Jasper														140.1488	6.5491	4.7
Joker (Old Joker)											84.7411	20.5447	1927-29	462.8385	39.5158	8.5
Jubilee [handwritten: Moreska ?]							5.8759	0.4583						1370.4564	122.4083	8.9
Kangaroo Rat														9.4459	2.2805	24.1
Kingfisher					46.2067	3.6347	8.2024	1.4361			5.4634	1.0913	1908-29	59.8725	6.1521	10.3
Llomas											2.0000	0.5000	1907	2.0000	0.5000	25.0
Margaret									5.9218	0.8113				5.9218	0.8113	13.7
Maria Dell														42.2082	2.2630	6.2
Mata											14.0000	4.30000	1904	14.0000	4.3000	30.7
May Graham											60.0000	18.0000	1905-6	60.0000	18.0000	30.0
McKinlay											0.5000	0.1600	Prior to 1906	0.5000	0.1600	32.0
Meteor					2.1690	0.1583					23.0000	7.0000	1904-5	25.1690	7.1583	28.4
Mount Dorothy														48.9064	2.0410	4.2
Mount Norman														73.2435	6.5960	9.0
Mountain Home Laird									131.6308	21.4126	61.8700	18.7491		193.5008	40.1617	20.8
Mountain Queen											2.4446	0.1582	1929	2.4446	0.1582	6.5
New Moon			13.8387	0.3598										17.3958	0.5732	3.3
Pinnacle														7.5919	0.9072	12.0
Raggedy														59.7413	1.4165	2.4
Rotor														25.7648	1.8706	7.3
Three Johns											7.5000	1.9000	1905-6	7.5000	1.9000	25.3
Toole Creek									8.3061	0.9608				8.3061	0.9608	11.6
Trough											12.0000	3.6000	1906	12.0000	3.6000	30.0
Victory	22.6964	1.5232			20.4237	1.7553			23.8288	3.9828	2.0000	0.3800	Prior to 1908	175.3856	14.1061	8.0
TOTAL	93.5610	6.1456	87.0042	8.4655	87.6701	7.5507	22.3700	2.7650	1231.9091	172.3658	578.1543	124.9702		8576.5540	723.5087	

Sheet area, particularly in the Mount Norna and Soldiers Cap areas. The reported copper production figures are tabulated in Table 2. The total ore production reported to 1968 is 8576 tons, yielding 723 tons of copper. In the following the principal geological features of the main copper deposits are taken from Honman et al., (1939), and supplemented by observations the authors.

Mountain Home lode (Mt. Norna):- This lode was first described by Jack (1898). The lode occurs in a prominent quartzite ridge in silicified meta-sediments of the upper Snake Creek Meta-turbidites. It strikes NNW, and consists of altered ferruginous quartzite intruded by small veins of quartz arranged in en echelon pattern, and impregnated by malachite, minor chalcocite and cuprite.

Mount Dawson:- The lode is emplaced in a fault which displaces quartzites intercalated in amphibolites at the base of the Toole Creek Meta-volcanics. The bedding swings between N40°W and N60°W, reflecting the flexuring of the strata at the hinge of a cross-fold. The fault strikes N75°W and the displacement is 40 metres. The copper mineralization occurs in brecciated, silicified and quartz veined rocks along the fault zone, which may be up to 13 metres wide. Malachite, azurite, chrysocolla and cuprite are present, and are associated with abundant iron oxides.

The Joker (formerly The Old Joker):- The oxidized zone of the lode consists of ferruginous breccia, quartz, limonite, and malachite. The primary ore is lower in copper, and consists of quartz, chalcopyrite and pyrite. The lode occurs in a fissure striking N18°E and dipping 80° west, and measures approximately 120 metres along the strike. The country rocks consist of amphibolites and quartzites of the Weatherly Creek Quartzites.

The Elder (Lady Michelle):- This lode is located at the axial zone of an eastward plunging cross-folded syncline. The country rocks consist of mica schists, arenaceous schists and quartzites in the upper part of the Snake Creek Meta-turbidites. The beds near the mine strike N80°E and dip 70° south. The lode consists of quartz veins striking between NS and S30°W, and impregnated by malachite, azurite, cuprite and limonite. A thin gossan is developed at upper levels of the lode. The mine is being worked at present.

The Laird (Mountain Queen):- The lode occurs within mica schists of the upper part of the Snake Creek Meta-turbidites, which strike EW and dip steeply north. It consists of an irregularly shaped body of quartz impregnated by malachite and limonite.

Mount Wheeler:- The lode occupies a shear zone within a band of ferruginous and carbonated slate intercalated with amphibolites of the Toole Creek Meta-volcanics. A thick silicified gossan containing chrysocolla, malachite and atacamite is developed. The ore body occurs south of the intersection of two faults.

The Bosca:- The lode is located in contorted interbedded amphibolites and slates of the Toole Creek Meta-volcanics, and follows an amphibolite-slate contact. It consists of quartz containing gossanous vugs and malachite impregnations. One of the quartz veins is known to contain gold.

The Weatherly:- The lode consists of thin veins of quartz and thin veins of quartz and iron oxide stained with copper minerals, and occurs within a silicified slate intercalation. Both copper and gold have been recovered from the ore. The country rocks consist of NS striking amphibolites and slates of the Toole Creek Meta-volcanics.

The Wallace:- Malachite and finely dessiminated gold occur in quartz-veined siliceous slate which is intercalated in amphibolites of the Toole Creek Meta-volcanics. The country rocks are poorly exposed, and little structural detail is known.

The I.X.L.:- The lode is located in graphitic slate intercalated in amphibolites of the Toole Creek Meta-volcanics. The slate is veined by quartz, and includes siderite, calcite, malachite, azurite and cuprite.

Lady Norman:- Copper carbonates occur in a gossan developed in an EW striking intercalation of slate in amphibolites of the Toole Creek Meta-volcanics.

<u>Corbetts Gully</u>:- The lode consists of small malachite-bearing quartz lenses emplaced in fissures in amphibolites of the Toole Creek Meta-volcanics.

The Ace:- The lode is located along the contact of amphibolites and slate of the Toole Creek Meta-volcanics, and consists of quartz and ironstones.

<u>Copper occurrences in the Marimo Slate and Corella Formation</u>

A number of small copper occurrences are located in the far southwest of the Sheet area, about 12 to 16 km south of Roxmere homestead. Most are located in slate and silt of the Marimo Slate, and are associated with zones of faulting, silicification and iron enrichment. Brief descriptions of these mines follow:-

<u>Bluebell</u> and <u>Duchenese No.4</u>: The old workings consist of large pits and dozer scrapings: mineralization occurs in narrow quartz veinlets trending southeast, parallel to cleavage and bedding in the wall rock, which is pale grey to purple silt. Malachite and chalcocite are present. Leases and Authority to Prospect No.709 in this area are currently held by Valiant Exploration.

<u>Copper Canyon</u>: This area embraces a ridge of grey to black slate 100 metres wide and 300 metres long. Minor scrapings are scattered along the ridge. Malachite is present in small (1 cm to 10 cm.) quartz veins which are cross-cutting and sub-parallel to foliation in the host slate. Secondary deposition of malachite along joints and bedding is widespread; thin coatings of malachite up to 7 square metres cover rock faces. The area is currently held under lease.

<u>Dodge</u>: Disused workings consist mainly of irregular trenching and some shallow pitting in the axial region of folded grey slate. Bedding trends southeast, but mineralization is localized in a zone 3 metres wide trending south-southwest. The series of mineralized quartz veins are up to 2 cms thick, and wall rock is extensively kaolinized. Malachite, chalcocite, cuprite and hematite have been noted.

Duchenese: This is an unworked mass of pyritic limonitic quartz. The pyrite forms nodules up to 25 cms diameter in milky quartz, and is associated with an unidentified yellow-green mineral. A small floater of dolerite occurs in quartz scree surrounding the deposit. Host rocks are folded slates. No copper mineralization was evident, but the area is held under lease, and covered by Authority to Prospect 709 held by Valiant Exploration. Copper-iron mineralization is reported (W. Presley, pers. comm.) in an area 600 metres southwest of this lease.

Just Found: This is an old series of open pit workings and small shafts in a sequence of silt and sand conformable with limestone of the Corella Formation. Copper occurs in masses of fractured limonite and quartz veins which cut the bedding at a high angle. Lumps of chrysocolla are abundant in limonite gangue, with lesser amounts of malachite; an unidentified amorphous khaki-green coating occurs with some chrysocolla.

Robur: These are old workings described briefly by Honman (1939) under the heading "Silver-lead deposits". No silver-lead was observed during the present survey, or by Honman, and copper appears to be the only metal of importance. Mineralization occurs in a north-northwest trending ridge of highly jointed, quartz-veined grey to buff siltstone. Chrysocolla is common in small quartz veins, and malachite, azurite, chrysocolla, cuprite and chalcocite occur in siliceous hematite. Small caves are coated with supergene concentrations of malachite. A small adit dug 13 metres into the ridge revealed a zone of schist 3 metres wide with centimetre-thick seams of malachite along joints.

In the scree slope and valley east of the ridge, phyllonite and black siliceous hematite with malachite, chrysocolla and cuprite have been observed. Along the ridge 1.5 km. to the northwest small scrapings in slate (?Robur North) contain chrysocolla and malachite.

Great Australia: This mine, situated on the southern outskirts of Cloncurry township, is described in Carter et al. (1961). The north-trending intersecting fault system with which mineralization is associated (Main Lode and Orphan Lode) is flanked to the east by siltstone and calcareous breccia of the Corella Formation, and to the west by diorite or dolerite. The contact between breccia and siltstone dips steeply to the northwest. Large tonnages of low grade siliceous ore with cuprite, malachite and chrysocolla are presently "at grass". About 400 metres west of the main workings a further body of copper ore has been delineated; this body is mushroom-shaped, and plunges gently to the north. It crops out as mineralized gossan near a low east-trending ironstone ridge. The country rock is fine-grained dolerite or diorite. Western Nuclear are currently evaluating the mine, and early in 1970 renewed their option over it.

Other areas of copper mineralization: About 700 metres southwest of the Just Found show, traces of malachite and chrysocolla occur in grey slate. The copper occurs in microshears subparallel to bedding and cleavage, and extends along strike for about 7 metres.

A similar deposit with signs of some scraping occurs in black slate 600 metres west of Bluebell show. Azurite and malachite are present. The microfractured zone of mineralization trends at a moderately high angle to bedding.

Other mineral deposits

Small deposits of scheelite are known from the Shamrock Reef (near the Falcon), the Falcon Reef itself, Comstock, Mt. Scheelite Reef (one quarter of a mile west of Comstock), and the Brilliant Extended Reef. Small lodes of cobalt, including cobaltite and erythrite are present in the southeastern part of the Soldiers Cap area in slates near a granite contact. Erythrite occurs in a garnet-bearing ferruginous band located approximately one mile west of the Comstock mine. Traces of cobalt have also been discovered in the Jewel. Silver-lead mineralization has been reported from two areas, namely one mile west-southwest of Camel trig, and the Robur workings west of Snake Creek. A small radiometric anomaly has been located immediately east of the Copper Canyon area, in a heavily ferruginized fault zone. Source of the anomaly is unknown.

Origin of the mineralization in the Soldiers Cap area

In concluding their survey of the Soldiers Cap area, Honman et al. (1939) pointed out to the preferential occurrence of the auriferous and copper-bearing lodes along lower stratigraphic levels of the volcanic sequence. These authors further indicated the role of faults in the control of mineralization, and regarded the granites as the source of the ore-bearing solutions. The results of the present survey are mainly in agreement with the above conclusions. In considering the origin and mode of emplacement of the gold and copper deposits, the following observations are pertinent:

(1) The majority of mineral occurrences are concentrated in the following stratigraphic zones:

(a) Several copper deposits are associated with the cross-folds in the upper part of the Snake Creek Meta-turbidites between Mt. Norna and Snake Creek (e.g., Mountain Home, The Laird, The Elder (Lady Michelle), Columbia, Montana.

(b) The most important zone of copper and gold mineralization roughly coincides with the upper levels of the Weatherly Creek Quartzites and the lower levels of the Toole Creek Meta-volcanics (e.g. Mt. Freda, Falcon, Comstock, The Jewel, Mt. Dawson, Brilliant, Gilded Rose, The Pinnacles, Ace, Holly).

(c) Copper and gold mineralization are also common at intermediate and upper stratigraphic levels of the Toole Creek Meta-volcanics (e.g., Iron Duke, Mount Wheeler, Canteen, Kingfisher, Corbetts Gully, Castle Hill, Bosca, Weatherly, Victory, I.X.L., Lady Norman).

(2) No ore deposits are known from the lower and middle stratigraphic sections of the Snake Creek Meta-turbidites. As is suggested below this lack of mineralization can be explained in terms of

the higher metamorphic grade of the Snake Creek Meta-turbidites, but may also have resulted from the absence of volcanic rocks in this formation.

(3) Amphibolite-meta-sediment contacts and slate intercalations in amphibolite constitute favourable loci for gold and copper mineralization. On the other hand, mineralization is relatively uncommon within thick and continuous amphibolite bodies.

(4) Faults oriented at high angles to the bedding may serve as important loci of mineralization, and their intersections with favourable stratigraphic horizons result in places in high ore concentrations (e.g., Falcon, Gilded Rose).

(5) The axial zones of fold structures may constitute favourable sites for mineralization (e.g., The Elder, Canteen).

(6) Both gold and copper mineralization are almost invariably associated with quartz veins and silicification, and may be accompanied by carbonatization and less commonly by potash metasomatism, represented by the development of muscovite or biotite.

(7) The quartz veins are little sheared and contain no metamorphic constituents. It follows that mineralization may have post-dated metamorphism.

(8) No gold mineralization is known from the Corella Formation which, on the other hand contains numerous copper shows.

(9) Because of the common association of gold with copper deposits, the origin of these minerals appears to be genetically related.

(10) The copper enrichment usually takes place within the gossanous and oxidized zones, and the grade decreases toward the primary sulphide zone.

It appears from the foregoing considerations that the major phase of mineralization post-dated both faulting, folding and metamorphism, and therefore may well have resulted from siliceous emanations associated with the granites. The ore-bearing solutions percolated through weakness planes such as faults and amphibolite-sediment contacts, with which the bulk of the mineralization is associated. In agreement with Honman et al.'s (1939) conclusions, it is recommended that future prospecting in the area should concentrate on low stratigraphic sections of the volcanic sequences, particularly where the latter are truncated by faults.

Origin of mineralization in the Marimo Slate and Corella Formation

Mineralization in the Marimo Slate appears to be associated with faulting, silicification, quartz veining etc. All deposits are located in highly cleaved slates and silts in favourable structural locations, e.g. fold axial regions or in intersecting shears.

The origin of the mineralization is obscure. In general an obvious igneous source is lacking; granite and dolerite are scattered through the area but only in the Great Australia and possibly Duchenese mines is there a close field relationship between basic intrusions and copper mineralization. An alternative source for the copper is the sequence of slate itself, which contains small amounts of pyrite, graphite etc. over most of the Sheet area. However, no copper minerals have been found dispersed in slate so far; slates in the Marraba Sheet to the west contain an average of 45ppm of copper, which is slightly higher than average, but the mechanism of concentration into ore deposits is unknown. This postulate of remobilizing syngenetic material, though attractive in the absence of obvious igneous sources, is supported by little or no evidence.

In most mines the mineralization occurs in rocks of low metamorphic grade, and almost certainly is synchronous with faulting and folding of the Marimo Slate. Since the granites of the area appear to be post-deformation and post-metamorphism, it is possible that they also post-date the Marimo Slate mineralization; there is also no evidence of mineralization around or near the margins of any of the granite intrusions. Dolerite, on the other hand, is associated with major mineralization at the Great Australia, and minor mineralization at various points in the Corella Formation. It is older than the granite, but appears to be syn or post-metamorphic also. However, it has been postulated elsewhere that tectonic activity in the belt west of Snake Creek may have initiated basic (and acid) igneous intrusion, and it thus seems possible that mineralization in the Marimo Slate-Corella Formation may be due more to basic intrusion than to any other source. In the Bluebell-Copper Canyon deposits one needs to postulate the presence of dolerite at depth, and this is a notable weakness in the argument for basic igneous sources.

VIII. GEOSYNCLINAL AND OROGENIC EVOLUTION

The earliest geological event in the development of the Soldiers Cap belt is represented by the interbedded greywacke and slates of the Snake Creek Meta-turbidites, and possibly by the black slates and the sandstones occurring as inliers under the Corella Formation west of Snake Creek. The turbidite sequence represents sedimentation from intermittent pulsations of density currents, interrupted by periods in which settling of fine muds predominated. Following Kuenen (1964), the turbidites probably correspond to the Alpine flysch and to modern deep sea sands. No igneous activity was associated with this sedimentary phase.

The transition from the Snake Creek Meta-turbidites into the Weatherly Creek Quartzite signifies the development of a stable shelf environment in which deposition of well-sorted current-winnowed sands took place. This change was concomitant with the initiation of basic volcanic activity, involving the extrusion of basaltic lavas over extensive tracts of the sea bed. The frequency of volcanic eruptions progressively increased with time, and intermissions between successive flows are represented by thin intercalations of cherts and pelitic sediments, testifying to the subaqueous nature of the volcanism. The almost complete absence of pillow structures and amygdales in the metabasalts may indicate a low volatile content of the lavas. The volcanism was associated with the emplacement of related sills of dolerite and gabbro. The geosynclinal succession of the Soldiers Cap Formation thus displays an opposite trend of evolution to that characteristic of Alpine geosynclinal sequence, in which the flysch stage succeeds the ophiolite stage (e.g., Auboin, 1956).

The volcanic stage was followed by isoclinal folding of the Soldiers Cap Formation on NS-trending axes, and by regional metamorphism which reached the staurolite-almandine subfacies of the amphibolite facies. The regional metamorphism was of the intermediate low-pressure type, and was associated with the development of flow-cleavages and fracture-cleavage sets. The development of the latter set may have conceivably been associated with the development of the cross-folding, discussed below.

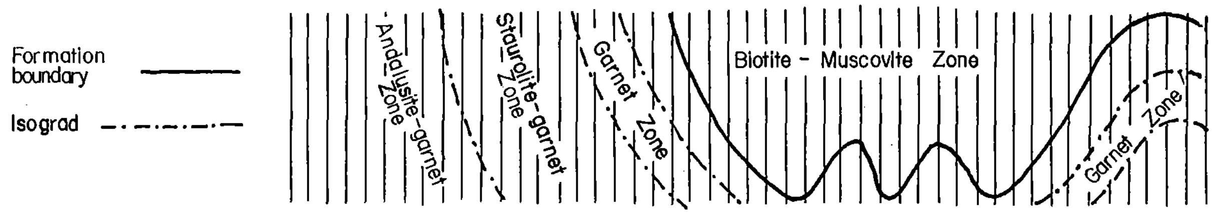
The isoclinal folding and metamorphism were succeeded by a general epeirogenesis and by subsequent erosion. A younger phase of submergence resulted in the deposition of marls, dolomites, limestones and siltstones of the Corella Formation, which was succeeded by the deposition of sandstone of the Roxmere Quartzite. This cycle was followed by the emplacement of leucocratic granites, which were presumably the source of the gold and copper mineralization. The intrusion of the northern granitic batholith is believed to have caused the extensive cross-folding of the Soldiers Cap Formation, as well as the brecciation and the folding of the Corella Formation and the Roxmere Quartzite. The cross-folding was followed by the intrusion of dykes and plugs of dolerite, and by a second phase of low-pressure regional metamorphism which accounts for the metamorphism of the Corella Formation. Some dolerite plugs possibly preceded granite intrusion. The possibility that the Corella Formation may have been metamorphosed during the first phase of regional metamorphism is not likely, because the metamorphic foliation in the Soldiers Cap Formation does not continue through the calc-silicates.

An elevation and denudation of the Precambrian series in pre-Cretaceous times was succeeded by the deposition of Cretaceous conglomerates, sandstones and siltstones. Humid climatic conditions during the late-Mesozoic or the Neogene resulted in the development of a lateritic crust underlain by silcrete. Elevation and erosion of the area, which probably occurred during the late Neogene, resulted in the configuration of the present terrain.

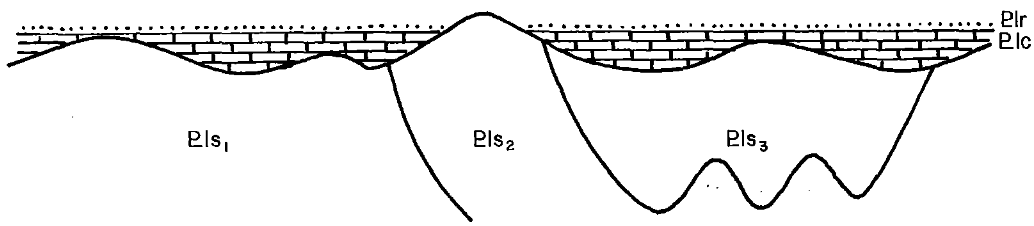
Fig. 33 A model of the structural and metamorphic development of the Soldiers Cap belt, Cloncurry District, N-W Queensland (Not to scale)

(1) Isoclinal folding of the Soldiers Gap Formation

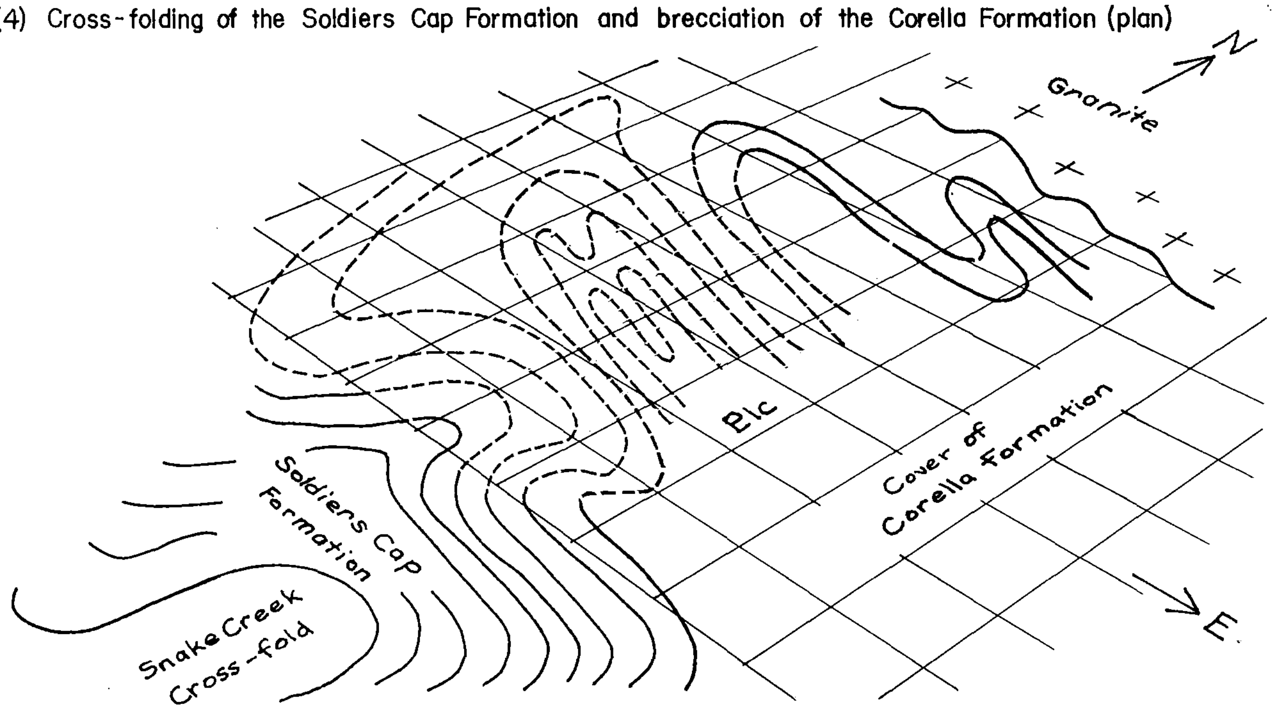
(2) Regional Metamorphism



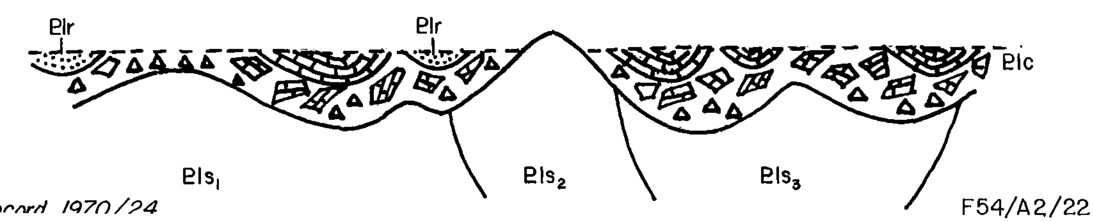
(3) Deposition of the Corella Formation and the Roxmere Quartzite



(4) Cross-folding of the Soldiers Cap Formation and brecciation of the Corella Formation (plan)



(5) Present structure



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REFERENCES

AUBOUIN, J., 1965 - "Geosynclines". (Elsevier: Amsterdam).

BALL, L.C., 1908 - Cloncurry copper mining district. Qld Geol. Surv. Pub. No.215.

CARTER, E.K., BROOKS, J.H., and WALKER, K.R., 1961 - The Precambrian Mineral belt of northwestern Queensland. Bur. Miner. Resour. Aust. Bull. No.51.

DEER, W.A., HOWIE, R.A. and ZUSSMAN, J., 1963 - "Rock Forming Minerals". (Longmans: London).

DERRICK, G.M., 1968 - Reconnaissance in the Mary Kathleen-Cloncurry area, July-August, 1968. Bur. Miner. Resour. Aust. Rec. 1969/9.

DERRICK, G.M., WILSON, I., HILL, R. and MITCHELL, J., 1970 - Geology of the Marraba 1:100,000 Sheet area. Bur. Miner. Resour. Aust. (in prep.).

DUNN, P.R., PLUMB, K.A. and ROBERTS, H.G., 1966 - A proposal for time-stratigraphic subdivision of the Australian Precambrian. J. Geol. Soc. Aust. 13: ~~584~~-593. 607

FYFE, W.S., TURNER, F.J. and VERHOOGEN, J., 1958 - Metamorphic reactions and metamorphic facies. Geol. Soc. Amer. Mem. 73.

HONMAN, C.S., 1936a - The Mt. Freda-Canteen area, Soldiers Cap, Cloncurry District. The Aerial, Geological and Geophysical Survey of northern Australia. Report (Queensland No.1).

HONMAN, C.S., 1936b - The Gilded Rose area, Cloncurry District. The Aerial, Geological and Geophysical Survey of Northern Australia, (Queensland No.2).

HONMAN, C.S., CLAPPISON, R.J.S. and RAYNER, E.O., 1939 - The Soldiers Cap area, Cloncurry District. Aerial, Geological and Geophysical Survey of Northern Australia. Report (Queensland No.18).

HOSCHEK, G., 1969 - The stability of staurolite and chloritoid and their significance in metamorphism of pelitic rocks. Cont. Min. Pet. 22. 208-232.

JACK, R.L., 1898 - Six reports on the geological features of part of the district to be traversed by the proposed transcontinental railway. Qld Geol. Surv. Bull. No.10 .

KUENEN, Ph.H., 1964 - Deep sea sands and ancient turbidites. In "Turbidites" (ed. A.H. Bouma and A. Brouwer). 1-33. (Elsevier: Amsterdam).

MIYASHIRO, A., 1961 - Evolution of metamorphic belts. J. Pet.2: 277-311.

RANDS, W.H., 1895 - The Leichhardt goldfield and other mining centres in the Cloncurry District, Qld Geol. Surv. Publ. No.104.

RICHARDS, J.R., COOPER, J.A., and WEBB, A.W., 1963 - Potassium-argon ages on micas from the Precambrian region of northwestern Queensland. J. Geol. Soc. Aust. 10: 299-312.

SHEPHERD, S.R.L., 1931 - Gilded Rose and Pinnacles area, Cloncurry District, Qld Govt Min. Jour. XXXII.

SHEPHERD, S.R.L., 1932 - The Gilded Rose area at Cloncurry. Qld Govt Min. Jour. XXXIII.

SHEPHERD, S.R.L., 1933(a) - Mount Freda, Soldiers Cap, Cloncurry District. Qld Govt Min. Jour. XXXIV.

SHEPHERD, S.R.L., 1933(b) - Comstock mine, Soldiers Cap, Cloncurry District. Qld Govt Min. Jour. XXXIV.

SLATYER, R.O., 1964 - Climate of the Leichhardt-Gilbert area. In: C.S.I.R.O. Land Research Series No.11.

TURNER, F.J. and VERHOOGEN, J., 1960 - "Igneous and Metamorphic Petrology". (2nd ed.) (McGraw-Hill: New York).

TURNER, F.J., 1968 - "Metamorphic Petrology". (McGraw-Hill: New York).

ZWART, H.J. et al., 1967 - A scheme of metamorphic facies for the cartographic representation of regional metamorphic belts. I.U.G.S. Geological Newsletter No.2: 57-72.

APPENDIX I

Petrographic descriptions of specimens from the Cloncurry 1:100,000 Sheet area.

The list of contents is given on page ii.

ABBREVIATIONS

Crypt.	-	Cryptocrystalline	(<0.01 mm)
Mic.	-	Microcrystalline	(0.01-0.05 mm)
F.g.	-	Fine-grained	(0.05-0.3 mm)
M.g.	-	Medium-grained	(0.3- 3.0 mm)
C.g.	-	Coarse-grained	(3.0-10.0 mm)
V.c.g.	-	Very coarse-grained	(10 mm <)
sp.	-	Specimen	
tr.	-	trace	
est.	-	estimated	

Specimen numbers:

1) BMR Number (Year, project number, serial number)
2) Field Number (Sheet, run, photo, point)

Specimen localities:- Plotted on the geological map (in pocket), as the serial number only (e.g., for 69200064 only 64 is given).

APPENDIX I

List of contents

A. META-SEDIMENTS

(1) META-SILTSTONES

sp. 69200027 (C15-52-7)

Definition:- Spotted biotite-feldspar-quartz-sericite meta-siltstone (BlS_3).

Hand-specimen:- Off-white to light grey slate, spotted by f.g. to m.g. dark prismatic minerals.

Microsection:- The rock consists of aggregates of crypt. to mic. sericite, quartz and feldspar. Weak compositional banding with quartzo-feldspathic bands alternating with micaceous bands is apparent. Aggregates and isolated flakes of f.g. biotite (z - yellowish brown) are common, and are in many instances accompanied and replaced by tourmaline (z - bluish green). F.g. to m.g. pseudomorphs of rutile and opaques after (?) ilmenite account for the visible spotting of the rock. - Iron staining along cracks is common.

Mode (est.):- Sericite 45%; Quartz and Feldspar (plagioclase)40%; Biotite 10%; Tourmaline, rutile, opaques 5%.

Petrogenesis:- The rock is a low-grade metamorphosed pelitic sediment, which underwent alteration processes resulting in alteration of the biotite, development of tourmaline, and possibly replacement of original ilmenite by rutile and iron ore.

sp. 69200029 (C15-52-15)

Definition:- Black meta-siltstone/slate (BlS_3).

Hand-specimen:- Black to dark grey siltstone showing crude foliation. Some bands show fine white spotting.

Microsection:- The rock consists of cryptocrystalline opaques (black in reflected light), as well as of aligned streaks and lenses of aggregates of mic. - f.g. quartz and feldspar. Two foliation sets at low angle to one another are defined by these elongated aggregates, as follows: (1) A foliation defined by the smaller quartzofeldspathic streaks (0.1 mm), and (2) a foliation with which larger quartzofeldspathic aggregates (0.3 mm) are aligned. Sericite, altered biotite, and submicroscopic clouding are associated with the feldspar.

Mode (est.):- Crypt. opaques 55%; Feldspar, Quartz 40%; Mica 5%.

Petrogenesis:- The rock is a low-grade metamorphosed black carbonaceous and/or pyritic shale, which underwent at least two stress phases, and shows a fine segregation of quartzofeldspathic aggregates. The abundance of quartz and scarcity of mica may indicate secondary silicification of the rock.

sp. 69200034 (C15-52-36)

Definition:- Muscovite-biotite-quartz laminated meta-siltstone(BlS_2).

Hand-specimen:- Finely laminated and cross-laminated grey to black meta-siltstone.

Microsection:- The rock consists of a moderately well foliated assemblage of mic. biotite, muscovite and quartz. The biotite flakes are usually coarser grained and less well aligned than the muscovite scales. The quartz grains are mostly equidimensional. Finely disseminated opaques and epidote form accessory constituents. The banding results in variations in the amount of biotite and opaques.

Mode (est.):- Quartz 45%; Biotite 30%; Muscovite 20%; Opaques 5%.

Petrogenesis:- The high percentage of quartz and the cross-lamination indicate that the original rock was a siltstone. Metamorphism resulted in the development of aligned muscovite and biotite in this order, as well as in the recrystallization of the quartz.

sp. 69200056 (C14-74-36)

Definition:- Chlorite-veined muscovite-quartz meta-siltstone (BlS_2).

Hand-specimen:- F.g. light-grey finely cleaved uniform meta-siltstone.

Microsection:- The rock consists of a uniform aggregate of mic. granular quartz, well-aligned mic. muscovite (sericite), and finely disseminated crypt. opaques. Veins of well-aligned aggregates of mic. ferroan chlorite are very common, with the (001) planes of the chlorite lying parallel to the vein walls.

Mode (est.):- Quartz 60%; Muscovite 35%; Chlorite and opaques 5%.

Petrogenesis:- The rock is a metamorphosed siltstone.

sp. 69200057 (C14-74-39)

Definition:- Chlorite-biotite-muscovite-quartz crenulated spotted meta-siltstone (BlS_2).

Hand-specimen:- Phyllite, banded in light grey to black, with m.g. porphyroblasts of chlorite aligned parallel to a fracture cleavage set. The sedimentary banding, flow-cleavage and fracture cleavage are oriented at angles to each other.

Microsection:- In thin-section the rock consists of mic. quartz, undulatory foliated mic.-f.g. biotite (z - deep brown) and mic. muscovite. In places the flow-cleavage is shear-folded. The muscovite scales are younger, and may develop at the expense of the biotite. Epidote, rutile and opaques form accessories. The sedimentary banding results from variations in the proportion of biotite. M.g. poikiloblastic ferroan chlorite is developed with the (001) planes parallel to the axial planes of the crenulation (parallel to the fracture cleavage). The chlorite carries mic. quartz inclusions.

Mode (est.):- Quartz 40%; Muscovite 35%; Biotite 20%; Chlorite + accessories 5%.

Petrogenesis:- The rock is a metamorphosed pelitic sediment. The development of fracture cleavage was associated with retrograde metamorphism represented by the growth of chlorite at a discordant orientation to the flow-cleavage, and parallel to the fracture-cleavage.

sp. 69200075A (C11-22-13A)

Definition:- Chlorite-biotite-muscovite-quartz spotted meta-siltstone ($B1S_2$).

Hand-specimen:- Weakly-cleaved light grey meta-siltstone, with abundant euhedral c.g. (up to 10 mm) porphyroblasts of chlorite.

Microsection:- The rock consists of f.g. even-grained quartz interspersed with mic. sericite and f.g. biotite (z - orange brown). The mica is poorly aligned, and its orientation is commonly determined by quartz grain boundaries. Opaques and tourmaline are the main accessories. Microporphyroblasts of ferroan chlorite are common and are younger than the mica.

Mode (est.):- Quartz 40%; Muscovite 30%; Biotite 25%; Chlorite + accessories 5%.

Petrogenesis:- The rock is a metamorphosed siltstone which reached the biotite grade. The chlorite represents a late growth, presumably associated with retrograde metamorphism.

sp. 69200075B (C11-22-13B)

Definition:- Chlorite-biotite-sericite-quartz spotted meta-siltstone ($B1S_2$).

Hand-specimen:- A mottled banded meta-siltstone, showing elongated green micaceous lenses densely set in an aphanitic white siliceous groundmass. The ratio of mica lenses to the siliceous material varies with the banding.

Microsection:- The green micaceous lenses and patches consist of f.g. quartz and non-aligned f.g. biotite (z - orange brown). The interstitial siliceous matrix consists of crypt. to mic. quartz and sericite. F.g. to m.g. microporphyroblasts and lamellar bundles of ferroan chlorite are common, and are younger than the mica. Opaques and tourmaline form accessories.

Mode (est.):- Quartz 50%; Sericite 25%; Biotite 20%; Chlorite and accessories 5%.

Petrogenesis:- The rock is a metamorphically segregated low-grade meta-siltstone showing the effects of retrograde metamorphism.

sp. 69200078 (C12-60-25)

Definition:- Banded calc-silicate-meta-siltstone (BlC).

Hand-specimen:- Banded rock, including dark aphanitic bands, m.g.-c.g. porphyroblastic bands, and light-coloured bands.

Microsection:- The dark bands consist of aggregates of f.g. granular heavily-clouded carbonate and clear carbonate, with which lamellar altered biotite (z-yellow-orange) and chlorite are associated. Granular quartz is common. The porphyroblastic bands include m.g. prismatic pseudomorphs of calcite, sericite, and quartz, after original ?plagioclase. The pseudomorphs are set in an assemblage of f.g.-m.g. carbonate and quartz mosaics. Porphyroblasts of biotite with abundant quartz inclusions are common. The light coloured bands consist of mic. quartz and foliated mic. sericite and f.g. biotite.

Mode:- Because the mode varies abruptly between the various bands, no reliable overall estimate is warranted.

Petrogenesis:- The specimen is a metamorphosed laminated marl-siltstone-shale rock. The grade was presumably not higher than middle greenschist. The primary nature of the phenocrysts is not clear.

sp. 69200097 (C13-34-7)

Definition:- Carbonate-quartz-microcline-albite meta-siltstone(BlC).

Hand-specimen:- Finely laminated and cross-bedded grey to light-pink fine-grained calc silicate.

Microsection:- The rock consists of a uniformly textured aggregate of mic. to f.g. feldspar (albite and microcline), quartz and carbonate, accompanied by finely disseminated opaques, and minor chlorite sphene and tourmaline. The feldspar grains show irregular outlines. Veins of m.g. quartz, microcline and carbonate (with quartz inclusions), are present.

Mode (est.):- Quartz and feldspar 70%; Carbonate 25%; Accessories 5%.

Petrogenesis:- The rock is a metamorphosed lime-rich feldspathic siltstone.

(2) PHYLLITES

sp. 69200025 (C15-52-1)

Definition:- Rutile-bearing albite-quartz-muscovite crenulated phyllite ($B1S_3$).

Hand-specimen:- Fractured cleaved crenulated white phyllite, with red hematite spotting. The fracture-cleavage truncates the flow-cleavage at high angles.

Microsection:- The rock consists of mic. to f.g. muscovite scales aligned with an undulating foliation, and mic. to f.g. quartz and albite grains and aggregates, usually elongated with the foliation. Bands rich in quartz or mica may occur. The muscovite may be re-crystallized to sericite along fracture cleavage planes. Disseminated opaques, rutile and tourmaline occur as minor constituents, with the rutile usually forming granular aggregates.

Mode (est.):- Quartz and albite 45%; Muscovite 45%; Opaques (mainly hematite) 5%; Rutile 5%.

Petrogenesis:- The rock is a low-grade metamorphosed shale, yielding evidence of two stress phases. An original high titania content is represented by the abundance of rutile.

sp. 69200033 (C15-52-34)

Definition:- Biotite-quartz-muscovite spotted phyllite ($B1S_3$).

Hand-specimen:- Light grey phyllite finely spotted with biotite.

Microsection:- In thin-section a well-foliated aggregate of crypt.-mic. muscovite and quartz is shown. Mic. to f.g. (up to 1 mm) microporphyroblasts of biotite (Z-red brown) are very common. The biotite flakes are usually elongated parallel to the schistosity of the matrix. (001) planes of the biotite, on the other hand, may be oriented at high angles to the schistosity. The foliated muscovite is deflected around the biotite. Opaques (elongated parallel to the foliation) and apatite grains form accessories.

Mode (est.):- Biotite 15%; Muscovite 45%; Quartz 38%; Opaques, apatite 2%.

Petrogenesis:- The rock is a metamorphosed shale corresponding to the middle greenschist facies. The development of biotite post-dated the growth of muscovite, and its common orientation at high angles to the flow-cleavage reflects changes in the stress field.

sp. 69200037 (C15-52-43)

Definition:- Biotite-muscovite-microcline-albite-quartz phyllite ($B1S_3$).

Hand-specimen:- Grey laminated phyllite, showing alternating fine biotite-rich and quartzose bands.

Microsection:- The rock consists of a mosaic of mic. quartz, microcline and albite, and of well-aligned mic.-f.g. scales of muscovite and biotite. Microporphyroblasts of muscovite may be oriented either parallel or at high angles to the cleavage. Tourmaline (Z-green) and finely disseminated opaques form minor constituents.

Mode:- Biotite 25%; Muscovite 15%; Quartz and feldspar 57%; Accessories 3%.

Petrogenesis:- The rock is a metamorphosed siltstone which reached the biotite grade. Two generations of muscovite are present; the first parallel and the second discordant with relation to the flow-cleavage.

sp. 69200051 (C14-74-14)

Definition:- Garnet-bearing andalusite-biotite-quartz-muscovite porphyroblastic phyllite ($B1S_2$).

Hand-specimen:- Grey phyllite, with spotting by f.g. biotite, and coarse-grained lenticular porphyroblasts of andalusite.

Microsection:- The rock consists of a foliated microcrystalline aggregate of quartz and muscovite, spotted by f.g. microporphyroblasts of biotite (Z-dark brown) which may be oriented at high angles to the foliation. A biotite with Z-greenish yellow is also present. The matrix is clouded by finely disseminated crypt. opaques. Zircon and tourmaline are minor accessories. The andalusite porphyroblasts are very finely sieve structured, and include inclusion of mic. quartz and mic.-f.g., biotite, muscovite, garnet, and opaques. Much of the biotite is altered and displays exsolution of iron ores.

Mode (est.):- Quartz 25%; Muscovite 40%; Biotite 20%; Andalusite 10%; Accessories 5%.

Petrogenesis:- The rock is a metamorphosed pelitic sediment which reached the garnet grade. Sequence of crystallization: muscovite, biotite, garnet, andalusite. Late alteration is apparent from the exsolution of opaques from the biotite.

sp. 69200059 (C13-36-1)

Definition:- Weathered garnet-biotite-sericite-quartz meta-siltstone phyllite ($B1S_1$).

Hand-specimen:- Grey to light brown cleaved and lineated siltstone, with garnet porphyroblasts up to 1 mm in size.

Microsection:- The matrix consists of crenulated flow-cleaved mic. quartz and sericite aggregates. Fine-grained microporphyroblasts of weathered biotite are widespread, and are usually oriented with their (001) planes at high angle to the flow-cleavage. The garnets are heavily replaced by hematite, mainly at the rims and along fractures.

Mode (est.):- Quartz 35%; Sericite 35%; Biotite 26%; Garnet, opaques 4%.

Petrogenesis:- The rock is a meta-siltstone which underwent two stress phases, and reached the garnet grade. Weathering is represented by the exsolution of iron from the biotite and the garnet.

sp. 69200061 (C13-36-9)

Definition:- Carbonaceous garnet-quartz-muscovite-crenulated phyllite ($B1S_1$).

Hand-specimen:- Black strongly crenulated phyllite, with garnets up to 2 mm across.

Microsection:- The matrix consists of well-aligned elongated mic. quartz and sericite, and is heavily clouded by finely disseminated crypt. opaques. The flow-cleavage is strongly microfolded and shear-folded. Rods of f.g. opaques occur parallel to the foliation. F.g.-m.g. anhedral to subhedral porphyroblasts of garnet are sparsely distributed, and are associated with deflection and deformation of the matrix around them. The garnet is partly replaced by hematite. Biotite is an accessory component.

Mode (est.):- Quartz 35%; Muscovite 45%; Opaques 17%; Garnet and biotite 3%.

Petrogenesis:- The rock is a metamorphosed carbonaceous pelitic sediment which reached the garnet zone, and displays the effects of two stress phases represented by a flow-cleavage set and a fracture cleavage set.

sp. 69200074 (C11-24-18)

Definition:- Biotite-muscovite-quartz crenulated phyllite ($B1S_3$).

Hand-specimen:- Well cleaved finely lineated light grey phyllite, with fine grey spots.

Microsection:- Microscopically, a foliated and crenulated aggregate of mic. muscovite and quartz is resolved. The quartz may occur as mosaics in elongated pockets lying with their long axes parallel to the foliation. The dark spotting is produced by clusters of weathered biotite and opaques. Mic. tourmaline (Z-honey green) is an accessory mineral.

Mode (est.):- Muscovite 45%; Quartz 50%; Opaques, biotite and accessories 5%.

Petrogenesis:- The rock is a metamorphosed shale, displaying the effects of two stress phases, represented by a flow-cleavage set and a fracture cleavage set.

sp. 69200084A (C12A-36-25a)

Definition:- Garnet-biotite-muscovite-quartz laminated spotted phyllite (BlS_2).

Hand-specimen:- F.g. laminated phyllite, with light-green bands (a few mm across) and white bands (about one mm across). The rock is densely spotted by f.g. biotite and garnet.

Microsection:- The light green bands consist of well-foliated and crenulated mic. muscovite, and of granular quartz, and are spotted by microporphyroblasts of biotite (Z -yellow brown). The biotite displays pleochroic haloes, and carries inclusions of quartz and opaques. Subhedral f.g.-m.g. porphyroblasts of garnet are developed at the expense of the mica. Inclusions of quartz abound at the central parts of the garnets. The white bands are rich in quartz, and have sharp boundaries with the micaceous bands. Apatite is an accessory constituent. The foliation lies at low angle to the bedding.

Mode (est.):- Quartz 40%; Muscovite 40%; Biotite 15%; Garnet 3%; Accessories 2%.

Petrogenesis:- The rock was collected from a gold mine. It represents a metamorphosed interbanded shale-siltstone. Metamorphism reached the garnet zone. The sequence of crystallization was: Sericite, biotite, garnet.

sp. 69200084B (C12A-36-25B)

Definition:- Chlorite-garnet-biotite-quartz-muscovite banded meta-siltstone-phyllite (BlS_2).

Hand-specimen:- Interbanded meta-siltstone and garnetiferous light-coloured phyllite. The flow-cleavage is oriented at a high angle to the bedding.

Microsection:- The meta-siltstone horizons display mosaics of quartz intergrown with well aligned mic. muscovite and f.g. biotite, accompanied by finely disseminated opaques. Sedimentary banding is represented by thin micaceous laminae oriented at angle to the flow-cleavage. The phyllitic bands consist mainly of foliated and crenulated mic. muscovite, abundantly replaced by f.g.-m.g. subhedral to euhedral porphyroblasts of garnet. Biotite, tourmaline and opaques are accessories. Chlorite is a minor constituent, and may occur as porphyroblasts which may carry inclusions of garnet.

Mode (est.):- Meta-siltstone bands: Quartz 75%; Muscovite 20%; Biotite 5%. Phyllite bands: Muscovite 85%; Biotite 5%; Garnet 8%; Accessories 2%.

Petrogenesis:- The specimen is a metamorphosed banded siltstone-shale rock which reached the garnet grade. Weak retrogressive metamorphism is represented by the chlorite, which appears to be younger than the garnet.

(3) PELITIC SCHISTS

sp. 69200035B (C15-52-37B)

Definition:- Garnet-staurolite-muscovite-biotite-quartz schist (BlS_2).

Hand-specimen:- White to light grey, strongly laminated, fine-grained schist, with abundant f.g.-m.g. microporphyroblasts of biotite, and a few microporphyroblasts of garnet.

Microsection:- The rock is composed of mosaics of granular mic. quartz, well-aligned mic. scales of muscovite, and mic. to f.g. microporphyroblasts of biotite (with pleochroic haloes) which are commonly aligned parallel to the flow-cleavage, but in many instances may be of discordant orientation. The biotite includes abundant inclusions of quartz. Staurolite and garnet occur as rare m.g. euhedral poikiloblasts. The staurolite is of pleochroic yellow colour, and contains numerous irregular inclusions of quartz. The flow-cleavage of the matrix is deflected around the poikiloblasts. Tourmaline, apatite and opaques also form minor constituents.

Mode (est.):- Quartz 55%; Muscovite 20%; Biotite 22%; Accessories 3%.

Petrogenesis:- The rock represents a metamorphosed siltstone which reached the staurolite grade. The sequence of crystallization suggested by the textural relationships is: Muscovite, biotite, garnet and staurolite.

sp. 69200036B (C15-52-39B)

Definition:- Garnet-staurolite-muscovite-biotite-quartz porphyroblastic schist (BlS_1).

Hand-specimen:- Banded white and grey f.g. schist riddled with m.g. porphyroblasts of garnet and staurolite, and showing fine metamorphic segregation banding and microfolding.

Microsection:- The microsection displays euhedral to subhedral porphyroblasts of garnet, and euhedral poikiloblasts of staurolite (riddled with inclusions of quartz) set in a schistose matrix composed of mic. quartz and aligned biotite and muscovite. The staurolite is pleochroic (Z-yellow), and the garnet is partly altered by hematite. Metamorphic segregation is represented by the development of mica-rich bands. Weakly oriented matrix aggregates may be developed at "pressure shadows" adjacent to the porphyroblasts. The porphyroblasts may be developed in both quartzose and biotite-rich bands, but the larger crystals appear to be preferentially associated with the latter. The accessory opaques are mainly associated with biotite-rich bands.

Mode (est.):- Biotite 25%; Quartz & Plagioclase 40%; Muscovite 15%; Garnet and Staurolite 14%; Opaques 6%.

Petrogenesis:- The rock is a metamorphically segregated schist, which reached the staurolite grade. The sequence of crystallisation is: Muscovite, biotite, garnet and staurolite.

sp. 69200036C (C15-52-39C)

Definition:- Garnet-biotite-quartz-staurolite sieve-structured schist (BlS_1).

Hand-specimen:- Medium-grained dark-grey biotite schist with abundant m.g.-c.g. (up to 10 mm) prismatic and cross-twinned porphyroblasts of staurolite, and m.g. (up to 2 mm) porphyroblasts of garnet.

Microsection:- The staurolite (Z-yellow) is highly poikiloblastic, with irregular inclusions of mic. quartz which occupy up to 50% of the crystals. The garnet is subhedral to euhedral, contains numerous inclusions of quartz, and is commonly entirely surrounded by the staurolite. Garnet crystals enclosed by staurolite are typically surrounded by thin envelopes of biotite (Z-orange brown) with the (001) planes of the biotite parallel to the boundaries of the garnet. The biotite may occupy fractures in the garnet. The porphyroblasts are set in a matrix of mic.-f.g. quartz mosaic and of moderately well-aligned biotite. Garnet crystals included in the matrix are commonly free of envelopes of biotite. The biotite shows pleochroic haloes. Opaques form minor constituents of the rock.

Mode (est.):- Staurolite (including quartz inclusions) 35%; Garnet 15%; Biotite 20%; Quartz 28%; Opaques 2%.

Petrogenesis:- The rock is a metamorphosed pelitic sediment which reached the staurolite grade. The sequence of crystallization: Biotite, garnet, staurolite. Garnet is developed at the expense of biotite. The growth of garnet resulted in the concentration of biotite pushed parallel to the boundaries of the growing porphyroblasts. A younger growth of biotite occurs in fractures in the garnet.

sp. 69200040A (C15-52-54A)

Definition:- Andalusite-bearing garnet-muscovite-staurolite-quartz-biotite porphyroblastic schist (BlS_1).

Hand-specimen:- C. to v.c.g. porphyroblastic schist, with prismatic and twinned staurolite (up to 15 mm) and garnet (up to 3 mm) set in a schistose biotite-rich matrix.

Microsection:- Sieve-structured twinned porphyroblasts of staurolite (Z-yellow) and subhedral to euhedral garnet are set in a strongly schistose base of f.g.-m.g. biotite. The staurolite is riddled by irregular and amoeboid inclusions of mic-f.g. quartz, except for the crystal margins, which are almost free of inclusions. The garnet crystals carry only little inclusions of quartz. The biotite (Z-orange brown) contain pleochroic haloes. Minor epidote, andalusite, tourmaline, and opaques are associated with the biotite. Mosaics of quartz intergrown with f.g.-m.g. biotite are common. Microfolding and deflection of the foliated biotite aggregates are common, particularly around the porphyroblasts.

Mode (est.):- Biotite 35%; Staurolite (including quartz) 20%; Muscovite 10%; Garnet 10%; Quartz 23%; Accessories 2%.

Petrogenesis:- The rock is a metamorphosed iron-rich shale, which reached the staurolite grade. Sequence of crystallization: Biotite, andalusite, garnet, staurolite.

sp. 69200040B (C15-52-54B)

Definition:- Garnet-staurolite-muscovite-biotite$\frac{3}{4}$quartz schist (BlS_1).

Hand-specimen:- Laminated and cross-laminated schist, with v.c.g. porphyroblasts of staurolite, and medium-grained porphyroblasts of red garnet.

Microsection:- The microsection displays a well developed banding, with the various bands characterized by variations in mineralogy, mode, grain-size, and texture. Mic.-f.g. biotite, mic.-f.g. muscovite, and granular mic. quartz are the chief components. Micaceous bands consisting of over 90% mica alternate with quartzose bands. The muscovite appears to be texturally younger than the biotite and in some bands is m.g. Sieve-structured subhedral c.g. staurolite (with inclusions of quartz) and euhedral to subhedral m.g. garnet (partly altered by hematite) are characteristic of certain biotite-rich bands. The staurolite occurs both as poikiloblasts and as crystals relatively free of inclusions. Sphene, tourmaline, and opaques are accessory components.

Mode (est.):- Biotite 35%; Muscovite 20%; Quartz 40%; Staurolite, garnet, and accessories 5%.

Petrogenesis:- The rock is a metamorphically segregated meta-sediment. Metamorphism reached the staurolite grade. Sequence of crystallization: Biotite, muscovite, garnet, staurolite.

sp. 69200041 (C15-52-55)

Definition:- Staurolite-andalusite-muscovite lens in quartz-biotite schist (BlS_1).

Hand-specimen:- F.g. garnet-bearing grey schist, including leucocratic lenses up to 5" across.

Microsection:- The schist consists of mic. grains of quartz, well-aligned mic.-f.g. biotite, and mic. flakes of muscovite. The grain size, texture and proportion of these components vary with the various bands. Biotite may also form f.g.-m.g. microporphyroblasts, which may be oriented at high angles to the flow-cleavage, and are partly replaced by slender mic. scales of muscovite which parallel the flow-cleavage. Ferruginous chlorite, which may be replaced by biotite, and opaques, are minor constituents.

The leucocratic lense shown in the thin-section displays a marginal zone consisting of an aggregate of bladed f.g.-m.g. little-aligned muscovite flakes. The central part of the lense is occupied by aggregates of lamellar crypt.-mic. sericite, partly replaced by m.g.-c.g. subhedral porphyroblasts of andalusite, and to a lesser extent m.g. porphyroblasts of staurolite and biotite. The andalusite is partly replaced by sericite. Hematite staining along crystal boundaries and cracks is very common.

Mode (est.) of leucocratic lense:- Muscovite 65%; Andalusite 30%; Staurolite, Biotite 5%.

Petrogenesis:- The lenses represent metamorphic segregation and possibly potash metasomatism of staurolite-grade schists. The sequence of crystallization appears to have been: Muscovite, biotite, andalusite, staurolite, sericite. The sericite may represent late hydrothermal alteration.

sp. 69200044B (C15-52-61B)

Definition:- Biotite-chlorite-quartz-garnet-tremolite schist (BlS_1).

Hand-specimen:- M.-c.g. garnet-amphibole schist, with euhedral porphyroblasts of pink garnet set in bundles of fibrous dark green amphibole.

Microsection:- The rock consists of sheaf-like aggregates of m.g.-c.g. tremolite, accompanied by lamellar aggregates of aluminous chlorite, biotite (Z-orange brown), and quartz, and abundantly replaced by m.g.-c.g. (up to 4 mm) euhedral porphyroblasts of garnet, pocked by inclusions of mic. quartz, Needles of tremolite commonly occur as inclusions in f.g.-m.g. quartz grains. The amphibole may replace both the biotite and the chlorite. The chlorite is younger than the biotite. Opaques are common accessories. The rock includes a band of garnet-andalusite-biotite-quartz schist.

Mode (est.):- Tremolite 50%; Garnet 25%; Chlorite 10%; Quartz 10%; Biotite 4%; Accessories 1%.

Petrogenesis:- The sequence of crystallization is: Biotite, chlorite, tremolite, garnet. The magnesian composition suggests either a derivation from an ultrabasic rock, or strong magnesia metasomatism of biotite schist.

sp. 69200044C (C15-52-61C)

Definition:- Quartz-staurolite-garnet-biotite porphyroblastic schist (BlS_1).

Hand-specimen:- C.g. porphyroblastic schist, with m.-c.g. euhedral garnet (up to 6 mm) and staurolite set in f.g.-m.g. foliated biotite-rich matrix.

Microsection:- The garnet is subhedral to euhedral, heavily fractured, and includes little inclusions of quartz. The staurolite occurs as short sieve-structured prisms, pocked by uneven-grained quartz inclusions which may constitute up to 50% of the crystals. The porphyroblasts are set in biotitic and biotite-quartz matrices. The biotite flakes (Z-red brown) are f.g. to m.g., well defined, moderately well aligned, and with abundant pleochroic haloes. Muscovite and chlorite occur as minor constituents, and are older and younger than the biotite, respectively. Mosaics of quartz and accessory albite are common. Apatite and opaques form minor accessories.

Mode (est.):- Biotite 40%; Garnet 35%; Staurolite 15%; Quartz and Albite 8%; Accessories 2%.

Petrogenesis:- The sequence of crystallization is: Muscovite, biotite, chlorite, garnet and staurolite. The rock represents a metamorphically segregated pelitic meta-sediment enriched in iron, magnesia and potash, and metamorphosed up to the staurolite grade.

sp. 69200044D (C15-52-61D)

Definition:- Garnet-staurolite-muscovite-biotite-oligoclase-quartz schist ($B1S_1$).

Hand-specimen:- Light grey to off-white banded f.g. schist, showing pelitic and arenaceous laminae, and including few m.g.-c.g. porphyroblasts of garnet and staurolite.

Microsection:- The rock consists of mic.-f.g. granoblastic mosaic of quartz, and weakly to very well aligned mic.-f.g. biotite and muscovite. Metamorphic segregation banding is represented by the occurrence of micaceous streaks parallel to the foliation, with the mica forming comb-like textures. The arenaceous bands consist of mic.-f.g. granular quartz, plagioclase (oligoclase) and biotite. The muscovite is texturally younger than the biotite. Both biotite and muscovite are very commonly oriented at high angles to the flow cleavage. The accessories consist mainly of finely disseminated opaques. The staurolite (Z-yellow) and garnet are pocked by inclusions of mic. quartz and quartz mosaics.

Mode (est.):- Quartz and plagioclase 60%; Biotite 20%; Muscovite 18%; Accessories (staurolite, garnet opaques) 2%.

Petrogenesis:- The rock is a meta-sediment showing alternating pelitic and silty bands. Metamorphism reached the staurolite grade, and was accompanied by slight compositional differentiation, and by the growth of porphyroblasts. Two stress phases are present.

sp. 69200048 (C15-50-4)

Definition:- Garnet-andalusite-muscovite-biotite-quartz porphyroblastic schist ($B1S_1$).

Hand-specimen:- Mica-quartz grey schist with coarse-grained porphyroblasts of andalusite (up to 15 mm), and m.g. porphyroblasts of pink garnet.

Microsection:- The schist consists of moderately well aligned f.g. biotite (Z-red brown) and muscovite, intergrown with quartz mosaics. The muscovite is clearly younger than the biotite. Andalusite occurs as coarse-grained columnar discontinuous poikiloblasts, enclosing quartz and biotite inclusions. Garnet occurs as m.g. euhedral crystals, usually developed at the expense of mica, and may be engulfed by the andalusite. Epidote is a minor component, and may be surrounded by pleochroic haloes when occurring within biotite. Patches of clay minerals indicate localised alteration of the rock.

Mode (est.):- Quartz 40%; Biotite 25%; Muscovite 20%; Andalusite 10%; Garnet and Accessories 5%.

Petrogenesis:- The rock is a metamorphosed pelitic sediment, with the sequence of crystallisation as follows: Biotite, muscovite, garnet, andalusite.

sp. 69200049 (C15-50-13)

Definition:- Garnet-biotite-muscovite-quartz-andalusite porphyroblastic schist (BlS_1).

Hand-specimen:- Very coarse-grained cubic to short prismatic porphyroblasts of andalusite are set in medium-grained two-mica schist with m.g. garnets. The schistosity is deflected around the porphyroblasts.

Microsection:- The andalusite is finely sieve-structured, and is pocked by mic. rounded to amoeboid-shaped quartz. Inclusions of f.g. to m.g. biotite and muscovite which are usually rounded and embayed are very common. Non-poikiloblastic andalusite is also present. The garnet is confined to the schist matrix, where it occurs as euhedral m.g. porphyroblasts. The matrix is composed of intergrown mic.-f.g. quartz and well aligned biotite and muscovite, the latter being the younger phase. The muscovite is also better aligned than the biotite. Small-scale folding and kink folding of the flow-cleavage is widespread. Opaques are common accessories.

Mode (est.):- Andalusite 30%; Biotite 15%; Muscovite 25%; Quartz 25%; Garnet and Accessories 5%.

Petrogenesis:- The rock is a metamorphosed pelitic sediment which reached the garnet zone of the low-pressure facies series. The sequence of crystallisation is: Biotite, muscovite, garnet, andalusite. The growth of porphyroblasts was associated with microfolding.

sp. 69200099 (C14-76-42)

Definition:- Garnet-chlorite-biotite-muscovite-quartz schist (BlS_1).

Hand-specimen:- Light brown fine-grained muscovite schist, with medium-grained to coarse-grained (up to 6 mm) phenocrysts of chlorite, oriented at a high angle to the foliation. Both flow-cleavage and fracture-cleavage are developed.

Microsection:- The schist consists of an evenly-textured foliated and crenulated aggregate of clear mic. quartz and well-aligned mic.muscovite and biotite, accompanied with finely disseminated mic. opaques. The muscovite appears to be texturally younger than the biotite. Ferroan chlorite (Z-light green) occurs as subhedral poikiloblasts with mic. inclusions of quartz, and is usually oriented with the (001) planes at high angle to the foliation. Inclusions of biotite and opaques occur in the chlorite, which may be also intergrown with the chlorite in composite flakes. Rutile is an accessory. Garnet is a minor constituent, and is usually enveloped by biotite.

Mode (est.):- Quartz 50%; Muscovite 30%; Biotite 15%; Chlorite 3%; Opaques, garnet 2%.

Petrogenesis:- The rock is a metamorphosed pelitic sediment which reached the garnet grade. Retrospective metamorphism is represented by the chlorite, and was presumably associated with the development of the fracture cleavage.

sp. 692000103 (C14-76-49)

Definition:- Garnet-andalusite-sericite-clinozoisite-biotite-plagioclase-quartz schist ($B1S_1$).

Hand-specimen:- Medium-grained feldspathic biotite schist, showing fine-scale folding.

Microsection:- The rock consists of quartzo-feldspathic bands and of biotite-rich clinozoisite-bearing bands. Quartz-albite aggregates occur as bands or lenses, and consist of irregularly-shaped f.g. quartz and untwinned albite. Augen of m.g. oligoclase are present. The micaceous bands comprise well-aligned f.g.-m.g. biotite, f.g. quartz and albite, and crypt.-mic. (?) clinozoisite. Sericite is a common constituent. M.g. garnet, apatite, tourmaline, andalusite muscovite, epidote, chlorite and opaques occur as minor constituents. Microfolding of the foliation is common.

Mode (est.):- Quartz 40%; Feldspar 25%; Biotite 15%; Sericite 5% Clinozoisite 10%; Accessories 5%.

Petrogenesis:- The rock is a metamorphosed pelitic sediment, which reached the garnet grade. The feldspar has been clouded by (?) clinozoisite. The sequence of crystallisation is: Sericite, biotite, andalusite, garnet. The chlorite is the youngest phase, and represents retrogressive metamorphism.

sp. 692000106 (C15-50-28)

Definition:- Garnet-magnetite-albite-quartz-biotite schist ($B1S_1$).

Hand-specimen:- Medium-grained biotite, with c.-v.c.g. euhedral porphyroblasts of garnet.

Microsection:- The biotite consists of moderately-well aligned m.g. biotite flakes (Z-yellow brown), set in a mic. groundmass of quartz and feldspar, with scattered f.g. angular quartz grains.

Rod-like f.g. opaques and mic. opaque grains are characteristic of the rock, and are finely disseminated in the biotite and the groundmass alike. The garnet contains inclusions of quartz and opaques.

Mode (est.):- Biotite 45%; Quartz and Feldspar 40%; Opaques 13%; Garnet 2%.

Petrogenesis:- The specimen is probably a metamorphosed basic rock, possibly a basic meta-igneous rock which underwent potash and iron metasomatism. Metamorphism is represented by the alignment of biotite and the growth of garnet.

(4) ARENACEOUS SCHISTS AND SEMI-SCHISTS

sp. 69200050 (C15-50-12)

Definition:- Garnet-bearing biotite-muscovite-quartz meta-sandstone schist (BlS_1).

Hand-specimen:- Light grey fine-grained arenaceous schist with m.g. (up to 1 mm) garnets.

Microsection:- Microscopically, a uniform mic.-f.g. aggregate of quartz, muscovite, and biotite is resolved. The quartz grains form an interlocked mosaic with uneven grainsize. The biotite (z-brown) and muscovite are moderately-well aligned, with the latter constituting the younger phase. Discordant mica flakes, however, are not uncommon. The garnet forms f.g.-m.g. anhedral crystals. Apatite, tourmaline (Z-blue green), and opaques are the chief accessories. Rutile is also present, and is surrounded by pleochroic haloes when occurring within biotite.

Mode (est.):- Quartz 45%; Muscovite 33%; Biotite 20%; Garnet + Accessories 2%.

Petrogenesis:- The rock is a metamorphosed sandstone which reached the garnet zone. The sequence of crystallization is as follows: Biotite, muscovite, garnet.

sp. 69200042 (C15-52-56)

Definition:- Garnet-bearing biotite-albite-quartz mud-flake bearing meta-sandstone (BlS_1).

Hand-specimen:- Dark-grey meta-sandstone, wiih thin discontinuous layers and lenses of light grey meta-siltstone up to 3 inches in length.

Microsection:- Medium-grained irregular and embayed quartz grains are set in a matrix of mic.-f.g. quartz, anhedral f.g. plagioclase (albite, An3), biotite (Z-orange brown), and accessory garnet, muscovite, chlorite, apatite, zircon, and finely disseminated opaques. The garnet occurs as f.g. subhedral to euhedral crystals. The biotite scales are weakly aligned, defining a crude foliation. The plagioclase grains are usually twinned according to the albite law, and are cloused by sericite to a minor extent. The general texture corresponds to that of reconstituted sandstone. The light-coloured lenses consist of aggregates of mic. quartz and plagioclase.

Mode (est.):- Quartz 45%; Plagioclase 33%; Biotite 20%; Accessories 2%.

Petrogenesis:- The rock represents a metamorphosed mud-flake bearing sandstone, with pockets of siltstone embedded in a quartz-feldspathic sandstone. Metamorphism reached the garnet zone, and was accompanied by little shearing.

sp. 69200044A (C15-52-61A)

Definition:- Garnet-chlorite-biotite-tremolite-microcline-albite-quartz porphyroblastic meta-sandstone (BlS_1).

Hand-specimen:- Light grey fine-grained feldspathic quartzite, with abundant m.g. to c.g. (up to 4 mm) pink euhedral porphyroblasts of garnet, and radiating aggregates of c.g. acicular amphibole.

Microsection:- The rock consists of a granular aggregate of irregularly-shaped unevenly grained mic.-f.g. quartz, albite, and microcline. F.g.-c.g. discontinuous columnar and needle-like colourless tremolite, m.g. flakes of aluminous chlorite (Z-light green), and euhedral porphyroblasts of garnet are common. Mic.-f.g. flakes of biotite and opaques are common accessories. Rutile and apatite are minor constituents. The tremolite may be replaced by chlorite.

Mode (est.):- Quartz, Albite, Plagioclase 75%; Tremolite 15%; Biotite, Chlorite 7%; Garnet and other accessories 3%.

Petrogenesis:- The rock is a potash-poor metamorphosed quartzo-feldspathic sandstone, which possibly underwent magnesia metasomatism resulting in the growth of tremolite. Sequence of crystallization: Biotite, tremolite, chlorite, garnet. The development of tremolite indicates a high lime to potash ratio.

sp. 69200053 (C14-74-27)

Definition:- Garnet-biotite-muscovite-quartz meta-greywacke semi-schist (BlS_1).

Hand-specimen:- Fine-grained grey arenaceous schist.

Microsection:- In thin-section the rock consists of a granular aggregate of irregularly shaped f.g. quartz grains, and foliated mic. muscovite. Mic.-f.g. flakes of biotite (Z-deep brown) and f.g.-m.g. poikiloblasts of garnet with quartz inclusions are very common. Chlorite (ferroan) and tourmaline (Z-dark green) form accessories.

Mode (est.):- Quartz 40%; Muscovite 30%; Biotite 8%; Garnet 5%; Accessories 2%.

Petrogenesis:- The rock is a metamorphosed greywacke which reached the garnet grade.

sp. 69200058A (C14-74-48)

Definition:- Tourmaline-bearing albite-muscovite-biotite-quartz meta-greywacke semischist ($B1S_1$).

Hand specimen:- Grey fine-grained arenaceous schist, with light coloured lenses up to 7 mm across.

Microsection:- The microsection displays an uneven-grained aggregate of subangular mic.-m.g. quartz and plagioclase (albite) set in a predominantly micaceous matrix of weakly aoigned mic. muscovite and f.g. biotite. The biotite is less well aligned than the muscovite. Green tourmaline, with pleochroic rims surrounding pale coloured cores are commonly developed at the expense of biotite. Apatite, zircon and opaques are the other common minor components present. The general texture is similar to that of grey-wackes, with m.g. grains of quartz and feldspar set in mic.-f.g. matrix. The white lenses are caused by quartzo-feldspathic aggregates accompanied by little biotite.

Mode (est.):- Quartz and Albite 65%; Muscovite 15%; Biotite 18%; Accessories 2%.

Petrogenesis:- The rock is a metamorphosed greywacke, which reached the biotite grade. The quartz and plagioclase grains appear to present original detrital grains.

sp. 69200060 (C13-36-5)

Definition:- Albite-biotite-muscovite-quartz meta-greywacke semischist ($B1S_1$).

Hand specimen:- The rock is a brown micaceous and feldspathic meta-sandstone, showing a weak schistosity.

Microsection:- The rock consists of mic.-m.g. irregularly shaped and angular grains of quartz, polycrystalline quartz grains, and clouded plagioclase, set in a mic. matrix of foliated sericite, weathered biotite (Z-orange) and mic. granular quartz. Pseudomorphous aggregates of f.g. biotite and fresh flakes of f.g. muscovite are common. Some of the biotite is altered to ferrean chlorite. Apatite is a minor accessory. Altogether, the matrix constitutes a third of the volume of the rock.

Mode (est.):- Quartz 45%; Albite 15%; Muscovite 25%; Biotite 18% Accessories 2%.

Petrogenesis:- The texture of the rock suggests it was derived through the metamorphism of greywacke, which comprised quartz, feldspar and lithic (polycrystalline) grains embedded in a pelitic matrix. The rock is slightly weathered.

sp. 69200095 (C12A-34-1)

Definition:- Tourmaline-bearing feldspathic quartzite (Blr).

Hand specimen:- Light brown fine-grained quartzite, with lamination and cross-bedding structures.

Microsection:- The rock consists of angular fragments of mic.-f.g. quartz and albite, set in a crypt.-mic. quartzo-feldspathic groundmass, accompanied by minor opaques, tourmaline, and crypt. clouding, and with abundant pockets of crypt. material (probably clay minerals).

Mode (est.):- Quartz 55%; Feldspar 20%; Clay 20%; Opaques and Tourmaline 5%.

Petrogenesis:- The rock is an unmetamorphosed feldspathic quartzite, with the detrital texture preserved. Hydrothermal activity is represented by the tourmaline, which is younger than the other minerals.

sp. 69200100 (C14-76-46)

Definition:- Chlorite-microcline-albite-quartz meta-sandstone(BlS_1).

Hand specimen:- Light coloured fine-grained meta-sandstone, spotted by m.g. chlorite flakes.

Microsection:- The rock consists of an unequigranular, mic.-f.g. aggregate of quartz, albite, and microcline, accompanied by microporphyroblasts of ferroan chlorite (Z-green), intergrown with biotite in composite flakes. Opaques, zircon and apatites form accessories.

Mode (est.):- Quartz 50%; Feldspar 45%; Chlorite 4%; Accessories 1%.

Petrogenesis:- The rock is a metamorphosed feldspathic sandstone. Retrograde metamorphism may be represented by the chlorite.

(5) CHERTS

sp. 69200080 (C12A-38-28)

Definition:- Clinozoisite-quartz banded meta-chert (BlS_3).

Hand specimen:- Dark grey to black aphanitic chert. Fine-scale banding is well developed.

Microsection:- The rock consists mainly of mic. quartz and mic.-f.g. clinozoisite. The quartz forms irregularly-shaped grains showing undulatory extinction. The clinozoisite occurs as granular aggregates and euhedral prisms. A well-pronounced banding is formed by variations in the concentration of clinozoisite, carbonate, chlorite, and crypt. phases from accessories.

Mode (est.):- Quartz 70%; Clinozoisite 28%; Accessories 2%.

Petrogenesis:- The rock is a metamorphosed chert, which included line-rich and alumina-rich bands. The primary mineralogy of these bands, however, is not understood.

sp. 69200082 (C12A-38-31)

Definition:- Amphibole-quartz meta-chert ($B1S_3$).

Hand specimen:- Dark grey uniform chert.

Microsection:- The rock consists of crypt.-mic. quartz, well-aligned mic. needles of amphibole (Z-green), and crypt.-mic. granular leucoxene and saussurite. A nematoblastic texture is well-developed.

Mode (est.):- Quartz 80%; Amphibole 12%; Crypt. constituents 8%.

Petrogenesis:- The rock is a metamorphosed recrystallized chert, which included primary ferromagnesian constituents (e.g., chlorite).

sp. 69200108 (C15-52-73)

Definition:- Tourmaline-veined graphitic chert ($B1S_3$).

Hand specimen:- Black aphanitic cherty rock, heavily veined by white and brown veins.

Microtexture:- The rock consists of crypt.-mic. banded heavily clouded quartz, and is veined by tourmaline (Z-yellow-orange)-quartz-albite-veins. The veins incoude also crypt. brown mica aggregates and f.g. calcite. The albite commonly occurs as euhedral twinned crystals. Veins consisting exclusively of carbonate and of quartz also occur.

Mode (est.):- Quartz 75%; Opaque clouding 15%; Tourmaline 8%; Albite and Calcite 2%.

Petrogenesis:- The rock is a (?) graphitic chert, intruded by tourmaline-quartz-albite-carbonate veinlets.

(6) CALC-SILICATES

sp. 69200064 (C12a-36-8)

Definition:- Sericitic-quartz-calcite banded meta-limestone (B1C).

Hand specimen:- Weakly banded off-white to grey m.g. meta-limestone.

Microsection:- Calcite is the major constituent of the light-coloured bands and occurs as f.g.-m.g. anhedral grains displaying lamellar twinning and comprising mic.-f.g. quartz inclusions. The dark bands consist of clouded mic. aggregates of quartz, sericite, and submicroscopic constituents. The sericite scales are aligned, defining a metamorphic foliation. Biotite (with exsolved opaques) and discrete opaque grains form accessories. Limonitic staining is common.

Mode (est.):- Calcite 50%; Quartz 30%; Sericite 18%; Accessories 2%.

Petrogenesis:- The white bands represent metamorphosed limestone which included quartz grains and no dolomite. The sericitic bands represent shale intercalations. The grade of metamorphism appears to have been lower greenschist, for no alumino-silicates representing the higher grades (e.g. tremolite, diopside) are present.

sp. 69200085 (L5-26-31)

Definition:- Carbonate-biotite-quartz-scapolite calc-silicate (BlC).

Hand specimen:- Banded rock, including carbonate bands, and dark aphanitic bands spotted with m.g. rounded scapolites.

Microsection:- The light-coloured bands consist of mic. to f.g. carbonate, quartz, albite, microcline, anhedral f.g. poikiloblasts of scapolite, and minor apatite and mic. biotite. The scapolite contains abundant inclusions of quartz. The spotted dark bands consist of lenticular aggregates of f.g.-m.g. poikiloblastic scapolite, intervened by interstitial aggregates of mic.-f.g. biotite (Z-khaki brown), and by minor carbonate. Quartz, opaques tourmaline (Z-green), and apatite are common accessories.

Mode (est.):- (Dark bands): Scapolite (inc. quartz inclusions): 65%; Biotite 25%; Carbonate 5%; Accessories 5%.

Petrogenesis:- The rock is a metamorphosed impure ferruginous dolomite, which either contained original chloride, or was later metasomatized by chloride-bearing solutions.

sp. 69200093A (C11-24-37A)

Definition:- Biotite-quartz-scapolite-carbonate porphyroblastic calc-silicate (BlC).

Hand specimen:- Coarse-grained yellow to light green tetragonal prisms are set in a light pink f.g. carbonate matrix. The prisms stand out on weathered surfaces.

Microsection:- The prisms constitute pseudomorphs of scapolite, completely replaced by crypt. to mic. sericite, quartz, and albite. The sericite is aligned parallel to pre-existing cleavage directions of the scapolite. The groundmass in which the pseudomorphed scapolite is set consists of anhedral f.g.-m.g. carbonate showing lamellar twinning, irregularly-shaped quartz which often form inclusions in carbonate, and minor f.g. biotite and opaques.

Mode (est.):- Pseudomorphed scapolite 25%; Carbonate 40%; Quartz, albite sericite 30%; Biotite and accessories 5%.

Petrogenesis:- The rock is a metamorphosed impure siliceous limestone, which included primary or added secondary chlorides, which accounted for the growth of the scapolite. Late alteration is represented by the disintegration of the scapolite.

sp. 69200093B (C11-24-37B)

Definition:- Albite-microcline-biotite-quartz-sericite-carbonate calc-silicate (altered scapolite-bearing calc-silicate) (B1C).

Hand specimen:- Fine-grained calc-silicate, with grey-pink and greenish patches and bands, and abundant veins of carbonate. White spots are well displayed on weathered surfaces.

Microsection:- The greenish patches consist of foliated mic. sericite and biotite, of mic. granular quartz, of biotite (Z-light brown) and f.g. carbonate. The pink-grey patches are composed of f.g. carbonate, quartz, microcline, albite, and minor biotite, ferroan chlorite, and tourmaline. The chlorite is riddled with crypt. rutile, and represents therefore altered biotite. Opaques occur as aggregates pseudomorphous after (?) magnetite. The sericite-biotite aggregates may be pseudomorphous after euhedral scapolite.

Mode (est.):- Sericite and biotite 35%; Quartz, microcline and albite 30%; Carbonate 30%; Accessories 5%.

Petrogenesis:- The rock is probably a metamorphosed marl. The pre-existing scapolites have been replaced by sericite, quartz, and biotite.

sp. 69200094 (C12-62-26)

Definition:- Biotite-albite-quartz-carbonate calc-silicate (B1C).

Hand specimen:- Light-coloured fine-grained calc-silicate, with grey spots up to 4 mm across.

Microsection:- The light-coloured rock consists of m.g. anhedral carbonate showing well developed lamellar twinning, and of aggregates of mic. quartz and sericitized feldspar, accompanied by minor yellow biotite (? phlogopite). The dark patches are composed of mic. quartz and feldspar, well-aligned yellow biotite, and accessory opaques. The biotite contains crypt. dark clouding, possibly of rutile. Apatite is a minor component.

Mode (est.):- Carbonate 48%; Quartz and feldspar 40%; Biotite 10%; Accessories 2%.

Petrogenesis:- The rock represents a metamorphosed marl.

(7) AMPHIBOLE-BEARING CALC-SILICATES

sp. 69200063B (C13-36-12B)

Definition:- Sphene-rich tremolite-albite-calcite porphyroblastic calc-silicate (B1C).

Hand specimen:- Medium-grained light brown feldspathic and carbonate-rich rock, with porphyroblasts of amphibole up to 4 mm across.

Microsection:- The rock consists mainly of irregularly-shaped m.g. calcite and of mic.-f.g. subhedral lath-like albite, which shows very slight clouding by a brown crypt. substance, and common albite twinning. The porphyroblasts of tremolite ranging from f.g. to c.g. are usually xenoblastic, display narrow rims of blue-green amphibole, and contain mic. inclusions of quartz, opaques, and sphene. These constituents are also very common accessories associated with the calcite and the feldspar. Biotite and apatite are the other accessories. The tremolite is younger than and developed partly at the expense of calcite.

Mode (est.):- Calcite 50%; Albite 30%; Tremolite 15%; Sphene 3%; accessories 2%.

Petrogenesis:- The rock probably originated through the metamorphism of a dolomitic limestone with a pelitic component. Interaction of the dolomite and the clay minerals resulted in the growth of tremolite. The albite is probably derived from the dehydrated clay minerals.

sp. 69200065A (C12A-36-10A)

Definition:- Dolomite-edenite porphyroblastic lineated calc-silicate ($B1S_3$).

Hand specimen:- A well-aligned aggregate of coarse-grained (up to 10 mm) grey amphibole, and radiating bundles of amphibole set in and veined by fine-grained light-coloured carbonate matrix.

Microsection:- The amphibole occurs as colourless f.g.-c.g. columnar subhedral to euhedral prisms, which may display twinning, and is abundantly clouded by dark crypt. opaques, mainly along fractures. The amphiboles are usually well aligned in a nematoblastic texture. Some bands are composed almost exclusively of amphibole. In other bands, the amphiboles are set in matrix of mic.-f.g. granular carbonate accompanied by finely disseminated brown crypt. opaques. The amphibole displays euhedral boundaries, and is clearly younger than the calcite. On the other hand, veinlets of carbonate may cut through the amphibole. Pseudomorphs of talc and calcite after amphibole may be present.

Mode (est.):- Amphibole 60%; Carbonate 35%; Talc and opaques 5%.

Petrogenesis:- The rock is a metamorphosed impure dolomite; the reaction of dolomite with clay minerals presumably gave rise to the amphibole. Late alteration is represented by veins of carbonate and replacement of some amphiboles by talc and carbonate.

sp. 69200065B (C12A-36-10B)

Definition:- Edenite-dolomite porphyroblastic calc-silicate ($B1S_3$).

Hand specimen:- Medium-grained grey well-aligned amphibole set in an aphanitic matrix of carbonate.

Microsection:- f.g. to c.g. idioblasts of colourless amphibole are set in a mosaic of mic.-f.g. granular carbonate showing widespread lamellar twinning. The amphiboles are invariably rimmed by thin veneers of opaques. Chlorite and opaques are the chief accessories.

Mode (est.):- Amphibole 30%; Carbonate 68%; Opaques 2%.

Petrogenesis:- The rock is a metamorphosed dolomite which contained alumino-silicate impurities. The opaque rims around the amphiboles may either represent late exsolution of iron from the amphibole or primary veneers by the growing magnesian amphiboles.

sp. 69200065C (C12A-36-10C)

Similar to sps 69200065 a, b. Showing spotted clouding of the amphibole by brown crypt. constituents.

sp. 69200066 (C12A-36-10d)

Definition:- Carbonaceous amphibole-dolomite calc-silicate ($B1S_3$).

Hand specimen:- The rock occurs as lenticular aggregates of black coarse-grained anhedral carbonate included in amphibole dolomite calc-silicates.

Microsection:- The carbonate crystals are embayed and sutured, and are heavily clouded by crypt. opaques. Pseudomorphs of talc and crypt. opaques after amphibole, often including armoured relics of amphibole, are present. Veins of clear carbonate grains cut through the rock.

Mode (est.):- Carbonate 67%; Amphibole 3%; Opaques 30%.

Petrogenesis:- The rock may represent carbonaceous concentrations in the original dolomite. Alternatively, the clouding may be due to secondary processes.

sp. 69200069 (C11-24-7)

Definition:- Tremolite-muscovite-quartz-carbonate porphyroblastic calc-silicate (B1C).

Hand specimen:- Porphyroblastic bands showing m.g.-c.g. prisms of tremolite embedded in f.g. calcitic matrix, alternate with grey aphanitic siliceous patches.

Microsection:- The tremolite crystals are developed at the expense of granular f.g.-m.g. carbonate, and are in turn veined and partly replaced by mic. carbonate. Lamellar aggregates of mic.-f.g. muscovite and hematite-stained mica are common. Mosaics and isolated grains of mic. quartz are widespread, with the grains commonly displaying sutured boundaries. Much of the calcite is spotted by hematite. Radiating aggregates of crypt.-mic. talc are present.

Mode (est.):- Tremolite 5%; Carbonate 60%; Quartz 20%; Muscovite 10%; Accessories & Opaques 5%.

Petrogenesis:- The rock represents a metamorphosed dolomitic limestone with siliceous impurities. A late alteration of the tremolite by calcite took place.

sp. 69200079B (C12-62-8B)

Definition:- Chalcopyrite-rich apatite-phlogopite-quartz-tremolite-carbonate porphyroblastic para-amphibolite (B1C).

Hand specimen:- M.-c.g. porphyroblastic calc-silicate, with prismatic light green amphiboles (up to 10 mm across) set in a white carbonate matrix, accompanied with abundant m.g.-c.g. chalcopyrite. Veins and lenses (up to several inches long) of carbonate are common.

Microsection:- Tremolite (Z-colorless) forms subhedral to euhedral columnar porphyroblasts, which are partly replaced by mic.-f.g. carbonate, and may be riddled by mic. inclusions of quartz. The groundmass consists of f.g.-m.g. anhedral carbonate, showing abundant lamellar twinning, quartz, phlogopite, and clusters of rounded apatite. The phlogopite (Z-light yellow) may be well aligned, and is usually associated with mosaics of f.g. quartz. Rounded quartz inclusions are common in the calcite. The sulphides appear as the youngest phases present.

Mode (est.):- Tremolite 20%; Carbonate 45%; Quartz 15%; Phlogopite 13%; Apatite 5%; Chalcopyrite 2%.

Petrogenesis:- The rock is a metamorphosed impure dolomite. The sequence of crystallization as suggested by the textural relationships is: Phloropite, apatite, carbonate, tremolite, sulphides. The mineralization may have been associated with the nearby granite occurrence.

(8) PARA-AMPHIBOLITES

sp. 069200062 (C13-36-13A)

Definition:- Sphene-quartz-diopside-tremolite-calcite-sodic plagioclase para-amphibolite (B1C).

Hand specimen:- Red fine½grained to aphanitic rock with light green patches, white calcitic spots, and f.g. opaques.

Microsection:- The most important constituent is sodic plagioclase occurring as partly sericitized poorly-defined irregularly shaped mic.-f.g. anhedra, showing undulatory extinction and merging imperceptibly into one another. The parallel orientation of the sericite scales, which are developed along cleavage traces in the feldspar, show that the original plagioclase was coarse-grained and prismatic. Granular calcite (up to several mm across) with lamellar twinning is a major constituent of the rock mic.-f.g. light green diopside and aggregates of mic.-f.g. sphene (Z-brown orange) and quartz are minor components. Light green f.g. to m.g. poikiloblasts of tremolite (with quartz inclusions) are common, and display margins of pleochroic (z-blue green) of hornblende. M.g. equant subhedra of apatite occur as minor components. Mic.-f.g. opaques are also present.

Mode (est.):- Plagioclase and sericite 55%; Calcite 25%; Diopside and Tremolite 10%; Sphene 4%; Quartz 4%; Accessories 2%.

Petrogenesis:- The rock is probably a metamorphosed dolomitic marl. The sequence of crystallization is: Plagioclase, sericite and calcite, tremolite, diopside. The rims of hornblende around tremolite imply a transition from the greenschist to the amphibolite facies of regional metamorphism.

sp. 69200063A (C13-26-12A)

Definition:- Sphene-diopside-tremolite-calcite-albite porphyroblastic para-amphibolite (B1C).

Hand specimen:- F.- to m.g. rock showing light red and white (calcite) patches, and spotted by m.g. (up to 3 mm) porphyroblasts of amphibole.

Microsection:- The groundmass consists of an interlocked mosaic of f.g. saussuritized albite, granular calcite showing lamellar twinning, aggregates of drop-like pleochroic mic.-f.g. sphene (Z-red-brown), granular diopside, tremolite, apatite and opaques. M.-c.g. porphyroblasts of amphibole (Z-light green), rimmed by deep blue-green amphibole and by fibrous amphibole are very common, and include albite, sphene, and apatite inclusions. The opaques may be up to 1 mm across. The diopside is heavily altered to and occurs as armoured relics within brown cryptocrystalline aggregates.

Mode (est.):- Albite 40%; Calcite 30%; Amphibole 20%; Diopside and sphene 7%; Accessories 3%.

Petrogenesis:- The rock is a metamorphosed dolomitic marl. The amphibole probably formed through the interaction of dolomite clay minerals and silica. The sequence of crystallization is: Calcite, tremolite, diopside.

sp. 69200076 (C11-22-21)

Definition:- Hematite-spotted tremolite-epidote-albite para-amphibolite (B1C).

Hand specimen:- Pink fine-grained feldspathic rock, with m.g. specularite spotting, and thin veins of epidote.

Microsection:- The bulk of the rock consists of f.g. heavily clouded irregularly-shaped untwinned albite. F.g.-m.g. columnar weakly zoned tremolite (Z-light blue green) occur in clusters. Anhedral, heavily veined and clouded f.g.-m.g. epidote grains are very common, and are usually associated with the amphibole. Clusters of irregularly-shaped opaques are widespread.

Mode (est.):- Albite 65%; Amphibole (zoned tremolite) 10%; Epidote 17%; Opaques 8%.

Petrogenesis:- The rock is a metamorphosed sodic magnesian shale, the sequence of crystallization appears to have been: Albite, tremolite, amphibole, epidote, opaques.

sp. 69200104 (C14-76-53)

Definition:- Diopside-epidote-sphene-amphibole-plagioclase para-amphibolite (B1C).

Hand specimen:- M.g-amphibolite, showing white round leucocratic spots set in green aphanitic matrix.

Microsection:- Aggregates of slightly clouded and recrystallized f.g. plagioclase (showing undulating extinction), are interveined by aggregates of f.g. amphibole (Z-grass green) and tremolite. The feldspar is commonly clouded by mic. amphibole and by sphene. The latter mineral may enclose armoured relics of ilmenite. F.g.-m.g. subhedral diopside is a minor constituent developed at the expense of amphibole. Clinozoisite, epidote, calcite and apatite occur as minor components. Strings of f.g.-m.g. anhedral opaques cross the rock, and veins of weakly saussuritized f.g. albite and mic. acicular tremolite are present. The rock has a fine-grained margin displaying a relic basaltic texture.

Mode (est.):- Plagioclase 45%; Amphibole 40%; Epidote 3%; Sphene 5%; Diopside 2%; Accessories 5%.

Petrogenesis:- The amphibolite presumably originated through the low-grade metamorphism of a basic igneous rock, or an impure dolomitic marl. The development of diopside may represent contact metamorphic effects. The feldspar has entirely recrystallized, and the released lime became incorporated in the amphibole, the epidote and sphene.

sp. 69200105 (C15-50-20)

Definition:- Apatite-sphene-tremolite-diopside-albite para-amphibolite (B1C).

Hand specimen:- Pink aphanitic rock with abundant greenish patches, and coarse-grained porphyroblasts of amphibole.

Microsection:- The chief constituent is albite, which occurs as clear f.g. subhedral prisms which may be twinned according to the albite law. Anhedral f.g.-m.g. diopside occurs as patchy aggregates and isolated grains. Tremolite forms columnar aggregates abundantly replaced by diopside. Apatite and sphene are very common accessories. Calcite, epidote, and chlorite are minor components.

Mode (est.):- Albite 57%; Diopside 30%; Tremolite 5%; Sphene 3%; Apatite 3%; accessories 2%.

Petrogenesis:- The rock is probably a metamorphosed dolomitic low-potash marl; the abundance of soda, however, is little understood. The sequence of crystallization appears to have been: Tremolite, diopside, sphene.

(9) MISCELLANEOUS META-SEDIMENTS

sp. 69200077 (C12-60-22)

Definition:- Calcite-tourmaline-sericite-plagioclase-quartz meta-sediment (BlC).

Hand specimen:- A banded f.g. rock, with white-spotted green bands alternating with a parallel set of aphanitic off-white to light pink veins.

Microsection:- The green bands consist of clusters of mic. tourmaline (Z-apple green) accompanied by finely disseminated opaques, and surrounding lenses of crypt. quartz-sericite aggregates. The light-coloured veins consist of clouded aggregates of mic. quartz. Narrow veins of calcite and muscovite are common. F.g. sodic plagioclase and microcline occur as veins and patches. Apatite and chlorite are accessories.

Mode (est.):- Quartz and Albite 50%; Sericite and Muscovite 30%; Tourmaline 15%; Calcite and Accessories 5%.

Petrogenesis:- The rock is a heavily altered siliceous meta-sediment; carbonization, silicification, and tourmalinization processes are evident.

B. META-IGNEOUS ROCKS

(10) META-BASALTS

69200028 (C15-52-11)

Definition:- Sphene-rich labradorite-amphibole porphyritic meta-basalt ($B1S_3$).

Hand specimen:- Dark green to black, aphanitic, uniformly textured amphibolite.

Microsection:- Aggregates of f.g.-m.g. (about 0.2-0.4 mm) non-aligned columnar amphibole (Z-yellowish green) are interspersed by clouded and occasionally twinned (Carlsbad law) subhedral mic.-f.g. plagioclase grains. The clouding consists of amphibole needles and of submicroscopic constituents. Granular clusters of sphene are abundantly associated with the amphibole. Some f.g.-m.g. plagioclase crystals are twinned and show relic lath-like shapes, suggesting an original porphyritic basaltic texture.

Mode (est.):- Amphibole 60%; Plagioclase (labradorite) 30%; Quartz 30%; Sphene, leucoxene, opaques, apatite 5%.

Petrogenesis:- The amphibolite represents a low-grade metamorphosed porphyritic basalt. The principal effects of metamorphism were replacement of pyroxene by amphibole, and clouding of the plagioclase.

sp. 69200055A (C14-74-29A)

Definition:- Carbonated chlorite-biotite-albite interpillow mesostasis ($B1S_1$).

Hand specimen:- Fine-grained light grey feldspathic rock, occurring at interstices between volcanic pillows.

Microsection:- Microscopically the rock consists of unaligned f.g.-m.g. lath-like albite, showing well developed twinning according to the albite law, and clouded by sericite and crypt. constituents. The feldspar is abundantly substituted by irregularly shaped calcite, and is accompanied by quartz, biotite (Z-honey yellow), aluminous chlorite (Z-light green) and granular opaques. The distribution of minerals is uneven, and calcite-rich or biotite-rich patches alternate with patches of little-altered albite.

Mode (est.):- Albite 60%; Calcite 20%; Biotite 10%; Quartz, chlorite, Opaques 10%.

Petrogenesis:- The rock constitutes an interpillow mesostasis: the albite probably formed from hydrothermal solutions percolating between the pillows. Extensive lime metasomatism is represented by the carbonates. Alteration is also presented by the biotite and the chlorite.

sp. 69200055B (C14-74-29B)

Definition:- Carbonated biotite-bearing quartz-labradorite-amphibole pillow core (BlS_1).

Hand specimen:- Medium-grained amphibolite, displaying a relic doleritic texture. Specimen derived from a pillow core.

Microsection:- The thin-section consists of heavily clouded equant to lath-like plagioclase, columnar amphibole (Z-light bluish green), calcite, and accessory quartz, biotite, epidote, apatite needles, and skeletal ilmenite. The plagioclase (labradorite) is mostly untwinned, and is heavily sericitized at crystal cores. Clear recrystallized plagioclase (sodic plagioclase) is also present. The amphibole may show twinning, and may be partly replaced by calcite. Biotite occurs in association with the opaques, and epidote as clouding of the plagioclase. The biotite may replace amphibole. Doleritic texture is retained by the restriction of plagioclase to original positions. Quartz occupies interstitial positions.

Mode (est.):- Amphibole 40%; Plagioclase 35%; Calcite 15%; Quartz, biotite and accessories 10%.

Petrogenesis:- The rock represents the metamorphosed doleritic core of pillowed basic volcanics. The medium-grained texture testifies to a relatively long cooling period. The metamorphism was followed by lime and potash metasomatism, represented by the development of calcite and biotite, respectively.

sp. 69200091 (C11-24-32)

Definition:- Leucoxene-quartz-albite-epidote-tremolite blastophitic meta-basalt (BlS_3).

Hand specimen:- M.g. to c.g. porphyroblasts of amphibole set in a fine-grained dark green matrix, with abundant yellow-green specks of epidote.

Microsection:- The rock consists of m.g.-c.g. poikiloblastic plates of tremolite, riddled with abundant pseudomorphs of f.g. epidote after plagioclase microlites. The amphiboles are set in a f.g. assemblage of granular tremolite, epidote, quartz, albite and leucoxene. Blue-green pleochroic f.g. amphiboles occur as accessories.

Mode (est.):- Tremolite 45%; Epidote 40%; Quartz and Albite 12%; Leucoxene 3%.

Petrogenesis:- The rock is a metamorphosed ophitic basalt, with most of the feldspar replaced by epidote, and the opaques replaced by leucoxene.

sp. 69200092 (C11-24-33)

Definition:- Leucoxene-albite-quartz-amphibole-epidote meta-basalt (BlS_3).

Hand specimen:- F.g. amphibolite, with yellow-green specks of epidote.

Microsection:- A uniform aggregate of f.g. to m.g. columnar amphibole (Z-bluish green), set in a granular base of mic.-f.g. epidote, quartz and albite which are accompanied by mic.-f.g. leucoxene and sphene. Spherical aggregates of euhedral epidote are common and may be up to 1 mm in diameter. The quartzo-feldspathic aggregates define poorly-retained microlitic outlines.

Mode (est.):- Amphibole 30%; Epidote 40%; Quartz and albite 27%; Leucoxene and Sphene 3%.

Petrogenesis:- The rock is a metamorphosed basalt. The primary plagioclase has been completely replaced by epidote and albite.

sp. 69200107 (C15-52-72)

Definition:- Scapolite-albite-amphibole meta-basalt (BlS_3).

Hand specimen:- Aphanitic light green rock with white lenses up to 5 mm in length.

Microsection:- The rock consists of a nematoblastic aggregates of mic. amphibole (Z-light green), which enclose recrystallized f.g. microlites of plagioclase. Mic. opaques are very common, and quartz, apatite, biotite and calcite are minor components. The leucocratic lenses consist of m.g.-very coarse-grained scapolite, abundantly clouded by mic. amphiboles. The scapolite may contain inclusions of pseudomorphs after lath-like and microlitic plagioclase, and apatite inclusions.

Mode (est.):- Amphibole 65%; Scapolite 15%; Plagioclase 15%; Accessories 5%.

Petrogenesis:- The rock is a metamorphosed basalt which underwent scapolitization.

(11) META-DOLERITES

sp. 69200030 (C15-52-20)

Definition:- Ilmenite-bearing andesine-amphibole blastoglomeroporphyritic meta-dolerite (BlS_3).

Hand specimen:- F.g. to m.g. grey to dark green amphibolite, with numerous rounded leucocratic aggregates.

Microsection:- The amphibolite consist of an intergrown aggregate of f.g.-m.g. columnar and acicular amphibole (Z-light green), and intergranular partly recrystallized and sericitized relic f.g.-m.g.

lath-like plagioclase, which is clouded by needles of amphibole. Aggregates of mic. granular sphene and leucoxene replace relic f.g.-m.g. skeletal crystals of ilmenite, which is usually partly retained. Ophitic textures may be well preserved. The leucocratic aggregates consist of mic. sheaf-like prehnite, crypt.-mic. sericite and saussurite, mic. to f.g. anhedral clinozoisite, and acicular amphibole (Z-blue green).

Mode (est.):- Amphibole 45%; Plagioclase (Andesine) 30%; Sericite, Clinozoisite, Saussurite, Prehnite 23%; Ilmenite, Sphene, Leucoxene 2%.

Petrogenesis:- The rock has probably been a glomeroporphyritic dolerite. Metamorphism resulted in extensive recrystallization and alteration of the calcic plagioclase, giving rise to sericite, prehnite, and clinozoisite.

sp. 69200031 (C15-52-23)

Definition:- Ilmenite-bearing amphibole-andesine meta-dolerite ($B1S_3$).

Hand specimen:- Grey-green amphibolites, with m.g.-c.g. (4.0mm) laths of feldspar in greenish aphanitic matrix.

Microsection:- Subhedral to euhedral lath-like plagioclase (andesine) and columnar to fibrous amphibole (Z-bluish green) are the chief constituents. A subophitic texture is moderately-well retained. The plagioclase is commonly twinned according to the albite law, is weakly saussuritized, and includes mic. grains of amphibole. Skeletal crystals of ilmenite are preferentially associated with the amphibole, and may be up to 2 mm across. Biotite (Z-yellow brown) occurs as a minor component developed at the expense of amphibole. A coarser-grained gabbroic band is included in the meta-dolerite.

Mode (est.):- Amphibole 40%; Plagioclase (andesine) 45%; Saussurite 10%; Ilmenite, Biotite 5%.

Petrogenesis:- The rock is a low-grade metamorphosed dolerite. A retardation of the metamorphic reactions is suggested by the retention of original plagioclase, as well as by the preservation of the primary texture.

sp. 69200032A (C15-52-32A)

Definition:- Biotite-amphibole-andesine f.g. sheared meta-dolerite ($B1S_3$).

Hand specimen:- Sheared dark green to black fine-grained amphibolite.

Microsection:- The rock consists of an aggregate of mic.-f.g. amphibole, mic. biotite (Z-reddish brown), and subhedral twinned f.g. plagioclase (andesine). The plagioclase is clouded by mic. biotite and amphibole. The biotite is usually developed at the expense of the amphibole. Apatite, sphene, opaques and quartz constitute accessories.

Mode (est.):- Amphibole 40%; Biotite 15%; Plagioclase 40%; Opaques, Quartz, Sphene, Apatite 5%.

Petrogenesis:- The rock is a low-grade metamorphosed dolerite, which underwent slight potash metasomatism resulting in a late development of biotite. This development may have been associated with the shearing of the rock.

sp. 69200036A (C15-52-39A)

Definition:- Iron-rich plagioclase-amphibole meta-dolerite (BlS_2).

Hand specimen:- Medium-grained uniform amphibolite showing relic doleritic texture.

Microsection:- The microsection shows remnant f.g.-m.g. lath-like untwinned crystals of calcic plagioclase, the outlines of which define a blasto-doleritic texture. The plagioclase is untwinned, is clouded by crypt. brown constituents (? saussurite) and by inclusions of quartz. The feldspar crystals are set in an aggregate of randomly oriented mic.-f.g. columnar amphibole (Z-bluish green), which is abundantly accompanied by irregular opaques grains. Apatite is a minor accessory.

Mode (est.):- Amphibole 60%; Plagioclase and Quartz 32%; Opaques 8%.

Petrogenesis:- The amphibolite has been derived from the low-to moderate-grade metamorphism of dolerite. The metamorphic reactions were accompanied by only a limited textural reconstitution.

sp. 69200073A (C11-22-2A)

Definition:- Ilmenite-quartz-epidote-plagioclase-amphibole blastophitic meta-dolerite ($Sill_1$ in BlS_2).

Hand specimen:- Medium- to coarse-grained amphibolite.

Microsection:- F.-c.g. zoned amphibole (tremolite zoned by green amphibole), enclose euhedral f.g. microlites and lath-like plagioclase and pseudomorphs of plagioclase (oligoclase-andesine) in a well-preserved blastophitic texture. The feldspar itself has been commonly replaced by aggregates of crypt., sericite, saussurite, and mic.-f.g. epidote. C.g. skeletal crysrals of ilmenite are present. The matrix consists of quartz, epidote, amphibole and opaques. Amphibole occurs also in narrow veins.

Mode (est.):- Amphibole 50%; Plagioclase and pseudomorphs after plagioclase (inc. epidote) 40%; Ilmenite 3%; Quartz 7%.

Petrogenesis:- The rock is low-grade metamorphosed ophitic dolerite. The zonation of the amphibole may represent the development of hornblende at the expense of actinolite with a transition from greenschist to amphibolite facies. The calcic plagioclase was partly recrystallized to more sodic plagioclase, and partly clouded by epidote and sericite.

sp. 69200090 (C11-22-46)

Definition:- Leucoxene-epidote-saussurite-albite-sericite-amphibole meta-dolerite (BlS_3).

Hand specimen:- M.-c.g. amphibolite.

Microsection:- An ophitic to subophitic texture is well retained, with pseudomorphs of crypt. saussurite, sericite, and feldspar, occupying original prismatic plagioclase positions. The amphibole is m.g.-c.g., is colourless at the cores, and is rimmed by pleochroic light green amphibole. Leucoxene, epidote and opaques are common accessories. The leucoxene may occur as m.g. grains (up to 2 mm), which are pseudomorphous after ilmenite.

Mode (est.):- Amphibole 50%; Pseudomorphs of plagioclase 45%; Epidote 3%; Sphene and Accessories 2%.

Petrogenesis:- The specimen is a metamorphosed ophitic dolerite or microgabbro. The original feldspar has recrystallized into granular feldspar, and has been replaced by sericite and saussurite. The released lime reacted with ilmenite to form leucoxene. The amphibole occupies original positions of the pre-existing pyroxene.

sp. 69200096 (C12A-36-38)

Definition:- Sphene-bearing altered amphibole-tremolite-plagioclase meta-dolerite (BlS_2).

Hand specimen:- M.-c.g. amphibolite, with light brown feldspar.

Microsection:- The amphibole is f.g.-m.g., and is colourless (tremolite) to deep blue-green. Zoned crystals with cores of blue-green amphibole and colourless rims are present. Clouding by crypt. minerals is very common. The feldspar is heavily clouded by sericite, may be recrystallized, and shows no twinning. Calcite apatite, sphene, and opaques form accessories. The opaques are commonly euhedral, and may be rimmed by sphene, M.g. pseudomorphs of sphene after ilmenite occur. A subophitic igneous texture is partly retained.

Mode (est.):- Amphibole 40%; Plagioclase (inc. sericite) 50%; Opaques 5%; Calcite, Sphene and other accessories 5%.

Petrogenesis:- The rock is a metamorphosed subophitic dolerite. The replacement of hornblende by tremolite possibly implies magnesia metasomatism. Alteration processes are also manifested by the recrystallization and sericitization of the feldspar, and the replacement of ilmenite by sphene, which was probably associated with the release of lime from plagioclase.

sp. 69200098 (C14-76-31)

Definition:- Ilmenite-bearing plagioclase-amphibole subophitic meta-dolerite (dyke).

Hand specimen:- M.g. meta-dolerite.

Microsection:- A subophitic texture is evident. Sericitized and re-crystallized plagioclase and crypt. mic. feldspar aggregates pseudomorphous after lath-like plagioclase, are set in and surrounded by f.g.-m.g. amphiboles. The plagioclase is commonly zoned. The amphiboles (Z-blue-green, Y-deep grass-green, X-yellow) are weakly zoned, with the rims showing the deeper pleochroic colours. Inclusions of mic. quartz are very common. M.g. skeletal crystals of ilmenite are common. Quartz, biotite, and apatite are minor constituents.

Mode (est.):- Amphibole 60%; Plagioclase (inc. sericite) 35%; Ilmenite 3%; Accessories 2%.

Petrogenesis:- The rock is a metamorphosed dolerite.

sp. 69200101 (C14-76-47)

Definition:- Plagioclase-amphibole meta-dolerite ($Sill_1$ in BlS_1).

Hand specimen:- M.g. meta-dolerite.

Microsection:- Recrystallized and partly clouded prisms of plagioclase (up to 2 mm) are set in an aggregate of f.g.-m.g. columnar amphibole (Z-deep blue green). Opaques and quartz are the main accessories.

Mode (est.):- Amphibole 65%; Plagioclase 30%; Accessories 5%.

Petrogenesis:- The rock is a metamorphosed dolerite.

(12) META-GABBROS

sp. 69200043A (C15-52-60A)

Definition:- Ilmenite-bearing amphibole-plagioclase blastoporphyritic meta-gabbro ($Sill_1$ in BlS_1).

Hand specimen:- M.-c.g. meta-dolerite, with lath-like feldspars (up to 5 mm) set in green aphanitic matrix.

Microsection:- The m.g. to c.g. blasto-phenocrysts of plagioclase (andesine-labradorite) are clouded by mic. amphibole, epidote, and crypt. sericite and saussurite. The plagioclase is intervened by columnar aggregates of f.g. amphibole (Z-bluish green), with which skeletal crystals of ilmenite are associated. Apatite occurs as slender needles which may be a few millimetres long. Clouded and clear patches alternate irregularly in the plagioclase. Twinning according to the pericline law may occur, but albite twinning is rare. Quartz is a minor accessory of the rock.

Mode (est.):- Plagioclase 60%; Amphibole 35%; Accessories 5%.

Petrogenesis:- The rock is a metamorphosed c.g. dolerite or micro-gabbro. Deuteric or metamorphic alteration resulted in heavy clouding of the plagioclase, and may have accounted for the development of the apatite needles, which appear to be texturally younger than the other phases.

sp. 69200052 (C14-74-21)

Definition:- Andesine-amphibole meta-gabbro ($Sill_1$ in BlS_1).

Hand specimen:- C.g. amphibolite, showing prisms of amphibole (up to 10 mm) and equant to lath-like feldspar.

Microsection:- The rock consists of columnar crystals and fibrous bundles of c.g. amphibole (Z-bluish green) and partly clouded (sericitized) twinned lath-like and equant plagioclase (calcic andesine). Mic. amphibole also occurs as clouding in the plagioclase. The amphibole carries quartz inclusions, and is accompanied by opaques, which may include c.g. skeletal ilmenite and euhedral magnetite. Apatite is a minor constituent, and may occur as slender needles. The primary igneous texture has been retained through the preservation of original plagioclase and the apparent confinement of the amphibole to original pyroxene positions.

Mode (est.):- Amphibole 50%; Plagioclase 45%; Sericite and accessories 5%.

Petrogenesis:- The amphibolite represents a metamorphosed gabbro. The pyroxene has been completely replaced by amphibole, whereas the plagioclase crystals retained original positions, and probably original compositions.

sp. 69200073B (C11-22-2B)

Definition:- Ilmenite-sphene-quartz-epidote-saussurite-amphibole meta-gabbro ($Sill_1$ in BlS_2).

Hand specimen:- C.g. meta-gabbro, with prisms of plagioclase (up to 20 mm across) and intervening m.g.-c.g. columnar amphibole.

Microsection:- The plagioclase is heavily sericitized and saussuritized, and is partly replaced by granular epidote and by amphibole. The amphibole (Z-light green) occurs as subhedral prisms showing undulating extinction, and as sheaf-like aggregates. The amphibole is clouded by crypt. brown dust (mainly sphene) and carries inclusions of irregularly-shaped opaques rimmed by crypt.-mic. aggregates of sphene, which also occur in a pattern representative of pre-existing skeletal ilmenite crystals. Quartz is common at interstitial positions.

Mode (est.):- Pseudomorphs after plagioclase 45%; Amphibole 40%; Sphene and Opaques 10%; Quartz 5%.

Petrogenesis:- The rock is a metamorphosed gabbro, in which the plagioclase has been almost completely clouded, and the pyroxene replaced by amphibole. Reaction between ilmenite and amphibole is reflected by the development of sphene.

sp. 69200086 (C11-22-27)

Definition:- Epidote-sericite-amphibole-tremolite blastophitic meta-gabbro ($Sill_1$ in BlS_2).

Hand specimen:- C.-v.c.g. amphibolite, with dark green amphiboles intervened by leucocratic and epidote-rich material.

Microsection:- A distinctive blastophitic texture is displayed, with f.g. prismatic pseudomorphs of sericite after plagioclase forming inclusions in c.g.to v.c.g. anhedral amphibole (Z-bluish green) crystals. The amphiboles are conspicuously zoned, with colourless cores of tremolite surrounded by pleochroic amphibole rims. Much of the amphibole displays replacement of the former type by the latter type. Clouding of the amphibole by crypt. brown minerals is very common. Yellow epidote is widespread, and forms anhedral to prismatic f.g.-m.g. grains, which are developed at the expense of amphibole and plagioclase. Skeletal ilmenite, clinozoisite (usually pseudomorphous after feldspar), zoisite (m.g. crystals, very small extinction angle), and quartz form accessories.

Mode (est.):- Tremolite and green amphibole 40%; Altered plagioclase 50%; Epidote 7%; Accessories 3%.

Petrogenesis:- The rock is a metamorphosed blastophitic gabbro. The amphibole occupies original pyroxene positions. The pyroxene must have been of magnesia-rich composition, as implied by its replacement by the tremolite. The plagioclase has been heavily altered to sericite and epidote, possibly due to deuteric or metasomatic processes.

sp. 69200102 (C14-76-48)

Definition:- Biotite-bearing amphibole-plagioclase meta-gabbro ($Sill_1$ in BlS_1).

Hand specimen:- C.g. amphibolite.

Microsection:- C.g. (up to 8 mm) columnar amphiboles (Z-deep bluish green) with inclusions of quartz, enclose lath-like crystals of m.g. plagioclase. The plagioclase is heavily clouded by crypt. sericite at crystal centres, and displays clear margins. Replacement of the feldspar by f.g. amphiboles is common. Twinning of the amphibole is widespread, and the c.g. amphibole crystals often enclose mic.-f.g. amphiboles. Skeletal ilmenite, rutile, sphene, quartz and biotite are minor components, the biotite being younger than the amphibole. Rutile inclusions in the amphibole are surrounded by pleochroic haloes.

Mode (est.):- Amphibole 45%; Plagioclase 50%; Accessories 5%.

Petrogenesis:- The rock is a metamorphosed gabbro. Slight potash introduction is represented by the late growth of biotite.

(13) METABASITES (ORTHO-AMPHIBOLITES)

sp. 69200026 (C15-52-4)

Definition:- Andesine-tremolite banded metabasite (BlS_3).

Hand specimen:- Grey green sheared amphibolite, showing moderately-well developed segregation banding, and irregular white spotting.

Microsection:- Bands of tremolite and opaques alternate with feldspathic bands. The tremolite occurs as mic.-m.g. (0.2 mm) anhedral to subhedral grains. The plagioclase occurs as anhedral aggregates, which consist of mic.-m.g. usually untwinned grains. Clouding by cryptocrystalline calcite and unidentified constituents is widespread. Bands of aggregates of crypt.-mic. amphibole and feldspar are present. Sphene and opaques are commonly associated with the tremolite.

Mode (est.):- Tremolite (Z-light green) 55%; Plagioclase (andesine) 30%; Calcite, Sphene 10%; Opaques (magnetite and ilmenite) 5%.

Petrogenesis:- The rock is a low-grade metamorphosed magnesian basic igneous rock, affected by shearing and compositional segregation, and displaying no relic igneous texture.

sp. 69200035A (C15-52-37A)

Definition:- Iron-rich quartz-plagioclase-amphibole metabasite (BlS_2).

Hand specimen:- F. to m.g. uniformly textured dark green amphibolite with fine white spots.

Microsection:- In thin-section the rock consists of an aggregate of randomly oriented f.g.-m.g. (up to 0.5 mm) columnar amphibole (Z-bluish green), interstitial quartz and untwinned sodic plagioclase and abundant mic. granular opaques. The quartz and the plagioclase usually form interlobate grains, which are mostly clear of inclusions and may show undulatory extinction. The opaques are preferentially associated with the amphibole. No remnant igneous texture is evident.

Mode (est.):- Amphibole 60%; Plagioclase and quartz 35%; Opaques 5%.

Petrogenesis:- The amphibolite represents a metamorphosed f.g. basic igneous rock, either a basalt or a f.g. dolerite.

sp. 69200039 (C15-52-46)

Definition:- Ilmenite-rich quartz-plagioclase-amphibole metabasite (BlS_3).

Hand specimen:- F.-m.g. dark green uniformly textured amphibolite. A very weak foliation is discernible.

Microsection:- Weakly-aligned aggregates of f.g.-m.g. columnar to acicular amphibole (Z-yellowish green, X-yellow) alternate with elongated aggregates of granular mostly untwinned mic.-f.g. plagioclase and quartz. Aggregates of mic. drop-like opaques which define skeletal outlines of ilmenite are abundantly associated with the amphibole. Short prisms of apatite occur as accessories. The amphibole and quartz-feldspar aggregates define a very weak segregation banding. No relic igneous texture is preserved.

Mode (est.):- Amphibole 60%; Plagioclase and Quartz 37%; Ilmenite 3%.

Petrogenesis:- The rock is a metamorphosed slightly sheared basic igneous rock. The parent rock has been either a basalt or a f.g. dolerite.

sp. 69200043B (C15-52-60B)

Definition:- Sphene-rich oligoclase-amphibole porphyroblastic metabasite ($Sill_1$ in BlS_1).

Hand specimen:- A weakly banded f.-m.g. amphibolite, with elongated leucocratic patches alternating with green patches, representing metamorphic segregation banding.

Microsection:- Elongated aggregates and porphyroblasts of columnar f.g.-c.g. amphibole (Z-bluish green) are intervened by aggregates of granular mic.-f.g. plagioclase, (oligoclase). The plagioclase grains are clear and commonly twinned according to the albite and pericline laws. Irregular grains of sphene (up to 2 mm) are common, particularly in association with the feldspar. Quartz, apatite and opaques form the other accessories.

Mode (est.):- Amphibole 48%; Plagioclase 48%; Accessories 4%.

Petrogenesis:- The specimen is a weakly sheared metamorphosed basic igneous rock, showing porphyroblastic and glomeroporphyroblastic development of the amphibole.

sp. 69200045 (C15-52-62)

Definition:- Tremolite-andesine-hornblende metabasite (BlS_1).

Hand specimen:- Sheared f.g. dark green amphibolite.

Microsection:- In thin-section granoblastic aggregate of f.g. clear plagioclase grains, and mic.-f.g. columnar amphibole (Z-dark green) is resolved. Tremolite, occurring as f.g. prisms is a common minor component, and clearly younger than the green amphibole composite green amphibole-tremolite crystals, may occur. The plagioclase (andesine) is rarely twinned, and forms clear or slightly clouded equant grains. Quartz, apatite and opaques are the chief accessories, the latter occurring as f.g. irregular grains associated with the amphibole.

Mode (est.):- Amphibole 55%; Plagioclase and Quartz 43%; Accessories 2%.

Petrogenesis:- The specimen is a metamorphosed basic igneous rock, showing weak late magnesia metasomatism represented by the tremolite. It occurs adjacent to meta-sediments which reached the staurolite grade, and which also bear evidence of magnesia metasomatism (e.g., sp. 69200054B).

sp. 69200047 (C15-50-3)

Definition:- Sphene and ilmenite-bearing quartz-plagioclase-amphibole metabasite (dyke).

Hand specimen:- F.-m.g. dark green amphibolite, with aphanitic and micro-doleritic bands (about 1" thick) alternating with each other.

Microsection:- In thin-section no igneous texture is retained. Columnar round grains of f.g.-m.g. bands consist of m.g. amphibole (Z-grass green), and untwinned f.g.-m.g. plagioclase grains. The plagioclase grains are usually sericitized at their centres and clear at their margins. Quartz occurs as mic.-f.g. inclusions in the amphibole. Clusters of ilmenite grains, often rimmed by sphene, are common, and are preferentially associated with the amphibole. The f.g. bands consist of amphibole with quartz inclusions, plagioclase being almost absent.

Mode (est.):- Medium grained bands: Amphibole 50%; Plagioclase 40%; Quartz 8%; Opaques and Sphene 2%.

Fine-grained bands: Amphibole 85%; Quartz 12%; Accessories 3%.

Petrogenesis:- The rock has been collected from a dyke. The banding may reflect multiple intrusions. Metamorphism of the associated meta-sediments reached the andalusite zone.

sp. 69200058B (C14-74-55)

Definition:- Talc-veined quartz-plagioclase-amphibole metabasite ($Sill_1$ in BlS_1).

Hand specimen:- M.g. amphibolite, with parallel streaks of amphibole.

Microsection:- In thin-section the rock displays a dense intergrowth of f.g.-m.g. anhedral amphibole (Z-bluish green) and heavily saussuritized and sericitized lath-like f.g.-m.g. plagioclase. The amphibole shows twinning, and colour zonation, with the margins being more deeply coloured than the cores. Interstitial quartz and patchy opaques are the main accessories. Biotite and amphibole occur as mic. clouding in the feldspar. Calcite is a minor component. Lamellar bundles of talc occur as alteration product along fractures.

Mode (est.):- Amphibole 60%; Plagioclase (including sericite clouding 30%; Quartz 5%; Accessories 5%.

Petrogenesis:- The rock is a metamorphosed dolerite with an unusually high percentage of amphibole. Deuteric or metamorphic alteration is represented by the clouding of the plagioclase, growth of biotite, and the talc veins. The zonation of the amphibole suggests a replacement of actinolite by hornblende.

sp. 69200066 (C12A-36-11)

Definition:- Sphene-rich labradorite-amphibole metabasite ($B1S_3$).

Hand specimen:- F.g. dark green amphibolite.

Microsection:- The thin-section displays an aggregate of columnar to acicular randomly oriented amphibole (Z-light green), interstitial quartz and plagioclase (labradorite), and minor mic. sphene, tremolite, and opaques. No relic igneous texture is apparent.

Mode (est.):- Amphibole 63%; Plagioclase and Quartz 30%; Opaques and Sphene 5%.

Petrogenesis:- The rock could be a metamorphosed mafic basalt. The high percentage of amphibole and quartz, however, indicate deviations from a basaltic composition.

sp. 69200072 (C11-22-1)

Definition:- Sphene-rich quartz-amphibole-epidote-oligoclase metabasite ($Sill_1$ in $B1S_2$).

Hand specimen:- Partly epidotized m.g. amphibolite.

Microsection:- Clear euhedral to subhedral twinned lath-like f.g.-m.g. plagioclase crystals (Oligoclase, An 11), are set in aggregates composed of mic. quartz and plagioclase, mic.-f.g. epidote aggregates, and poikiloblastic amphibole (Z-deep green) with mic. inclusions of quartz. Epidote occurs also as radiating clusters of m.g. slender prisms. Subhedral wedge-shaped crystals are very common, and may be up to 1 mm across. The sphene and the epidote may be developed at the expense of the amphibole. The epidote is also commonly replacing plagioclase. Apatite and opaques are minor accessories.

Mode (est.):- Plagioclase 25%; Quartz 15%; Epidote 35%; Amphibole 20%; Sphene 5%.

Petrogenesis :- The rock is a completely reconstituted basic meta-igneous rock; occurring at the margin of a meta-dolerite sill. The sequence of crystallization appears to have been: Recrystallization of plagioclase, formation of amphibole, epidote and sphene, in this order. The abundance of sphene is a unique feature of this rock.

sp. 69200081 (C12A-38-30)

Definition:- Sphene-quartz-plagioclase-amphibole metabasite ($B1S_3$).

Hand specimen:- F.g. dark green uniform amphibolite.

Microsection:- An assemblage of acicular to columnar f.g.-m.g. amphibole (Z-light blue green), intergranular recrystallized clear anhedral mic.-f.g. plagioclase, and accessory opaques, commonly rimmed and replaced by leucoxene and sphene. The patchy opaques define in some cases relic outlines of skeletal ilmenite crystals.

Quartz is a minor constituent, and may occur in veinlets. No igneous texture is preserved. The elongated opaques are weakly aligned.

Mode (est.):- Amphibole 60%; Plagioclase 30%; Quartz and accessories 10%.

Petrogenesis:- The specimen is a low-grade metamorphosed fine-grained basic igneous rock, probably a meta-basalt.

sp. 69200083 (C13-38-41)

Definition:- Iron-rich quartz-plagioclase-biotite metabasite ($B1S_2$).

Hand specimen:- Mottled f.-m.g. rock, with dark lenses (up to 2 mm) intervened by light coloured matrix.

Microsection:- The dark lenses consist of clots of mic.-f.g.biotite (Z-deep orange brown) and abundant irregular opaques. The light coloured matrix is composed of crypt.-mic. quartz, plagioclase and sericite. The opaques are clearly younger than the biotite. A translucent green unidentified substance occurs as a minor component.

Mode (est.):- Biotite 40%; Opaques 20%; Quartz and Plagioclase 30%; Sericite and Accessories 10%.

Petrogenesis:- The rock occurs near a copper mine, and probably represents a metasomatized and mineralized metabasite. The biotite may have replaced amphibole due to potash metasomatism. The opaques were probably the last introduced phase.

sp. 69200088 (C11-22-32)

Definition:- Scapolite-bearing epidote-quartz-plagioclase-amphibole metabasite (Sill. in $B1S_2$).

Hand specimen:- C.g. dark green amphibolite.

Microsection:- The major component is f.g.-c.g. fibrous to anhedral columnar amphibole (Z-from off-white to light blue green, in patchy pattern). Aggregates of mic. plagioclase, mic. quartz and sericite occur at interstitial position with respect to the amphibole. Minor epidote occurs as f.g. anhedral grains. Accessory f.g. scapolite, with abundant inclusions of amphibole and epidote, occur at interstitial positions. F.g. opaques are a minor component.

Mode (est.):- Amphibole 60%; Plagioclase, Quartz and Sericite 30%; Epidote 5%; Scapolite 3%; Accessories 2%.

Petrogenesis:- The specimen is a metamorphosed and completely reconstituted basic igneous rock.

(14) GRANITES

sp. 69200038 (C15-52-45)

Definition:- Oligoclase-quartz-microcline granite.

Hand specimen:- M.-c.g. (grains up to 5 mm) granite, with pink to orange-coloured feldspar.

Microsection:- The rock shows a hypidiomorphic-granular texture, with anhedral to subhedral f.g.-c.g. grains of microcline and plagioclase set in an aggregate of mic. interlobate quartz. The plagioclase (oligoclase) is clouded by muscovite, sericite and by cryptocrystalline constituents, whereas the microcline is relatively clear. Intergrowths of quartz mosaics with feldspar are common. Ferruginous chlorite (Z-brown green) anhedral sphene (up to 2 mm), and opaques are the chief accessories. The chlorite contains inclusions of rutile, which indicates its origin from the alteration of biotite. Hematite staining is common. The sphene, chlorite and opaques are often associated with each other.

Mode (est.):- Microcline 45%; Plagioclase 15%; Quartz 35%; Accessories 5%.

Petrogenesis:- The rock is a potash-rich leucocratic granite, showing effects of deuteric alteration and slight weathering.

sp. 69200068 (C11-24-3)

Definition: Microcline-bearing quartz-oligoclase granite.

Hand specimen:- M.g. pink feldspar-rich granite, with greenish chloritic spots.

Microsection:- The rock consists mainly of anhedral to subhedral m.g. (up to 2 mm across) plagioclase (oligoclase, An 14), twinned according to the albite and pericline laws, and showing very weak clouding by crypt. brown dust. Remnants of microcline may occur within plagioclase crystals. Interstitial aggregates of f.g.-m.g. granular quartz are very common. Green biotite and opaques occur as accessories. Some plagioclase grains display higher degrees of clouding, and may be partly sericitized and spotted by muscovite. Staining by hematite is common.

Mode (est.):- Plagioclase 65%; Microcline 3%; Quartz 30%; Accessories 2%.

Petrogenesis:- The rock is a sodic granite, which has evolved through the replacement of a microcline-bearing granite, possibly at late magmatic stages.

sp. 69200079A (C12-62-8A)

Definition:- Muscovite-quartz-oligoclase granite.

Hand specimen:- M.g. light pink granite.

Microsection:- The texture of the rock is m.g. hypidiomorphic-granular. Plagioclase (Oligoclase) is the predominant phase; it is usually twinned, and is only slightly clouded. Quartz forms f.g.-m.g. anhedral grains with irregular boundaries, and may form inclusions in the feldspar. Muscovite, calcite and opaques occur as minor constituents.

Mode (est.):- Plagioclase 65%; Quartz 30%; Accessories 5%.

Petrogenesis:- The rock is a sodic granite. No obvious signs of metamorphism are apparent.

sp. 69200109B (C15-52-83B)

Definition:- Chlorite-bearing oligoclase-quartz-microcline granite.

Hand specimen:- M.-c.g. pink granite, with green patches of ferro-magnesian minerals.

Microsection:- Hypidomorphic granular m.g.-c.g. subhedral weakly clouded crystals of twinned plagioclase (oligoclase), and clear anhedral crystals of m.g. microcline are separated by granular aggregates of f.g.-m.g. quartz with sutured boundaries, and by feldspar. Muscovite occurs either as clouding in the plagioclase or at interstitial positions. Biotite (Z-deep brown or green) is a minor constituent, commonly altered to ferroan chlorite (Z-green). Zircon (showing zonation), euhedral and finely disseminated opaques, and apatite are minor constituents.

Mode (est.):- Plagioclase 25%; Microcline 35%; Quartz 30%; Biotite, Chlorite, Muscovite 8%; Accessories 2%.

Petrogenesis:- The granite underwent hydrothermal alteration represented by the alteration of biotite, the clouding of plagioclase, and the development of muscovite (which is younger than the chlorite).

(15) MISCELLANEOUS META-IGNEOUS ROCKS

sp. 69200032B (C15-52-32B)

Definition:- Biotite-quartz-myrmekite-plagioclase-amphibole granophyre.

Hand specimen:- M.g. amphibolite, with leucocratic patches and amphibole-rich patches irregularly alternating with one another. M.g. anhedral porphyroblasts of quartz are present.

Microsection:- The rock consists of irregularly alternating leucocratic and amphibole-rich aggregates. The leucocratic patches consist of clouded f.g.-m.g. plagioclase, quartz, myrmekite mosaics and minor strongly pleochroic mic.-m.g. amphibole (Z-deep blue green, X-yellowish green, X-yellow; strong dispersion:), mic. biotite (Z-yellow brown), mainly as clouding of plagioclase, opaques and apatite. The melanocratic aggregates consist of intergrown mic.-m. g. grains of columnar amphibole (pleochroic, as above) accompanied by interstitial quartz, minor biotite, opaques, and subhedral apatite. The two latter constituents are mainly associated with amphibole. No relic igneous texture is present.

Mode (est.):- Amphibole 30%; Plagioclase 25%; Quartz and Myrmekite 35%; Biotite, Opaques, Apatite 10%.

Petrogenesis:- The rock represents a granophyre facies developed at the margin of an amphibolite sill.

sp. 69200067 (C12A-36-12)

Definition:- Partly silicified clinozoisite rock.

Hand specimen:- Grey aphanitic rock, with light coloured patches and lenses forming over fifty per cent of the volume.

Microsection:- The grey patches consist of mosaics of mic. quartz, accompanied by minor mic. clinozoisite, calcite, and acicular mic. amphibole (Z-green). The light-coloured patches consist mainly of mic.-f.g. clinozoisite and quartz, and accessory calcite and prehnite. Veinlets consisting of f.g.-m.g. clinozoisite are present.

Mode (est.):- Light-coloured patches: Clinozoisite 80%; Quartz 18%; Calcite 2%.

Grey patches: Quartz 85%; Clinozoisite 8%; Amphibole 7%.

Petrogenesis:- The rock is a partly silicified epidosite, which might have originated from the metamorphism of a plagioclase-rich rock.

sp. 69200070 (C11-24-13)

Definition:- Scapolite-bearing tremolite rock.

Hand specimen:- M.g. dark green amphibole rock.

Microsection:- The thin-section displays a dense intergrowth of f.g.-m.g. off-white to light green fibrous and columnar tremolite. Clouding by crypt. brown dust is widespread. Apatite, quartz, scapolite, clinozoisite chlorite and opaques form minor components. The scapolite occurs at interstitial positions in relation to the amphibole. The amphiboles are weakly zoned, with light green rims developed around off-white cores.

Mode (est.):- Amphibole 90%; Scapolite 3%; Opaques 3%; Accessories 4%.

Petrogenesis:- The specimen is a low-grade metamorphosed ultramafic rock. The zonation of the amphibole may represent slight introduction of iron. The occurrence of scapolite may imply introduction of chlorine.

sp. 69200087 (C11-22-29)

Definition:- Sphene-ilmenite-epidote-amphibole-albite meta-diorite.

Hand specimen:- M.g. grey amphibolite.

Microsection:- The rock consists of f.g.-m.g. subhedral short prisms of clear and twinned (albite and pericline laws) plagioclase (albite, An_8), f.g.-m.g. poikiloblastic amphibole (Z-deep green), with inclusions of mic.-f.g. quartz. Epidote is a common component, and occurs as f.g.-m.g. irregularly-shaped grains and aggregates. Relics of ilmenite replaced by sphene to varying degrees are common accessories. Prisms of apatite are minor accessories.

Mode (est.):- Plagioclase 65%; Amphibole 20%; Epidote 10%; Opaques, Sphene, Quartz and Accessories 5%.

Petrogenesis:- The rock is possibly a recrystallized metamorphosed diorite. The original intermediate plagioclase was completely replaced by albite, and the released lime and alumina went into the epidote molecule and facilitated the replacement of ilmenite by sphene. The amphibole may be partly primary.

APPENDIX II

Programmes for geochemical studies.

(1) Geochemical and electron probe studies of ortho-amphibolites and para-amphibolites from the Cloncurry 1:100,000 Sheet area.

36 specimens have been submitted for major and minor element analyses, as well as for an electron probe study of the principal constituent minerals. The following are the principal aims of the study:

1. An investigation of the relationships between base-metal concentrations, host-rock geochemistry and metamorphic grade.

2. The relationships between the compositions of the major phases (plagioclase, amphibole, epidote) and host-rock geochemistry.

3. The investigation of the possible use of some trace elements as ore indicators.

The following elements will be analysed for:

Si, Ti, Al, Fe^{+3}, Fe^{+2}, Mn, Mg, Ca, Na, K, CO_2, P_2O_5, S, Cu, Cr, Co, Ni, Zn, Pb, V, Rb, Sr, Ba, Sc, Y, La, Zr.

(2) Geochemical study of black slates.

33 specimens of black slate from the Marraba 1:100,000 Sheet area and the Cloncurry 1:100,000 Sheet area have been submitted for major and minor element analyses. The specimens are derived from the Marimo Slate, the Corella Formation, and the Soldiers Cap Formation. The following are the main aims of this work:

1. To facilitate a comparison with the Mt. Isa Shale, with possible implications as to the favourability of the various slate units as host-rocks for ore bodies of the Mt. Isa type.

2. A comparison between the composition of slates associated with copper deposits and barren slates.

3. The geochemical study of the slates may yield information on the salinity of the water (B Ga, Rb ratios), sedimentary maturity (Al/Na ratios), alkali contents of the environment (Na/K ratios), and possibly the role of biogenic agents (P_2O_5, C, CO_2 and S contents).

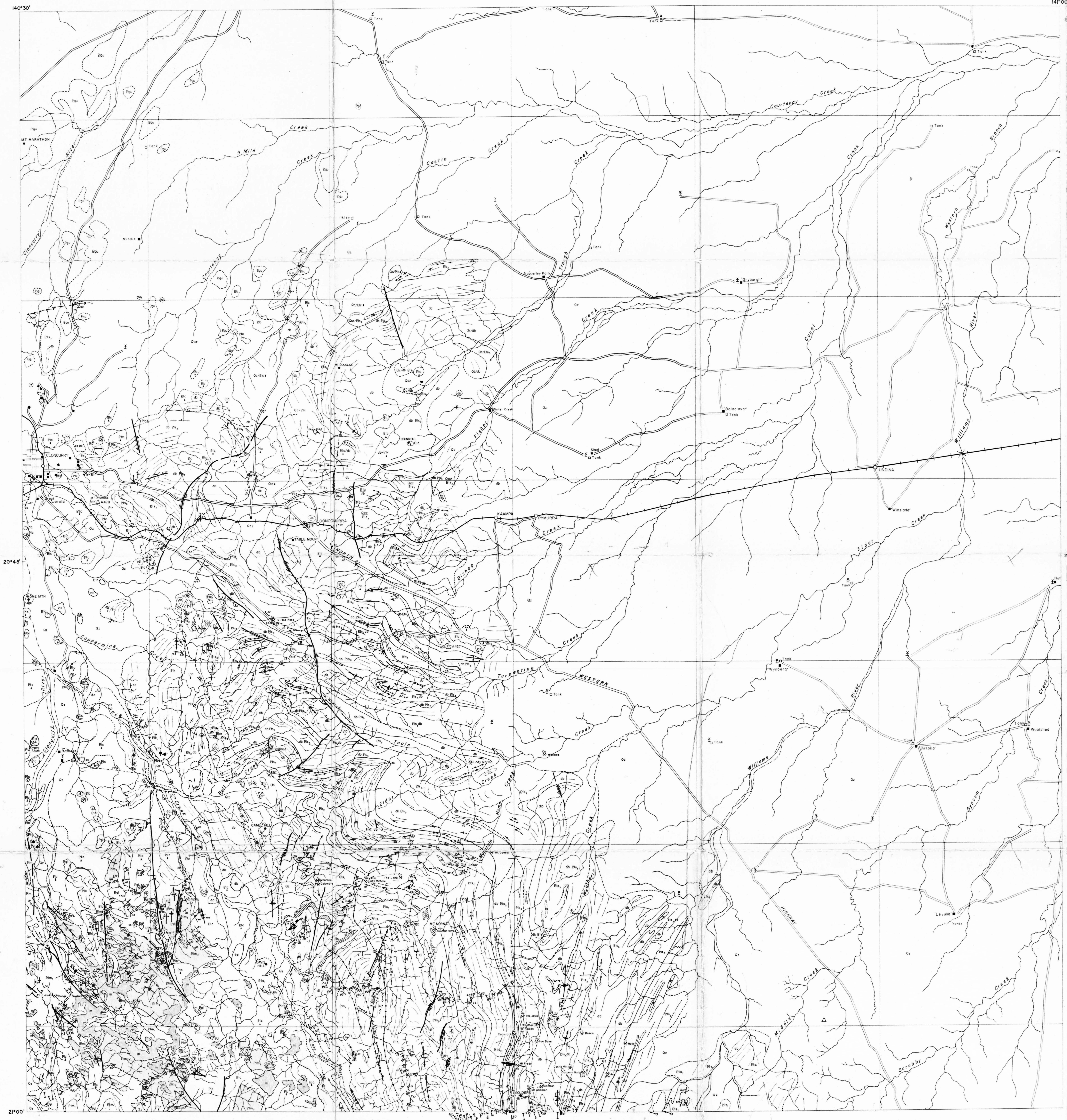
The elements to be determined are as follows:

Si, Ti, Al, Fe^{+3}, Fe^{+2}, Mn, Mg, Ca, Na, K, H_2O^+, H_2O^-, CO_2, P_2O_5, C, B, S, Ga, Zn, Pb, Cu, Cr, Co, Ni, V, Sr, Ba, Rb, Sc, Y, La, Zr.

All the specimens will be mineralogically analysed by X-ray diffraction.

GEOLOGICAL MAP
CLONCURRY
QUEENSLAND

Geology 1969 by A.Y. Glikson and G.M. Derrick
Compiled by A.Y. Glikson
Drawn by W.P. Shafron



SCALE 1:100,000

0 1 2 3 4 5 6 KILOMETRES
0 1 2 3 4 MILES

CAINOZOIC	QUATERNARY		Qz	*Alluvium*
			Qc	*Colluvium*
MESOZOIC			m	*Flat-lying sandstone, conglomerate, gritstone and siltstone. capped by silcrete and laterite.*
PROTEROZOIC			do	*Metamorphosed dolerite plugs*
			Egu	*Naraku Granite*
			Egl	*Williams Granite*
		Roxmere Quartzite	Elr	*Cross-bedded, ripple-marked well-sorted quartzite and sandstone*
		Corella Formation	Elc	*Metamorphosed bedded carbonate rocks, including calc-silicates (with tremolite, diopside, albite, scapolite and sphene), marble and para-amphibolites.*
			Elc ▲	*Brecciated Calc-silicates*
			dl	*Metamorphosed gabbro and dolerite sills*
	Marimo Slate	Mick Creek Sandstone	Elm2	*Feldspathic sandstone, ferruginous sandstone, siltstone, minor limestone and marl*
		Slate Member	Elm1	*Black and grey slate and brown meta-siltstone*
			db	*Meta-basalts, meta-dolerites and ortho-amphibolites*
	Soldiers Cap Formation	Toole Creek Meta-volcanics	Els3	*Massive meta-basalts and associated meta-dolerites with intercalations of pelitic meta-sediments, chert, sandstone & jaspilite*
			dbEls3	*Basic meta-igneous rocks of the Toole Creek Meta-volcanics, with sedimentary intercalations*
			Els3db	*Meta-sediments of the Toole Creek Meta-volcanics, with basic igneous intercalations*
		Weatherly Creek Quartzite	Els2	*Metamorphosed cross-bedded quartzite, siltstone, feldspathic and micaceous sandstone and pelitic sediments*
			dbEls2	*Meta-basalts and meta-dolerites with sedimentary intercalations of the Weatherly Creek Quartzite*
			Els2db	*Meta-sediments of the Weatherly Creek Quartzite with meta-basalt and meta-dolerite intercalations*
		Snake Creek Meta-turbidites	Els1	*Arenaceous & pelitic schists including graded-bedded & laminated meta-greywackes, meta-siltstones and meta-argillites Garnet, staurolite and andalusite-bearing schists are common*

Major geological boundary
Minor geological boundary
Outcrop boundary
Unconformity (U opens towards younger formation)
intrusion / country rocks — *Intrusive contact*
Anticline, showing plunge
Syncline, showing plunge
Overturned anticline, showing plunge
Overturned syncline, showing plunge
Plunge of minor anticline
Plunge of drag-fold
Fault
Inclined fault
Fault showing relative horizontal movement

Prevailing strike & dip of strata
Strike & dip of strata, measured
Strike & dip of strata, with plunge of lineation
Prevailing strike & dip of strata, facing unknown
Strike & dip of strata measured, facing unknown
Strike and dip of strata, facing unknown with plunge of lineation
Younging
Vertical strata
Overturned strata
Trend lines
Trend line, dip 0-30° (air-photo interpreted)
Trend line, dip 70°-90° (air-photo interpreted)
Strike and dip of foliation

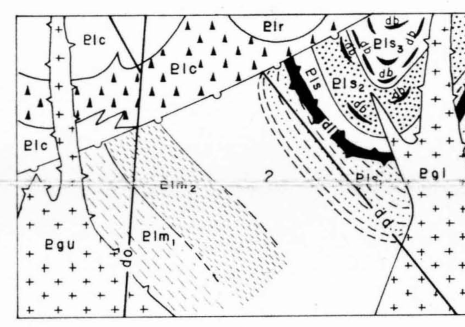
Strike & dip of schistosity
Strike & dip of schistosity with plung of lineation
Vertical schistosity
Prevailing strike and dip of joint
Vertical joint
X31A,B — *Sample locality with number*
Quartz veins or silicified zones
Basic igneous sheet or dyke
Metamorphosed dolerite dyke

Mine
Mine not worked
Open cut
Dump
AU — *Gold*
CU — *Copper*

Bore
Windpump

Road
Track
Railway with station
Airport
"Levuka" — *Homestead or building*
Trigonometrical station

DIAGRAMATIC RELATIONSHIP OF ROCK UNITS



INDEX TO AUSTRALIAN
1:100,000 SERIES

6957	7057	7157
6956	CLONCURRY 7056	7156
6955	7055	7155

To accompany Record 1970/24

F54/A2/34