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1961/142

EXPLANATORY NOTES TO THE DUCHESS GEOLOGICAL SHEET

Compiled by

E.K. Carter and A.A. Öpik

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GEOLOGICAL INVESTIGATIONS

The explorer Burke recorded in his diary notes on the rocks of the area (Jackson,1862), and McKinlay (1863) noted a specimen of copper in the east of the area. Government geologist Jack (1885) just entered the area, on a traverse along Duck Creek and the Cloncurry River. By this time alluvial gold and copper were being extensively worked farther north and the Hampden / Mount Elliott mineralization had been located. Rands (1895) reported on some of the workings along and near the Cloncurry River valley, and Ball (1908) reported on many of the workings on the Sheet area - they had become very numerous by this time. Cameron (1901) and Ball also gave general accounts of the geology of the mineral-bearing area. Dunstan (1920) was the next to attempt to interpret the general geology but, like Ball, did not attempt any stratigraphic subdivision of the mineral-bearing rocks. Shepherd (1928, unpublished, see Shepherd, 1946) subdivided the Precambrian sequence, and his classification was used by David (1932). The Aerial, Geological and Geophysical Survey of Northern Australia mapped the two most conspicuously mineralized areas - Kuridala/Mount Cobalt and Duchess/Trekelano - and carried out several geophysical surveys (see Bibliography) between 1935 and 1940. In addition many reports on mineral deposits were made by Government, and other, geologists.

Until recent years little work had been done on the Palaeozoic and Mesozoic rocks of the area. Whitehouse (1931,1936,1939) established the presence of Cambrian rocks, and brief accounts of the Mesozoic appear also in some of the publications referred to above.

The present map is based on regional surveys by the Bureau of Mineral Resources and the Geological Survey of Queensland in the years 1953-1956. The results are reported in detail in Carter, Brooks, & Walker (1961) and White (in press), for the Precambrian, and by Öpik (1961) for younger strata. Some geophysical, geochemical and palaeontological (Mesozoic) investigations of recent years are reported in unpublished Bureau records and Company reports.

In the notes that follow, Carter compiled the sections on Precambrian geology and economic geology, and Öpik those on physiography, geomorphology, history of the land surface, Phanerozoic geology, and underground water resources.

PHYSIOGRAPHY

The area lies within the Australian tropical interior province of climates, but it is still semi-arid. Summer is the rainy season, with about 15 inches in the south-west, and 20 to 25 inches in the north-east. It is pastoral land (cattle; sheep in the east). The vegetation on Precambrian rocks, and on the sediments of the Selwyn Range, is scrubby woodland with small grass plains and savannah on level ground. Tussock grassland (prairie) prevails on the plain of the Artesian Basin in the east and south-east, and on the Burke River Plain. Streams are fringed with tall timber and scrub. Skeletal soils are dominant, but the grass lands have dark brown pebbly and sandy soils with intervening black soil areas and rubble-covered limestone pediments.

The altitude is low, but the area has the highest summits in the whole region of north-western Queensland. Mount Guide (in north-west) may exceed 2000 feet and stands on a rugged upland with pass altitudes around 1500 feet. The Selwyn Range is mostly above 1200 feet, but declines to 920 feet in the extreme east of the area. High summits are also present south-west of the Selwyn Range, for example 'The Brothers' and Mount Aplin (1500 feet, and 450-500 feet above the pediment). The country declines in the east (east of the watershed formed by Precambrian and Mesozoic rocks) to 600 feet, and to the south and south-west to 800 feet. All streams are intermittent; Wills Creek, Malbon River, and Cloncurry River have distinct but shallow valleys, and especially broad is the valley of the Burke River with the plain as its floor.

The drainage is divided by the Selwyn Range into the Gulf of Carpentaria and Lake Eyre systems. Most of the Gulf of Carpentaria drainage belongs to the catchment of the Cloncurry River and tributaries, and a minor part to the headwaters of the Leichhardt River. Tributaries of the Diamantina River (Lake Eyre system) drain the southern, central and western part of the country. Among these streams the Burke River has the largest catchment (2700 square miles) within the area. The Hamilton, which is a large stream, drains only about 650 square miles of the area.

GEOMORPHOLOGY

The geomorphology of the area has been discussed previously by Twidale (1956), and by Öpik (1956; 1960)

The major structural divisions are:

I. the basement shield, which is divided into a western and an eastern upland by

II. the Burke River Outlier of lower Palaeozoic rocks;

III. the plain of the Artesian Basin in the east and south-east; and, finally,

IV. Plateaux and mesas of Cretaceous sediments which are outliers of the sequence of the Basin, and superimposed on the shield, and on the Burke River Outlier.

(See fig.1 page 4.)

The Shield

In the eastern upland of the shield the sub-Cretaceous old land is being exhumed, and its area is expanding concurrently with the retreat of the Mesozoic cappings. The rocks of the sub-Cretaceous surface are, according to White (in press), 'so highly leached and altered that their original nature is not always apparent'. 'They are the product of the deep and intensive weathering to which the Precambrian rocks were subjected before Mesozoic strata were laid down.' A large part of this surface is granite, with a rolling relief of a plateau, but the relief on folded strata consists of meridional valleys and rugged ridges, some of which are truncated.

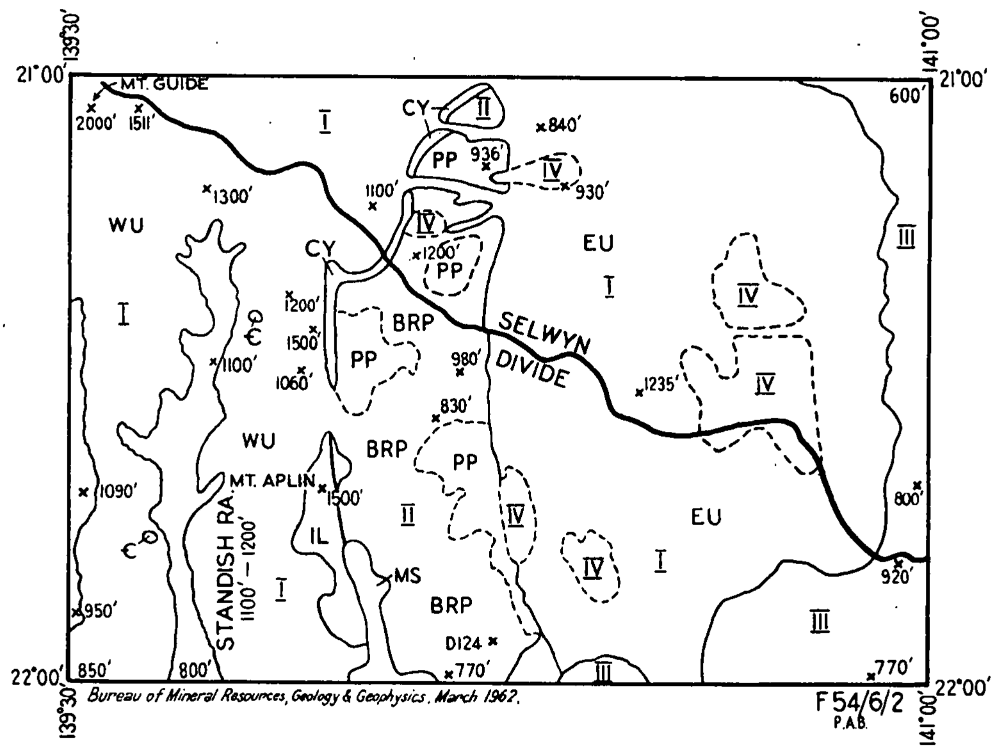


Fig. 1. Structural divisions and geomorphology of the Duchess Sheet area.

I - Shield; WU - western upland; EU -eastern upland.

II - Burke River Outlier of lower Palaeozoic rocks

CV - cuestas and marginal valleys; IL - inselberg landscape; MS - Mt. Merlin/Signal Hill limestone ridges; PP - plateaux, mesas, and pediments on Cambrian rocks;

BRP - Burke River Plain.

III - Plain of the Artesian Basin.

IV - Plateaux and mesas of Cretaceous rocks;

D124 - Cretaceous residual on a limestone pediment within the Burke River Plain.

Altitudes above sea level (e.g. 600) in feet.

The western upland is dominated by a ridge-and-valley relief with a rather immature appearance, but structural plains occur on less resistant Kalkadoon Granite and rocks of the Corella Formation, as for example around Trekelano. This relief is probably inherited from the sub-Cretaceous old land, but Cretaceous outliers are absent and intact remnants of an exhumed surface (in its strict sense) cannot be identified. Modern erosion is also progressing, although its pace appears to be slow. At Garden Creek (longitude 139°31' E, latitude 21°52'S) minor outliers of Beetle Creek shale and chert indicate a preserved fragment of the sub-Middle Cambrian land surface. On the whole little is preserved of this old land in the western upland, which was upwarped in the Ordovician (Smoky Anticline, Öpik 1960), and during the Ordovician-Jurassic interval lost its superstructure and some 400-500 feet of the basement at its eastern flank (Mount Aplin) and much more on the crest. The relief of the sub-Middle Cambrian surface is, however, preserved in the Urandangi Sheet area in the western flank of the anticline with the belt of 'minor outliers', and in the south.

The Burke River Outlier of Lower Palaeozoic Rocks

The relief of the Outlier is quite diversified, and can be classified as follows:

1. features on deformed strata along the western and northern margin;
2. Plateaux and pediments on subhorizontal rocks within the Outlier, and
3. the depositional Burke River Plain.

Along the margin north of Pilgrim Creek, cuestas and hogbacks are prevalent along the faults, and two narrow valleys, one along the Pilgrim Fault, and the other, smaller, at the Roaring Fault, are present. South of Pilgrim Creek, from Mount Birnie to Mount Murray, an inselberg landscape is developed. The hills are hogbacks (at Mount Murray), cuestas (e.g. Mount Birnie) and mesas (Mount Aplin, Mount Bruce, Mount Murray) fringed by pediments which are truncating Precambrian, and even Cambrian, rocks. Finally the Mount Merlin/Signal Hill area has a landscape of low anticlinal limestone ridges fringed by pediments. The relief on the subhorizontal rocks within the Outlier is low. The O'Hara Shale forms plateaux and mesas with cliffs up to 100 feet high. These cliffs and slopes are retreating and limestone pediments have gradually been exposed. The pediments are transitory, being dissected by streams, and a bastion landscape has developed, with terraced limestone hills and escarpments. It is most prominent in the Selwyn Range part of the Outlier. But within the Burke River Plain several small limestone pediments occur that are apparently part of a sub-Cretaceous surface, as a minute residual of Cretaceous shale may be seen at locality D124. In the north similar evidence is provided by a Mesozoic conglomerate whose residuals are present on the Cambrian and Precambrian rocks.

The Burke River Plain is a depositional feature. The limestone in it was deposited in a lake, late in Tertiary time. The surface of this limestone dips at a very low angle to the south, indicating a post-depositional tilting induced by the Selwyn Range uplift. This tilting drained the lake, restored the drainage on its floor, and accelerated the retreat of the shale plateaux and the dissection of the transitory pediments. To conclude, the surface of the Outlier was a part of the sub-Cretaceous old land, with a relief generally similar to the present surface. The exhumation began about the Cenomanian, but the ensuing erosion affected also the old-land cappings of the O'Hara Shale. The present course of erosion is directed toward a complete obliteration of the surficial features of the sub-Cretaceous old land.

The Plain of the Artesian Basin

The plain of the Artesian Basin in the east and south-east slopes down from the divide to the north, from 920 feet to 600 feet over a distance of 54 miles - about 6 feet in a mile; and to the south from 920 feet to 770 feet over a distance of 15 miles - about 10 feet in a mile. North of the divide, however, all streams run east, indicating a pronounced slope in the same direction and off the shield. This plain can be regarded as a product of pedimentation. The morphogenesis of the plain, however, cannot be solved in the narrow strip within the Duchess Sheet area (see Twidale, 1956). The area of the present plain was exposed to erosion since the Cenomanian, and attained its present relief before the Selwyn Range uplift.

The Plateaux and Mesas of Cretaceous Rocks

The superimposed plateaux and mesas of Cretaceous sediments have been discussed already. On the eastern upland they form a conspicuous feature; their number and size decreases rapidly to the west; very few of them are preserved on the surface of the Outlier and none has been found on the western upland. These outliers indicate a former continuity of the Cretaceous cover with the sequence of the Artesian Basin.

HISTORY OF THE LAND SURFACE

The geomorphological structural background of the area came into being with the downfaulting of the Burke River Outlier and the warping of the Smoky Anticline in the west about the later half of the Ordovician Period.

During the large interval between the Ordovician and early Cretaceous, erosion removed the Lower Palaeozoic superstructure from the horsts and degraded the upwarped basement, and shield conditions, diversified by the meridional Outlier, came into being. The erosion also obliterated the pre-Middle-Cambrian surface that existed during the Middle Cambrian/Lower Cambrian interval, and the sub-Cambrian land surface in general.

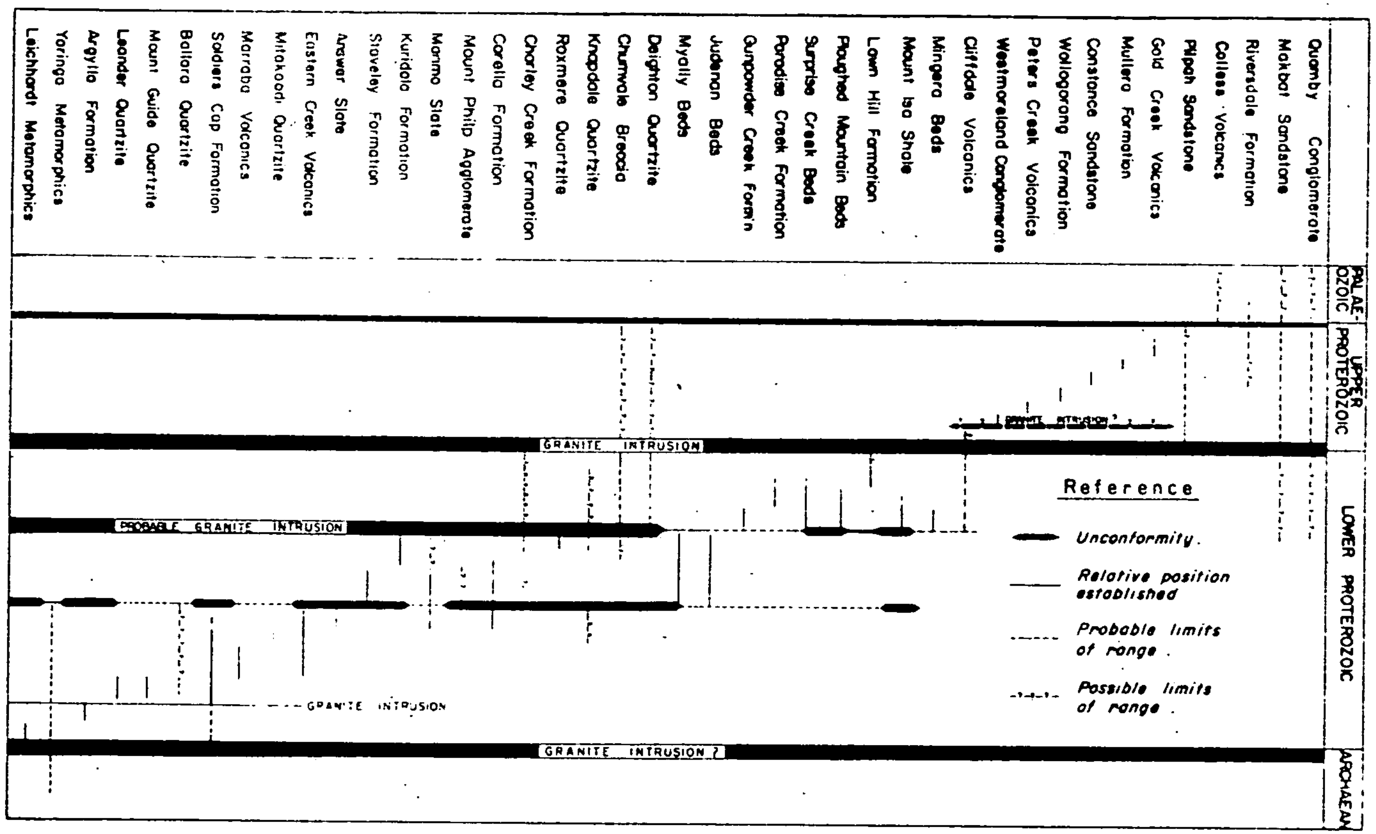
These surfaces are still preserved in the belt of the Minor Outliers in the west (Urandangi/Mount Isa/Camooweal Sheets) along the western flank of the Smoky Anticline (Öpik, 1960).

Late in the Jurassic subsidence began, and in the Aptian the land was inundated, except for the highest part of the ranges in the north-west.

In the Cenomanian the land emerged as a platform with a superstructure of Cretaceous sediments and a depositional surface. During the Upper Cretaceous and the greater part of the Tertiary this superstructure was eroded and the present drainage pattern, which reflects generally the drainage of the pre-Cretaceous landscape, was developed. The shield once more was exhumed.

At the end of the Tertiary an intervening subsidence slowed down the erosion even further, and the Burke River valley with its flood plains lost its grade and became temporarily a lake receiving deltaic material from its still

TIME RELATIONSHIPS OF PRECAMBRIAN UNITS
NORTH-WEST QUEENSLAND



Notes :

1. The relations [illegible] the E[illegible]stern Creek Volcanics, Marraba Volcanic[illegible], and Soldiers Ca[illegible] F[illegible] are assumed to be [illegible]
2. Lines re[illegible] Formations are not to scale.
3. The probable [illegible] unconformities (in terms of degree of angular unconformity or time break [illegible]) [illegible] indicated [illegible] the thickness of the symbol.
4. Distribution [illegible] which do not extend throughout the region is largely interpretative: an attempt has been made to [illegible] by reference to outer [illegible] units.
5. An unconformity [illegible] Middle from Lower Cambrian, and there may be several in the late Upper Proterozoic.

QG 34-4

TABLE 1

PRECAMBRIAN STRATIGRAPHY OF THE DUCHESS SHEET

AGE	ROCK UNIT	POSITION IN SEQUENCE, DISTRIBUTION	LITHOLOGY	THICKNESS (FEET)	TOPOGRAPHY	STRUCTURE	CORRELATIONS	UNDERGROUND WATER	MINERAL DEPOSITS
UPPER PROTEROZOIC?	Makbat Sandstone	Unconformably over Argylla Fm and Kalkadoon Gran. Possible range L. Proterozoic - Palaeozoic. S.W. of Sheet, also Boulia Sheet.	Quartzitic sandstone, siltstone, shale, some conglomerate.	1,000+	Forms small range; strike ridges, steep gullies.	Synclinal dips to at least 50°; ?faulted.	Possibly equivalent to Mt Birnie Beds but thicker, more altered.	Probably small local supplies.	None known.
LOWER PROTEROZOIC	Deighton Quartzite	Unconformably over Corella Fm. N.W. of Sheet, also Cloncurry Sheet.	Quartzite.	7,000 Thickness on Sheet unknown	High, steepsided hills.	Strongly folded, faulted.	?Roughly equivalent to Surprise Ck Beds & contemporaneous units (not on Sheet)	"	"
	Roxmere Quartzite	Probably conformably over Corella Fm. N.E. of Sheet, also Cloncurry Sheet.	Quartzite	4,000?	Hilly	Steep-dipping, faulted.	Probably equivalent to Knapdale Qte. (not on Sheet)	?	"
	Corella Formation	See 'Time relationship' diagram on map. Widely through Precambrian area of Sheet; extends 115 miles N of Sheet.	Calc-silicate and other moderate to high grade metamorphics generally thin-bedded; some breccia.	10,000?	Open plains to rough hills.	Intricately folded, faulted.	Myally and Judenan Beds (not on Sheet); Marimo Slate; Staveley & Kuridala Fms jointly.	Good local supplies.	Cu, Au, U, Ls. (other minerals on other Sheets).
	Mount Philp Agglomerate	Lens in Corella Fm? N. margin of Sheet at long. 139°58'E; adjoining part of Cloncurry Sheet.	Agglomerate, extensively feldspathised; metabasalt, metasediment.	?	Rough, low hills.	Domal?		?	None known.
	Marimo Slate	Conformably over Mitakoodi Qte. Along Cloncurry River, N.E. of Sheet, & Cloncurry Sheet, S. of Cloncurry.	Sandy slate, impure quartzite (qtz greywacke in part), calc-silicate rock, including breccia; limestone, some metabasalt.	8,000+?	Open valleys, some steep ridges.	Complex folding some beds overturned; extensive faulting.	Part, or all, of Corella Fm, Answer Slate, Staveley Fm & Kuridala Fm.	Local Supplies.	Cu, Au, Mn, Some U, Ls.
	Kuridala Formation	Conformably over Staveley Fm. N.S. belt in E-centre of Sheet; extends S. of Sheet.	Slate, sericite schist, quartzite; some silty, carbonaceous and limy beds.	8,000	Generally slight to moderate relief; some ridges.	Strongly folded, overturned, faulted.	Upper Corella Fm and part of Marimo Fm?	Poor local supplies	Cu, Au, Co. Mn, W, U.

TABLE 1

AGE	ROCK UNIT	POSITION IN SEQUENCE, DISTRIBUTION	LITHOLOGY	THICKNESS (FEET)	TOPOGRAPHY	STRUCTURE	CORRELATIONS	UNDERGROUND WATER	MINERAL DEPOSITS
LOWER PROTEROZOIC	Staveley Formation	Locally unconformably over Answer Slate. N.S. belt in E-centre of Sheet.	Limestone and dolomite, calcareous shale and siltstone, siltstone, calc-silicate rocks including breccia, sandstone.	2,000 to 8,000+	Generally low relief, some ridges.	Strongly folded, overturned, faulted.	Part of Marimo and Corella Fms.	Local supplies, probably small.	Cu, Fe, Mn, Probably other metals.
	Answer Slate	Conformably over Mitakoodi Qte. N.S. belt in centre of Sheet.	Slate, siltstone, chert. Deeply weathered.	2,000?	Low to moderate relief; strike ridges.	Strongly folded, faulted.	Lower Marimo Fm. Possibly lowermost Corella Fm. or uppermost Soldiers Cap Fm.	Local supplies, probably small.	Cu, Au. Probably other metals.
	Mitakoodi Quartzite	Conformably over Marraba Volcs. N.S. belt, centre of Sheet & S.E. centre of Cloncurry Sheet.	Quartzite; some metabasalt, tuff and schist.	4,000?	Strike ridges	Steep-dipping, faulted.	Top of Eastern Creek Volcs; top of Soldiers Cap Fm.	Small local supplies	Ag, probably other metals.
	Marraba Volcanics	Conformably above Argylla Fm. N.S. belt centre of sheet, E. centre in N; also Cloncurry Sheet S.W. of Cloncurry.	Quartzite, metabasalt, schist.	10,000+?	Strike ridges	Steep-dipping, faulted.	Middle part Soldiers Cap Fm; Eastern Creek Volcs.	Small local supplies	Cu, Co, Au, on other Sheets.
	Eastern Creek Volcanics	Conformably over Mt Guide Qte. W. edge of Sheet, part of 180 mile N.S. belt, also on Urandangi, Mt Isa, Cloncurry, Camooweal, and Dobbyn Sheets.	Interbedded metabasalt and metasediment; some moderate grade metamorphics.	20,000? Thickness in Sheet area unknown.	Rough, but low to moderate relief.	Strongly folded, faulted.	Mitakoodi Qte. and Marraba Volcs. jointly, part of Soldiers Cap Fm.	Local supplies	Cu and U on other Sheets.
	Soldiers Cap Formation	Unconformably below Corella Fm. on Cloncurry Sheet. Other contacts faulted or not clear. E. of Sheet, S.E. of Cloncurry Sheet.	Mica schist (including garnet-andalusite schist) and amphibolite (possibly intrusive). Metabasalt, quartzite, shale and chert on Cloncurry Sheet.	25,000+	Rough, hilly, to open plains with poor outcrop.	Strongly folded, some over-turned; faulted.	See 'Time Relationship' chart on map.	Local Supplies	Cu, Au, minor occurrences of other metals and mica.
	Ballara Quartzite	Conformably over Argylla Fm. N.W. of Sheet and S.W. centre of Cloncurry Sheet.	Quartzite	2,000+	Steep ridges and valleys	Strongly folded, faulted.	Probably equivalent to Mt Guide and Leander Qtes. and quartzite at base of Marraba Volcs.	Probably small local supplies	Cu (Cloncurry Sheet)

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AGE	ROCK UNIT	POSITION IN SEQUENCE, DISTRIBUTION	LITHOLOGY	THICKNESS (FEET)	TOPOGRAPHY	STRUCTURE	CORRELATIONS	UNDERGROUND WATER	MINERAL DEPOSITS
LOWER PROTEROZOIC	Mount Guide Quartzite	Disconformably or conformably above Argylla Fm W. margin of Sheet.	Quartzite, commonly feldspathic, some arkose and conglomerate; some metabasalt near top.	4,000 to 8,000+	Steep ridges and bedding- or joint-controlled valleys.	Strongly folded, faulted, jointed.	Leander Qte., probably Ballara Qte.	Local Supplies	None known
	Argylla Formation	Probably conformable on Leichhardt Metamorphics. West and centre of Sheet. Extends 115 miles to N. and 6 miles to S. of Sheet.	Altered acid lavas with interbedded altered tuff, schist, slate, quartzite, particularly in E. Metabasalt near top in west. Conglomerate?	10,000?	Generally rough but low to moderate relief; alluviated plain in S.	Strongly folded, faulted.	Lower part Soldiers Cap Fm.	Poor, Local supplies where deeply weathered.	Cu. Poor deposits of other metals.
	Leichhardt Metamorphics	Probably conformably below Argylla Fm (see text). Underlying rocks not known. Mainly N.W. of Sheet. Extends 90 miles N. of Sheet.	Gneiss, schist, recrystallized acid lavas, amphibolite; some metasediments and migmatite.	?	Generally low to moderate relief, but rough.	Highly deformed.	None	Poor	Weak metallic mineralization.

active tributaries. The Selwyn Range uplift restored (probably only partly) the grade of the river, and erosion was revived at its headwaters.

To conclude, the present land surface is a slightly 'trimmed' Tertiary land surface, which itself reflects the pre-Cretaceous landscape of the area.

GEOLOGY

PRECAMBRIAN

The stratigraphic relationships, lithology, thickness, distribution, topographic expression, and mineral resources, including underground water, are summarized in Table I. The time relationships of all the Precambrian units of north-western Queensland are shown in the chart opposite. Since the chart was printed a clearer understanding of the relationships between the Leichhardt Metamorphics, Argylla Formation, and Kalkadoon Granite has been obtained. It was previously known, from evidence in the Cloncurry Sheet area, that a part of the Kalkadoon Granite that intruded the Leichhardt Metamorphics was older than some of the younger Lower Proterozoic sediments; further, the Argylla Formation appeared to be less metamorphosed than the Leichhardt Metamorphics. The Leichhardt Metamorphics and the oldest parts of the Kalkadoon Granite (granodiorite, see p. 12) were therefore considered to be possibly Archaean. Later field work indicated that the Leichhardt Metamorphics and Argylla Formation are structurally, and presumably stratigraphically, conformable, and petrological work by Joplin & Walker (in press) showed that the dacites of the Leichhardt Metamorphics and the Argylla Formation could be co-magmatic with the granodiorite of the Kalkadoon Granite. All the Precambrian rocks in the Duchess Sheet area are therefore now regarded as Proterozoic.

The terms Proterozoic and Archaean are used for the younger and older Precambrian respectively. As little data are available for the age of the strata and, further, the point of division between the two, in terms of absolute ages, is not universally agreed upon, the rocks may be as old as rocks mapped elsewhere as Archaean. Preliminary determinations on uranium ore from Mary Kathleen indicate an age of

1640 ± 200 million years. Some of the rocks in the region are therefore probably older than 1700 million years.

The Leichhardt Metamorphics, the oldest rocks in the Sheet area, contain very diverse strata, but metamorphosed acid lavas - particularly grey metadacite and metarhyolite - form a large part of the succession in places. Structure is complex and has not been resolved, but presumably the overall structure of the outcropping formation is anticlinal, though modified by faulting. The boundary between the Leichhardt Metamorphics and the Argylla Formation is uncertain in many places.

Extensive conglomerate is found in, or in contact with, the Argylla Formation, in the north-west of the Sheet and the adjacent part of the Cloncurry Sheet. It marks an erosional break between either the Leichhardt Metamorphics and the Argylla Formation or the Argylla Formation and the Mount Guide Quartzite.

The Mount Guide Quartzite is the stratigraphic equivalent of the Leander Quartzite, in the Cloncurry and Mount Isa Sheet areas. The two formations are lithologically similar except that the Mount Guide Quartzite contains extensive feldspathic sandstone, and arkose and conglomerate at the base; both have pronounced meridional joints.

Ballara Quartzite appears to be conformably over the Argylla Formation, but locally has a basal conglomerate, and has two, or more, metabasalt flows; it is therefore regarded as contemporaneous with the Mount Guide Quartzite.

The body of Eastern Creek Volcanics shown in the extreme south-west of the Sheet area contains no metabasalt but is the same age as the Eastern Creek Volcanics in the Urandangi Sheet area; it has therefore been included with the Eastern Creek Volcanics rather than separated as a new unit. The absence of metabasalt may reflect the general increase in the volume of metasediments and diminution in lava content in the south of the outcrop area of the formation.

In the Duchess Sheet area the Soldiers Cap Formation consists mainly of schist. It resembles the lower beds of the formation in the Cloncurry Sheet area; both contain amphibolites, but those in the Cloncurry Sheet are known to be intrusive, whereas the origin of those in the Duchess Sheet area is not known. The quartzite, slate, and chert of the upper two divisions of the Soldiers Cap Formation, with the numerous interbedded metabasalt lavas, do not appear in the Duchess Sheet area.

The Marraba Volcanics are best developed in the Cloncurry Sheet area, where metabasalt is more abundant than farther south. South of the Wimberu Granite the formation appears to be much thinner than in the type area and owing to poor exposure quartzite, with some metabasalt, is the main outcropping rock type.

Some of the beds of the Mitakoodi Quartzite in the Duchess Sheet area are argillaceous, giving argillaceous or sericitic quartzite and siltstone, but pink quartzite, feldspathic and cross-bedded in part, is the predominant metasediment.

The Answer Slate is regarded as equivalent to the lowermost part of the Marimo Slate, and the minor unconformity above it is correlated with that at the base of the Corella Formation (which see). White (in press) suggests that the chert, which contains abundant feldspar, may have been formed by the silicification of a clayey limestone.

The Staveley Formation is highly lenticular; its thickness probably ranges from 2,000 to more than 8,000 feet owing to deposition on a near-shore shelving sea floor. White (in press) has named a large lens of siltstone the Agate Downs Siltstone Member. The lens is at the base of the Staveley Formation and is best developed between the Cloncurry River and Limestone Creek. White has also named two members in the Kuridala Formation. They are both mainly of carbonaceous and graphitic, commonly pyritic, slate: one, the Mount Elliott Slate Member, lies at the top of the formation, is lenticular, and is up to 800 feet thick; the other, the Hampden Slate Member, occurs only in the core of a basin near Kuridala, at the top of the formation, and is about 500 feet thick.

The Marimo Slate is considered to be contemporaneous with the Answer Slate, Staveley Formation, and part at least of the Kuridala Formation, but contains more greywacke and greywacke slate than the southern units. The southern contact of the formation is arbitrarily placed at a fault.

Characteristically the Corella Formation, the most extensive of all the Precambrian units of the region, is very thin-bedded; the numerous lenses of breccia provide the exception. Despite the wide range of metamorphism the bedding is generally well-preserved. Probably the base of the formation is not everywhere of the same age: in places the unit appears to overlie the Mitakoodi Quartzite conformably and in others it unconformably overlies older units. The Mount Philp Agglomerate is thought to form a lens within, and probably near the base of, the Corella Formation because it contains numerous fragments of actinolitic rock that were probably originally part of the Corella Formation and because the structure of the unit appears to be domal. The rocks have been so thoroughly metamorphosed and metasomatized that petrology has been of little help in establishing their origin. Determination of the main rock type as agglomerate is therefore based on field appearance, presence of rare basaltic fragments in the rock, and presence of interlayered vesicular metabasalt.

The stratigraphical position of the Roxmere Quartzite is also in doubt because of extensive faulting. One apparently unfaulted contact suggested a conformable, or possibly disconformable, relationship.

Only a few small outcrops of Deighton Quartzite appear in the Duchess Sheet area and relationships have not been determined from them; in the Cloncurry Sheet area the type occurrence is clearly unconformable over the Corella Formation. The unit is very strongly, though simply, folded and is therefore regarded as Lower Proterozoic, but its relationship to the various granite bodies has not been clearly established.

The age of the Makbat Sandstone cannot be clearly established. It may be contemporaneous with the Lower Cambrian Mount Birnie Beds, but owing to its greater thickness, the presence of quartz veins and the widespread silicification the two units have not been correlated.

Intrusive Igneous Rocks

Granite (see Joplin,1955; Joplin & Walker (in press); Carter, Brooks, & Walker, 1961).

Granitic bodies have been named according to distribution and not according to rock type; probably all are composite bodies, though for most named granites there is a dominant type. The petrological types include granite, adamellite, granodiorite, soda granite, and albitite.

The main rock type of the Kalkadoon Granite is a coarsely prophyritic microcline-plagioclase-biotite granodiorite, of similar composition to the metadacite it intrudes. The feldspar is generally white in the Duchess Sheet area, but pink farther north. South of Duchess, granite similar in composition to the Wonga Granite forms the main rock mass east of the Wills River: probably it should be mapped as Wonga Granite rather than Kalkadoon Granite. Other acid igneous rocks in the Kalkadoon Granite are a pink massive granite with large feldspar phenocrysts, and dyke-like bodies of pink microadamellite and microgranite, white albitite and soda granite, aplite and pegmatite. Outcrops of Kalkadoon Granite extend 90 miles north and 5 miles south of Duchess Sheet area.

Three bodies of granitic rocks in the north-central part of the Sheet, east and west of Cambrian sediments, have been grouped as Wimberu Granite. Field observations show them to be very varied both within each body and between outcrops. Probably the main rock type is a coarse-grained, porphyritic, massive, pink adamellite with large phenocrysts of microcline and plagioclase. The adamellite is intruded by both microgranite and aplite. The Wimberu Granite does not extend beyond the Sheet boundaries.

As mapped, the Williams Granite, which crops out extensively in the east of the Sheet area, also is confined to the Duchess Sheet. The main rock type is probably a coarse massive granite or adamellite, low in ferromagnesian mineral content. It is generally coarser and, in places, more porphyritic in the south than in the north. Other acid intrusive rocks included with the Williams Granite are microadamellite (which forms some large bodies), microgranite, and albitite. Aplite, including soda aplite, and mica pegmatite are common in places.

Only small bodies north of Duchess have been mapped as Wonga Granite (which extends 60 miles to the north of the Sheet) although the same rock type apparently extends to the south (see above). Generally the Wonga Granite is a pink medium to coarse-grained microcline-biotite-hornblende granite. North of the Duchess Sheet area it is commonly highly foliated and porphyritic, but these features are not so pronounced within the Sheet area. Extensive relict sedimentary structures, showing replacement, can be seen in places. The main granite mass is intruded by bodies of red microcline microgranite, and veins of potash-rich microgranite, aplite, and feldspar-rich pegmatite.

The age relationships and petrogenesis of the various granitic rocks are discussed by Joplin & Walker (in press).

Amphibolite, Metadolerite and Dolerite

Basic intrusives, of several ages but all probably Precambrian, occur widely in the Precambrian rocks. Five categories, based on field evidence, appear on the Sheet. Petrological work by K.R. Walker has resulted in some modification (see Carter, Brooks & Walker, 1961). The five categories are:

1. The swarms of dykes , shown without symbol, in the Leichhardt Metamorphics, Argylla Formation, and Kalkadoon Granite. The rock is mainly amphibolite, but at least two ages of intrusion are represented. The oldest may be older than the Argylla Formation; others may be related to the Eastern Creek and Marraba vulcanicity.

2. The bodies marked db, in the north-centre and north-west of the Sheet, are amphibolitic complexes that possibly contain both flows and intrusions. Some of the intrusions may be genetically related to the Eastern Creek and Marraba vulcanicity.

3. The sills and bosses in the east-centre of the Sheet, marked ds. They are of metadolerite and are affected by granite. Their age is not certain. Carter considers them to be younger than the first folding of the enclosing metasediments, but White (in press) believes that they probably antedate the deformation of the sediments. For this reason they are not grouped with either category 2 or 4.

4. The dykes and bosses marked dl. As these commonly occupy faults or fold structures they are clearly younger than the first folding of the region, but they have been altered by regional metamorphism to form metadolerites; some are also affected by granite.

5. The roughly east-striking dykes marked do are of dolerite. Many cut the Williams Granite; they are fresh, though sheared in places, and typically weather spheroidally.

In addition to the five groups shown on the map, amphibolite occurs extensively in the Soldiers Cap Formation, but it is not known whether it is derived from basalt or dolerite. Basic igneous rocks probably also intrude the Corella Formation and basic migmatites occur in several places.

Metamorphism and Metasomatism

The Makbat Sandstone is indurated and is silicified in places but appears to be unmetamorphosed; all older layered rocks, and some of the intrusives, are moderately to strongly metamorphosed. The grade of metamorphism of the Deighton Quartzite is not readily discernible because it is composed almost entirely of arenaceous sediments. The Corella Formation, together with contemporaneous and older units, is generally in the greenschist to amphibolite metamorphic facies; locally the cordierite-anthophyllite and staurolite-kyanite sub-facies of Turner & Verhoogen (1951) has been reached. Contact and dislocation metamorphism and metasomatism have been superimposed in places on the regional metamorphism and has produced a great diversity of products.

Some of the highest-grade metamorphic rocks to be found are garnet-andalusite-mica schists in the Soldiers Cap Formation; andalusite-bearing schist has also been recorded about one mile east of Duchess. Edwards & Baker (1954) have described in some detail the rocks around Duchess. These have been subjected to extensive soda and chlorine metamomatism, which has produced scapolite and albite bearing rocks. Typical assemblages in the more highly altered parts of the Corella Formation include scapolite-pyroxene granulite or hornfels, scapolite-biotite schist, scapolite-albite-hornblende schist, hornblende-biotite schist, pyroxene-hornblende-albite granulite or hornfels, and calcite-bearing rocks. The main pyroxenes are diopside and ferriferous augite. Epidote and bladed hornblende or actinolite are also abundant. White (in press) records staurolite-mica schist in the Kuridala Formation.

In addition to the soda-chlorine metasomatism some of the area has been affected by potash metasomatism, which in the extreme case has given rise to potash granite. Pronounced hydrothermal alteration has occurred in places.

Schistosity and cleavage strike parallel to the fold axes, that is generally within a few degrees of north, but are not conspicuous in most parts of the Corella Formation because the strata have yielded plastically and have recrystallized under stress. Some mimetic foliation parallel to relict bedding has been observed.

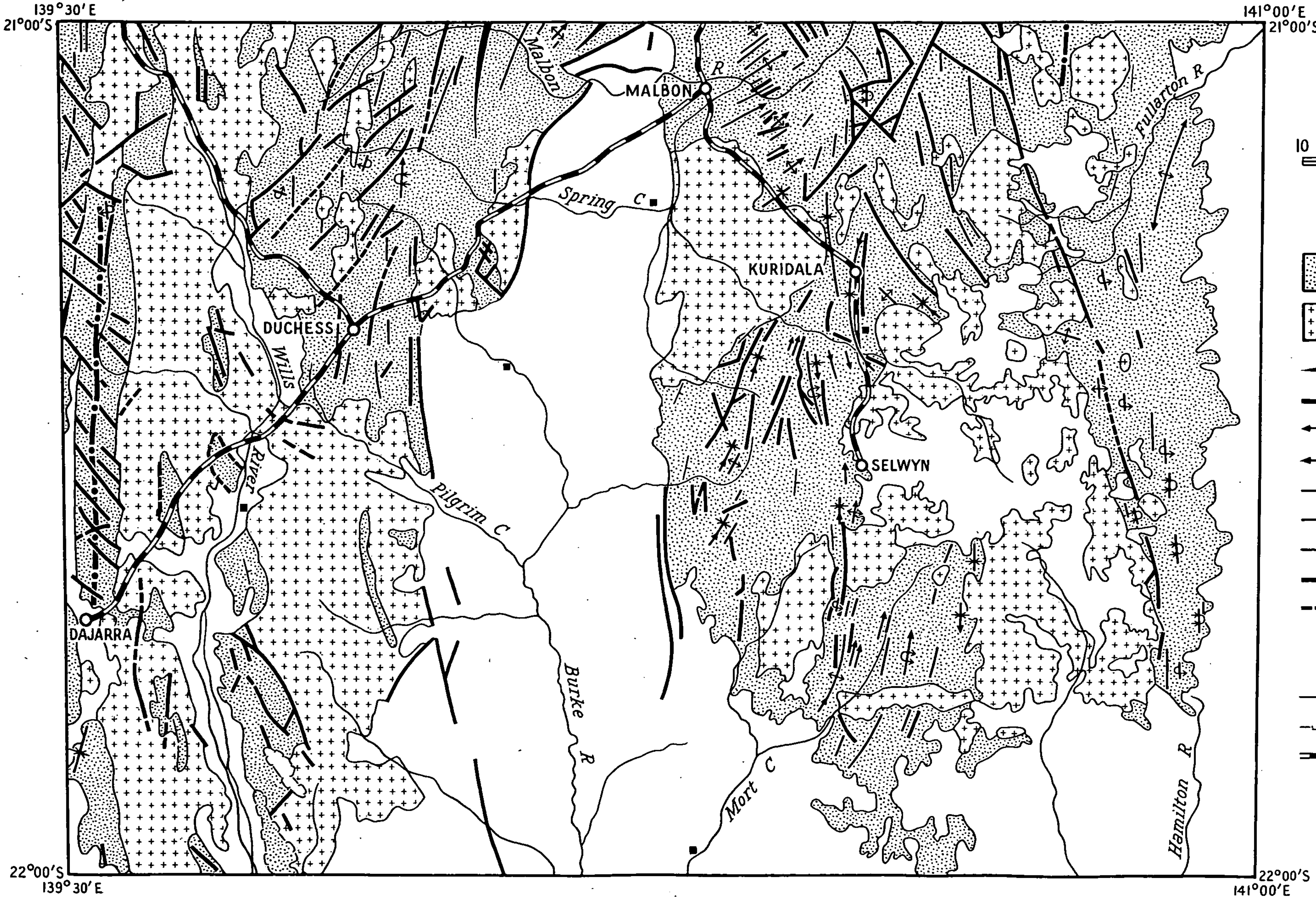
Structure

Fig. 2 presents the elements of the structure of the Precambrian. The deformation is largely the result of two periods of east-west compression. It can be seen that there are three major anticlinoria with roughly meridional strike. The deepest and simplest intervening synclinorium is that whose axis lies roughly along the Kuridala-Mount Cobalt line; the folds are generally overturned to dip east. In addition to the major folds numerous folds of lesser magnitude occur; west of the Cambrian sediments the fold axes generally dip west. Those in the Corella Formation are very complex because of plastic deformation - the beds dip at 60° or more and are folded into tight, elongate basins and domes. The more competent strata, such as the arenaceous beds of Mount Guide Quartzite, are generally fairly simply and openly, though strongly, folded. However, the Mitakoodi Quartzite north of the Wimberu Granite is intricately buckled by a secondary system of folds whose axes strike north-east to east.

Several ages and systems of faults have affected the Precambrian rocks (see Tectonic History):

Fig 2

STRUCTURE OF THE PRECAMBRIAN DUCHESS 4 MILE SHEET AREA



10 0 10 20 MILES

Reference

PRECAMBRIAN mainly LOWER PROTEROZOIC

PRECAMBRIAN Granite

Major anticline

Major syncline showing pitch

Minor anticline showing pitch

Minor syncline showing pitch

Overturned minor anticline

Overturned minor syncline

Fold axis anticline or syncline

Fault, position accurate

Probable fault

Regional dip of bedding

Overturned bedding

Geological boundary

Established unconformity

Railway

Township

Homestead

Bureau of Mineral Resources, Geology and Geophysics. February, 1962.

GD 128

To accompany Record Nº 1961/142

F 54/6/1

MK

1. The dolerite dyke swarm in the Kalkadoon Granite and volcanic formations occupies an early fault system, of roughly meridional trend, with intersecting components.

2. A set of conjugate strike-slip faults whose components strike roughly north-west and north-east. Many of these formed under the first orogenic compression and were reopened or modified by the final Precambrian orogenic deformation.

3. The 'Cloncurry Overthrust' of Honman (1939) - a discontinuous high-angle reverse fault in the east of the Sheet area. It strikes north-north-west and strata are overturned to dip east in its vicinity.

4. Generally roughly meridional strike faults. Both normal and high-angle reverse faults have been recognised. They are probably very widespread but are most readily identified in the eastern half of the Sheet area, west of the Williams Granite, where ironstone bodies and manganiferous cappings are associated with them.

5. The post-Precambrian - largely Palaeozoic - system of faults which forms the western boundary of the Cambrian sediments, in contact with Precambrian.

Probably other fault systems also exist: for example the emplacement of the body of granite elongated east-west, south of Mount Cobalt, may have been controlled by faults.

Joints are very well developed in the Mount Guide Quartzite. They strike parallel to the fold axes and some are filled by metadolerite: they must therefore have formed quite early in the history of the region. Joints are also common in the eastern mass of the Argylla Formation and the overlying Marraba Volcanics and Mitakoodi Quartzite. Most strike north-north-east to north-east in the Duchess Sheet area but fan out to the east in the Cloncurry Sheet area.

Some of the granite masses are very well-jointed. The joints in parts of the Williams Granite, in particular, form a very clear pattern on air photographs: some of the joints that strike east are filled by post-granite dolerite dykes.

Tectonic History.

The Duchess Sheet area forms the south-eastern part of the exposed portion of a Lower Proterozoic orogenic belt (only a few square miles of Precambrian crop out to the south and none crops out to the east), and the Lower Proterozoic history is therefore one of continued instability.

Owing to inadequate information the palaeogeography during the deposition of the Leichhardt Metamorphics is not clear. Many of the lavas were emplaced below water. There may have been an interval before the Argylla Formation acid lavas were extruded.

During Argylla Formation time lavas were extruded, probably from meridional fissures, on to land in the west, but extended eastwards into an area of sedimentation (presumably the sea) to give the interbedded sediments and rhyolite about, and east of, longitude 140°. The lavas apparently did not extend as far east as the Soldiers Cap Formation. As vulcanicity proceeded the sea advanced westwards.

The vulcanicity was accompanied, or followed, by granitic intrusion. The granodiorite of the Kalkadoon Granite is similar in composition to the metadacite in the Leichhardt Metamorphics and Argylla Formation. Its time of emplacement is not accurately known but, as suggested by Joplin & Walker (in press), it may have been co-magmatic with the metadacite. (The Ewen Granite, which crops out 70-120 miles north of the Sheet area, is similar in composition to the metarhyolite of the Argylla Formation; it intrudes the Argylla Formation but is overlain by the Eastern Creek Volcanics.)

A period free of vulcanicity followed, during which sheets of arenaceous sediments produced the Mount Guide Quartzite and Ballara Quartzite. At the same time a depositional basin developed to the west and a near-meridional tectonic welt began to rise. It was centred in the western halves of the Dobbyn, Cloncurry, and Duchess Sheet areas and divided the orogenic belt into two geosynclinal belts. In the Duchess Sheet the western belt is represented only by the Mount Guide Quartzite and the Eastern Creek Volcanics.

Emission of vast quantities of basalt from the tectonic welt produced the Eastern Creek Volcanics, the Marraba Volcanics, and part of the Soldiers Cap Formation (all of which are best developed beyond the Sheet boundaries). The welt continued to rise during the vulcanicity; it was probably similar to a modern volcanic island arc but may have formed continuous land. Detritus was contributed by erosion from the welt to both eastern and western depositional basins. Sediment also came from a foreland to the west.

With the waning of vulcanicity tectonic movements became more complex. Sedimentation in the eastern geosynclinal belt continued and the remaining Lower Proterozoic units (other than Deighton Quartzite) were laid down. Crustal movements are evidenced by unconformities at the base of the Corella Formation (only seen in the Cloncurry Sheet area) and the Staveley Formation. Mudcracks, mudrolls and grooved load casts, together with sharply lenticular sediments, show that low land lay about the present area of Cambrian outcrop while the Staveley Formation was being deposited.

Strong orogenic deformation followed the laying down of the Corella Formation and Roxmere Quartzite and resulted in meridional folding and conjugate strike-slip faulting. It was probably accompanied, or immediately followed, by granite emplacement. Much of the metamorphism evident in the region may have been produced by this orogenic deformation and granite intrusion.

Sedimentation continued uninterrupted in the northern part of the western geosynclinal basin, but there is no record of it in the Duchess Sheet area. After the orogenic deformation uplift and erosion of the rocks of the eastern basin took place for some time, but a further period of Lower Proterozoic sedimentation is represented by the Deighton Quartzite, which must once have occurred widely.

The final chapter of the Lower Proterozoic history was renewed east-west compression, with folding, conjugate strike-slip, and other, faulting, and further granite intrusion, followed by uplift and erosion. The extent and effect of granite emplacement at this time is not clear.

The moderately folded Makbat Sandstone may represent a period of Upper Proterozoic sedimentation, but its age cannot be closely established. The post-Precambrian geological history is presented under another heading.

TABLE 2

PHANEROZOIC STRATIGRAPHY OF THE DUCHESS SHEET

AGE		ROCK UNIT	POSITION IN SEQUENCE, DISTRIBUTION	LITHOLOGY	THICKNESS (FEET)	TOPOGRAPHY	STRUCTURE	CORRELATION & FOSSILS	UNDERGROUND WATER	MINERAL DEPOSITS
QUATERNARY			Surface deposits in stream valleys, on plain of Artesian Basin and Burke River Plain.	Unconsolidated alluvium; sandy and pebbly soil, erosional surfaces on older rocks and higher ground.	Over 50 in places.	Valley floors, flood plains, bajadas; grass plain, channelled streams.	Horizontal-depositional; unconsolidated	Recent and subrecent	Small supply, good water, for example in Wills Creek bed.	
Selwyn Range Uplift; accelerated erosion on the divide of Selwyn Range.										
TERTIARY	Not definable ('Late Tertiary')	Unnamed limestone on Burke River; Noranside Limestone.	Rests on Cambrian and Mesozoic sediments and probably on Tertiary clastics. Deposited in former lakes in lowlands.	Limestone and chalcedony, in offshore position; inshore apparently deltaic clastics, not readily separable from alluvium.	About 30	Plains	Tilt to S. maximum 4 ft/mile.		Local supply, small.	
		Subsidence, Burke River valley transformed temporarily into a lake.								
		Uplift and erosion of the Lower Cretaceous sedimentary cover; development of lateritic surfaces.								
CRETACEOUS	Upper									
	Lower	Wilgunya Formation with calcareous toolebuc Member	Rests on Longsight Sandstone, conformably; cover: alluvium. A formation of the Artesian Basin.	Siltstone with Radiolaria, fine-grained sandstone, claystone and gypsum; Toolebuc Member, an intercalation of calcareous sandstone, limestone, concretionary in part.	About 600 increasing to east.	Plain with soil cover; small mesas in the south of the Sheet.	Plunges toward basin in east.	Albian and Aptian *Cenosphaera*, *Dentalina*		
		Longsight Sandstone	Conformably below Wilgunya Formation	Siltstone, sandstone, and conglomerate	Over 200 in basin	Small mesas	Plunges toward basin in east.	*Pterophyllum (Nilssonia) princeps*, *Aspleniopteris* sp.	Main aquifer in the Artesian Basin	
		Unnamed, (undifferentiated)	At base of sequence of Artesian Basin.	Conglomerate, some fine-grained sandstone with plants.	Up to 100 in mesas	Mesas on granite and Cambrian sediments		Lower Cretaceous and possibly Upper Jurassic		
		Subsidence, marine ingression; the beginning of the Great Artesian Basin in East and South.								
Jurassic to Upper Ordovician		Geocratic interval; erosion, development of the main features of the present landscape; deep weathering and leaching.								

Unconformity: the Mesozoic sequence rests on an eroded surface of Precambrian, and deformed lower Palaeozoic rocks.

TABLE 2

AGE		ROCK UNIT	POSITION IN SEQUENCE, DISTRIBUTION	LITHOLOGY	THICKNESS (FEET)	TOPOGRAPHY	STRUCTURE	CORRELATION & FOSSILS	UNDERGROUND WATER	MINERAL DEPOSITS
ORDOVICIAN	ARENIGIAN	Swift Beds (Formation)	Overlain by Cretaceous, alluvium, or soil. Rest on Precambrian, or Beetle Ck., and Ninmaroo. Main outcrops in Boulia Sheet area.	Sandstone with chert, and dolomite and limestone interbeds; siltstone with chert.	About 20-30 on surface	Plain with pediments	Gentle folds, details obscure	Arenigian; trilobites and brachiopods; algae.		
		Unconformity; main deformation of the Burke River Structural Belt								
	TREMADOCIAN	Ninmaroo Formation	Overlain by soil, alluvium, Cretaceous, and Swift Beds. Rests on U. Cambrian Chatsworth L.; main outcrops in Boulia Sheet area.	Platy dolomitic limestone, dolomite, and limestone, interbedded with similar thin bedded and marly rocks. Intraformational breccias.	Estimated over 500 exposed.	Stripped structural ridges; pediments in plains. Rare sink holes but no karst topography.	N.N.W. folds with elevated anticlinal ridges; strike fault on crest, displacement small; east dipping slickensided fractures.	Tremadocian: Ellesmeroceroids, Eopteria, Ceratopea, algae.	Small supply at about 200 feet, in plain.	Galena, small amounts along fault, and even in travertine.
	Disconformity; passage beds, and upper part of Chatsworth L. (upper U. Camb.) missing, but present in the Boulia Sheet area.									
CAMBRIAN	Upper	Chatsworth Limestone	Overlain by Ninmaroo; rests in Mt Merlin area in contact with M. Cambrian Inca Fm, and in east above O'Hara Sh. Main outcrops in Boulia Sheet area.	Limestone, sandy limestone, with coarse calcite beds, and interbedded at regular intervals with marly beds. Intraformational breccias common.	1,000 estimated.	Stripped structural ridge north from Mt Merlin; bald pediments in plain.	Folded as Ninmaroo rocks (above). Gentle folds in pediments, trending N.W.	Franconian (in Sheet area); Billingsella, Ecorthis, Syntrophiids, Pseudagnostus, Homagnostus, Paramansuyella	Unreliable	
		Mt. Merlin Area: unconformity, O'Hara Shale, Pomegranate Lst., Selwyn Ra. Lst., Devoncourt Lst. and Roaring Sltst. absent.				Eastern Area (between Don Ck, and Mort R.): Contact between Chatsworth Lst. and O'Hara Sh. not exposed.				
	Upper	O'Hara Shale	Rests on Pomegranate Lst., on Selwyn Ra. Lst., and on Devoncourt Limestone; overlying rocks and upper part of Shale eroded. Diachronous.	Shale and siltstone with subordinate chert and sandstone beds; also conglomerate in extreme north.	Up to 200 preserved	Mesas and Plateaux (erosional residuals). Cuestas at the faults.	Gently folded to subhorizontal.	Irvingella fauna		
		Pomegranate Limestone	Overlain by O'Hara Sh. with contact rising to south; rests on Selwyn Ra. Lst., and in absence of these on Devoncourt Lst. Diachronous.	Bituminous; crystalline, flaggy, marly ellipsoidal; intraformational breccias common.	About 100 seen	Pediments and low terraced bastions	Gently folded	Eugonocare tessellatum fauna Glyptagnostus reticulatus, Olenus n. sp. Glyptagnostus stolidotus fauna.		

TABLE 2

AGE		ROCK UNIT	POSITION IN SEQUENCE, DISTRIBUTION	LITHOLOGY	THICKNESS (FEET)	TOPOGRAPHY	STRUCTURE	CORRELATION & FOSSILS	UNDERGROUND WATER	MINERAL DEPOSITS
CAMBRIAN	Upper	Selwyn Range Limestone	Below O'Hara Sh. and above Devoncourt Lst. in N. part of the outlier; not present in S. Diachronous.	Light coloured hard calcilutite with regular soft marly interbeds.	Variable; maximum 120	Stripped floors (pediments) and terraced bastions	Steep dips at faults, gently folded to sub-horizontal elsewhere; numerous E.-dipping (10°) slickensided fractures.	No diagnostic fossils recorded.		
	Middle	Devoncourt Limestone	On Roaring Sltst.; below O'Hara Sh. in N. and Selwyn Ra. Lst. in Selwyn Ra. In N. part of outlier only.	Sandy, bituminous, grey, bedded and laminated limestone with thin-bedded soft limestone interbeds.	350 in Selwyn Ra.; about 600 in N.	Pediments; terraced low bastions in N.	Gently folded; steep dips near faults. Numerous E. dipping (10°) slickensided fractures.	Devoncourt Lst. and Roaring Sltst. together cover full range of Leiopyge laevigata. L. laevigata armata, and Centropleura		
		Roaring Siltstone	On Precambrian basement and residuals of Mt Birnie Beds. Exposed only along N. faults. Should be present together with Devoncourt Lst. ((equivalents) in trough part of outlier.	Light grey, friable, laminated siltstone when fresh. Surface: mottled siliceous siltstone and shale with sandstone interbeds.	200-250	Cuestas and pediments along Roaring Fault; in creek banks along Pilgrim Fault.	Moderately to strongly folded in vicinity of faults.			
		Unconformity against Precambrian, and Mt Birnie Beds at Pilgrim Fault, and north of it. Contact with rocks below (Inca Formation) not exposed; sequence intermediate between Roaring Siltstone and Inca Formation presumably present in the trough, but not exposed on the surface.						Sequence with Goniagnostus nathorsti and P. punctuosus (upper part) not exposed.		
		Inca Formation	Upper contact, and uppermost beds not exposed; rests in W. on Precambrian basement, Mt. Birnie Beds, and residuals of Beetle Ck Fm and Thorntonia Lst. A formation of regional extent.	Siliceous shale with chert, siltstone, sandstone and bituminous limestone in lower part; bituminous limestone with shale partitions in upper part.	Up to 500 at Mt Murray; estimated 2,000 in trough.	Cappings of mesa, cuesta and hogback around Mt. Murray; pediment in Petticoat Ck and Monastery Ck area.	Moderately to strongly folded; gentle folds plunge south-south-east (20 degrees) in pediment north of Monastery Creek, in contact with Thorntonia Limestone.	Ptychagnostus punctuosus (above), and P. atavus - P. gibbus (below).		

TABLE 2

AGE		ROCK UNIT	POSITION IN SEQUENCE, DISTRIBUTION	LITHOLOGY	THICKNESS (FEET)	TOPOGRAPHY	STRUCTURE	CORRELATION & FOSSILS	UNDERGROUND WATER	MINERAL DEPOSITS
CAMBRIAN	Middle	Disconformity against Beetle Creek Fm ; unconformity against Thorntonia Lst. at loc. D158. Continuity of sequence in trough possible.						Part of *P. gibbus* - *Xystridura* sequence missing.		
		Beetle Creek Formation	Overlain by Inca Fn ; rests on Mt Birnie Beds and Precambrian basement; a formation of regional extent.	Siliceous shale and chert, and bituminous flaggy limestone (apparently a lentil).	Estimated several hundred	Cuestas; cluster of mesas S. of Dajarra.	Folded; W. of Mt Merlin a syncline, dips E 15°, W 80°.	*Xystridura*, *Lyriaspis*, *Oryctocephalites*, *Peronopsis normata* (Whitehouse)		
		DISCONFORMITY						Part of *Xystridura* and *Redlichia* sequence missing.		
		Thorntonia Limestone	Very little exposed; overlain by Inca Fn , and rests unconformably on Mt Birnie Beds. Continuity with Thorntonia Lst. (Camooweal Sheet) postulated.	Thick-bedded dolomitic limestone and dolomite with chert.	About 60 seen; total thickness not exposed	Low rugged hills, ribbed surfaces	Dips 25°-45° observed; inlier (anti-clinal core) at loc. D153.	*Biconulites*, fragments of cystids, *Redlichia*, and calcareous algae.		
		Unconformity: in absence of Mount Birnie Beds it is confluent with the basal unconformity.								
	Lower	Mt Birnie Beds	Erosional remnants beneath M. Camb. along W. margin of outlier.	Clastics: conglomerate, indurated sandstone, arkose, green shale. Arkose and shale profoundly weathered, lateritic.	Total unknown (not preserved); up to 250 seen.	Cappings on Precambrian; cuestas and hogbacks.	Folded along W.N.W. axes; dips 30°-45°. No metamorphism apparent.	*Diplocraterion* cf. *lyelli* Torrell, *Crossochorda*; no diagnostic fossils.		
		UNCONFORMITY								

PHANEROZOIC

The Phanerozoic ('Post-Precambrian') sequence is adequately described in Table 2, but some additional comment is needed.

The Cretaceous marine fossils have been determined by Crespin and Dickins (1955), and the plants by M.E. White (1957).

In Table 2, the sequence of the early Upper Cambrian faunas (from Glyptagnostus stolidotus to Irvingella) indicates the age of the Selwyn Range Limestone, Pomegranate Limestone, and O'Hara Shale taken together as a sequence, irrespective of the formation boundaries, which are diachronous.

The legend of the map shows separately 'undifferentiated sediments' (Pz) which occur as small scattered outliers on the surface of the Precambrian rocks. Their age is unknown and none of them could be included in the table.

Lateritic surfaces are indicated on the map in places where the rocks are altered to some degree and not only coloured red or mottled. The shale and arkose of the Mount Birnie Beds, especially on lower ground, are profoundly lateritized, with well developed mottled and pallid zones. The ferruginous zone is in places a thick layer of altered material heavily indurated by iron oxides. It is probable that weathering of the sub-Middle Cambrian and sub-Cretaceous land surfaces preconditioned these rocks to the final lateritization. Several small occurrences of laterite are shown on the map, along the 140°meridian near the Monastery Creek. The position of these rocks in the sequence is unknown: they may represent summits of the sub-Middle Cambrian surface or discordant cappings on limestone, or both.

The shales and siltstones of the Cambrian are red and mottled in outcrops and have an iron-indurated crust on the surface, but no alteration is observable that would justify the application of the term laterite, although they can be described as 'lateritic' in the sense of an incipient or unfinished lateritization. More pronounced is the lateritization of the Cretaceous cappings in the eastern upland.

Some amplifying information as regards the sequence is found in the description of selected localities, and aspects of regional distribution of the formations and their correlation are discussed in Öpik (1960).

As seen from Table 2 tectonic unrest was common in the area during the Cambrian and the early half of the Ordovician Period. The deformation consists of moderate folding and relatively strong faulting. A regional zone of deformation - The Burke River Structural Belt (Öpik, 1960) - is the final result of these movements, and the Burke River Outlier is its northern segment. The Outlier is a graben bounded by faults in the north, and a trough in the south. The thickness of the down-faulted sequence in the Selwyn Range (graben) is about 1,000 feet, whereas in the south it is estimated at 5,000 feet. Chatsworth No.1 Bore at the heads of Woodya Creek (longitude 140°01'30"E, latitude 21°44'S) penetrated 3266 feet of sediments in a place where Ordovician and Upper Cambrian rocks are absent. In another abandoned bore (Chatsworth No. 2, 'Pilgrim Creek Bore', about longitude 140°07'E, latitude 21°34'S, and west of Webb Tank) 1,375 feet have been penetrated.

The vertical displacement is the strongest at the Pilgrim Fault with about 1,000 feet. On the Camel Fault and Roaring Fault it is about 700 feet. Innumerable slickensided fractures occur in limestone. These fractures have a dip of about 10°east, irrespective of the attitude of the beds. Apparently after faulting a compression and thrusting from the east dissolved itself in these fractures. Near the faults the sediments are folded. Close to the faults the dip may reach 80°, but rapidly decreases away from the faults. The Upper Cambrian limestone exposed in pediments in the southern part of the Burke River Plain is gently folded along north-west-trending axes. Generally the intensity of folding decreases from west to east, and increases to the south. The deformation in the eastern flank of the Outlier south of Monastery Creek is relatively strong: the main feature is an anticline with an axial fracture which in parts is visibly a fault. At the northern end of the anticline (D153) Thorntonia Limestone crops out in the eroded anticlinal core; southward there follow Inca Formation, Chatsworth Limestone, and finally Ninmaroo rocks. These formations are separated one from another by unconformities, which are also deformed; furthermore strong relief of the substratum (Mount Birnie Beds) complicates the structure. To conclude, it is an anticline without an axial plunge, superimposed on sequences separated by south-dipping unconformities. This anticline (Mount Merlin/Signal Hill Anticline) arose between the Tremadocian and the Arenigian;

apparently the Smoky Anticline arose (or culminated) during the same interval. Thus, the Mount Merlin/Signal Hill Anticline marks, apparently, a hingeline between the rising Smoky Anticline in the west and the trough in the east. This hinge was probably a site of seismic activity which produced the abundance of intraformational breccias in the limestone and dolomite sequence of the trough.

Warping of the crust is indicated by the Cretaceous inundation and transgression, and by the late Selwyn Range uplift.

DESCRIPTION OF SELECTED LOCALITIES

Localities are marked on the map by red numbers. In the card register these numbers carry the letter D (for example D120) which is omitted on the map.

D1. Longitude 140°05'E, latitude 21°15'S. Selwyn Range Limestone with residuals of O'Hara Shale crop out in low hills along the banks of Sandy Creek. At D1A, close to the fault, the dip is to the east. A conglomerate rests on O'Hara Shale, and also direct on Selwyn Range Limestone, indicating a pre-conglomerate landscape of limestone pediments with hills of O'Hara Shale. At D1B, along the Roaring Fault, hard sandstone (Mount Birnie Beds) dips east 20° to 30°. Stratigraphically above it follows the Devoncourt Limestone, which is on edge; thus an unconformity is indicated between the Mount Birnie Beds and the Middle Cambrian sequence.

D2. Longitude 140°16'E, latitude 21°11'S, and just west of D3. Small hills consisting of friable conglomerate and sandstone occur as residuals on an uneven surface of partly decomposed granite.

D3. Longitude 140°15'E, latitude 21°12'S. Low hills of conglomerate rise above the black soil plain of the Devoncourt Limestone. The Fence Fault is indicated in the west by soaks and by a line of silicified contorted rocks.

D5. Longitude 140°10'E, latitude 21°14'S. In a low rise soft siliceous siltstone (or shale) with a chert-bearing layer at its base is exposed. In the pediment west of the slope, in a lutitic and aphanitic flaggy limestone, a specimen of _Glyptagnostus stolidotus_ Öpik has been collected by J.N. Casey.

D6. Longitude 140°00'E, latitude 21°25'S. In a cluster of cuestas the lower part of the O'Hara Shale contains a fossiliferous chert layer, about 15 feet above the base (the 'lower O'Hara fauna', Öpik 1956; 1960). Selwyn Range Limestone is exposed in pediments, and its top surface bears ripple marks.

D7. Longitude 140°05'E, latitude 21°18.5'S. This number refers to the whole section from O'Hara Shale down to the contact with the basement. The dip is variable (10° to 40°), with a reversal (a fold) in the Roaring Siltstone. About 50 feet of O'Hara Shale is present. The Selwyn Range Limestone and Devoncourt Limestone together are about 400-500 feet thick, and the Roaring Siltstone 230 feet.

D8. Longitude 140°07'E, latitude 21°07'S. At Mount Mundi the fault zone contains about 700 feet of Devoncourt Limestone on edge. In a short distance from the fault zone O'Hara Shale (with chert), about 100 feet in thickness, rests on south-east-dipping limestone. The top of the limestone is brecciated.

D9. Longitude 140°10'E, latitude 21°02'S. At Mount Tabletop the Camel Fault is a wide zone containing an altered red sandstone with quartz grit and ferruginous inclusions, and below it a conglomerate as a wall dipping 70° off the basement; the southern part of the fault zone contains distorted limestone (with reversals of dip). Mount Tabletop itself contains on top a conglomerate (20 feet) followed below by 120 feet of sandstone and shale. It rests on subhorizontal Devoncourt Limestone, of which 20-30 feet can be seen. The conglomerate in the 'wall', and in the capping are lithologically similar and can be considered as a part of the O'Hara sequence; that implies a very complicated structure. It is, however, probable that the conglomerate of the wall and the altered sandstone represent the Mount Birnie Beds, and that two conglomerates of a quite different age are present (see D10).

D10. Longitude 140°08'E, latitude 21°04'S. At the eastern end of the Camel Fault a high cliff of a south-dipping (70°-80°) conglomerate rises above the Precambrian rocks at its foot. Above the conglomerate follows an altered, strongly jointed red sandstone with quartz grit and ferruginous inclusions. The fault zone itself is complicated.

D13. Longitude 139°59'E, latitude 21°22'S. In the scrubby plain the Devoncourt Limestone is exposed in a ribbed, and partly rubble and soil covered pediment. These outcrops extend east and south, and are fossiliferous (Centropleura, agnostids); in the west the Pilgrim Fault is exposed in the creek, along which the contorted Devoncourt Limestone and Roaring Siltstone (not fully exposed) occur as a 150 yards wide belt.

D15. Longitude 139°59'E, latitude 21°21.5'S. At the road crossing, in a creek bed in a grey laminated marly limestone Leiopyge laevigata (Dalman), Diplagnostus humilis (Whitehouse) and other agnostids occur.

D16. Longitude 140°05'E, latitude 21°37'S. Gently rolling truncated grey platy limestone contains Centropleura, a complete specimen of which was collected.

D20. Longitude 139°56.5'E, latitude 21°21'S. In a west-facing cuesta contorted Roaring Siltstone with chert dips east 20°-40°, in close proximity to the Pilgrim Fault. The angle of dip decreases rapidly to the east, where on scrubby pediments floaters of thin sandstone interbeds contain abundant agnostids.

D29. Longitude 139°59.5'E, latitude 21°26'S. At the base of a white butte (all other hills are red) of the O'Hara Shale a very fossiliferous chert layer occurs (see D6). Immediately south-west of it, at the foot of an escarpment, the Bronzewing Fault can be seen in scrub and spinifex.

D33. Longitude 140°07'E, latitude 21°16'S. Near the junction of the modern road and the old track, and south of it in terraced hills, the Selwyn Range Limestone (aphanitic flaggy limestone with chert, and with laminated marly interbeds) is exposed. It is the highest part of the Selwyn Range (a dissected plateau) in the area.

D116. Longitude 140°00'E, latitude 21°34'S. At the junction of Pilgrim River and Bronzewing Creek, red-brown and mottled lateritic rock (mottled zone of laterite) is exposed (up to 20 feet) in the banks of the Bronzewing Creek. Pipe-rock (vestigial Diplocraterion) appears to be present. The same laterite forms small rapids in the bed of the Pilgrim River, and continues south to Mount Birnie. D116 is the southern end of a distinct but low plateau of Mount Birnie Beds. In its western escarpment (e.g. at D32) a hard, flaggy, red arkosic sandstone with ripple marks and clay galls occurs.

D118. Longitude 140°07'E, latitude 21°42'S. In the plain east of the Burke River numerous outcrops of a white limestone with chalcedony are present.

D120. Longitude 140°16'E, latitude 21°46'S. Fifteen miles north of Chatsworth, at the foot of a 50-foot escarpment of O'Hara Shale, large pediments consist of the Pomegranate Limestone. In the northern part and on low ground in bituminous limestone and ellipsoids *Glyptagnostus reticulatus* and *Olenus* are common. In the south, and higher in the sequence, *Proceratopyge*, *Eugonoscare tesselatum* Whitehouse, *Pseudagnostus*, etc., are abundant. At the top of the sequence *Irvingella* occurs.

D124. Longitude 140°16'E, latitude 21°57'S. Bare pediments on gently folded Chatsworth Limestone (north-west axes) occupy a large area in the Burke River Plain, some 3-5 miles north-west of Chatsworth. A small patch of Cretaceous shale is preserved near the point D124. Fine-grained laminated limestone with interbeds of coarse calcite (very fossiliferous), and aphanitic limestone are present. *Pseudagnostus*, *Paramansuyella*, *Billingsella* and *Eoorthis* are common.

D127. Longitude 139°57'E, latitude 21°37'S: Mount Birnie, a prominent west-facing cuesta. In the upper part of its face about 120 feet of arkosic sandstone and micaceous arkose of the Mount Birnie Beds rest on decomposed Precambrian rocks which constitute the lower part of the slope and the pediment in front of it. On lower ground the rock is lateritic and even laterite. The sequence dips east 15° to 20°.

D135. Longitude 139°58'E, latitude 21°57'S. A low scrubby rise west of Ibis Creek consists of slightly altered shale and chert of the Beetle Creek Formation. Fossils (*Xystridura* and associated forms) are abundant. Immediately to the south low outcrops of the Ordovician Swift Beds are in near-contact with the Beetle Creek. North of D135 (at D136) an inlier of lateritic Mount Birnie Beds is well exposed. The Beetle Creek shale dips east up to 15° and is the western flank of a syncline, the eastern steeper flank of which dips 80°-85°west and is exposed at D138. Another occurrence of Beetle Creek chert and limestone with *Xystridura* is at D129 (courtesy of Dr.C.R. Twidale).

D141. Longitude 140°01'E, latitude 21°53'S. The ridge, and its summit Mount Merlin, consist of dolomite and dolomitic limestone of the Ninmaroo formation (Ninmaroo Limestone in the map legend). Ellesmerocero-id nautiloids, Ceratopea and Eopteria have been recorded.

D146. Longitude 140°00'E, latitude 21°49'S. Fossiliferous thick-bedded Chatsworth Limestone dips 20°east. It is the dip slope of an unnamed ridge the rocks (limestone) of which are tightly folded in the west.

D157. Longitude 139°57'E, latitude 21°40'S. Two miles east of Mount Aplin the Mount Birnie Beds (conglomerate; sandstone with Diplocraterion and Crossochorda; green shale; with ferruginous arkose on top) occur in hills and ridges. The ferruginous arkose dips east, and on its eroded surface rests an erosional and rugged residual of Thorntonia Limestone (here dolomite, dolomitic limestone) (see D158).

D158. Longitude 139°58'E, latitude 21°40'S. Immediately east of D157, the Thorntonia Limestone, which is an exhumed erosional residual, is unconformably covered by a sequence of limestone, shale, and chert (Inca Formation), which in its turn is gently folded along south-west plunging axes.

Unnumbered Localities

Longitude 139°36'E, latitude 21°52'S. A small outlier of Beetle Creek shale yielded numerous fossils (Xystridura).

Longitude 139°47'E, latitude 21°24'S. Brecciated dolomitic limestone and contorted shale occur in two outliers (infolds, infaults) south-west of Duchess. Only sponge spicules are present.

Longitude 146°26'E, latitude 21°31'S. From this place (4 miles north of Selwyn) fossil plants, described by M.E. White, (1957) were collected.

Longitude 140°45'E (approx.), latitude 21°09'S. Cenosphaera and cf. Dentalina occur in a radiolarian siltstone (I. Crespin and Dickins, 1955).

ECONOMIC GEOLOGY

All production of metallic minerals has come from Precambrian rocks. Lead and uranium in sub-economic quantities have been recorded in Palaeozoic strata but only in very minor amounts. The following metals have been produced: gold, silver, cobalt, manganese, iron (for smelter flux), tungsten, and copper. In addition calcite ('limestone') has been quarried for use as flux. Nearly all the gold has been obtained as a byproduct of copper production, but silver has been mined as the sole metal from two deposits. For some years the Mount Cobalt mine was an important producer of cobalt and was the largest mine in Australia worked specifically for cobalt.

Table 3 shows the copper and gold production from the main mines.

TABLE 3

PRODUCTION FROM THE MAIN COPPER-GOLD MINES TO 31st DECEMBER 1958

Mine	Ore treated (Long tons)	Production		Grade of Ore	
		Copper (Long tons)	Gold (oz.)	%Cu	dwt/ton Au
Mount Elliott*	264, 250	24, 468.8	33, 910	9	2.6
Duchess*	203, 468	24, 747 (+ 1,988 oz	2, 448 of silver)	12	0.25
Trekelano	184, 811	20, 140.7 (+ 10,885 oz	13, 606.0 of silver)	10.9	1.5
Hampden	184, 501	12, 690.6 (+ 5, 582 oz	10, 951.7 of silver)	6.9	1.2
Hampden Consols	21, 418	1, 901.2	1, 138.9	9	1.05
Answer*	8, 488	828.5	355.6	10	0.85
St Mungo (Maiden)*	7, 017	1, 537.0	-	23	-
Mount Mascotte	4, 824	866	248.4	18	1.0
Lady Fanny*	2, 861	211.2	17.0	8	0.1
Labour Victory*	1, 303	239.8	19.5	22	0.35
Mount Hope	1, 441	103.4	3.5	8	0.05

An additional 8,000 tons of ore containing 1,621 tons of copper and 136.9 oz. of gold were produced from unspecified mines in the Kuridala district.

* Returns incomplete. Production and grade figures are not based on the ore figure given.

Copper

Production has been recorded from about one hundred mines, but most mines yielded only a few tons of ore; only the major mines were worked in the primary zone. Most of the ore has been obtained from two meridional lines of mineralization: the Trekelano-Duchess-Mount Hope line in the west and the Kuridala-Mount Cobalt line in the east. The deposits are everywhere associated with faulting, but the host rock differs considerably from deposit to deposit. Apart from reworking of dumps, only small-scale mining has taken place since the close of World War II, and has been largely confined to the Mount Hope group of mines, from which siliceous ore has been transported to Mount Isa. The Trekelano mine closed down in 1943, but the other major mines closed about 1920. Considerable exploration, including geophysical and geochemical prospecting, geological mapping, and drilling, has been done in recent years.

Gold has come almost entirely from copper-gold orebodies. The few gold workings have only yielded a few tens of ounces of gold. No gold production, apart from that from the Trekelano copper mine, has been recorded for over twenty years.

Cobalt. Mount Cobalt has been the only producer of cobalt within the Sheet area. Between 1920 and 1934, 3225 tons of hand-picked ore and concentrates yielded 266.4 tons of cobalt. Production ceased because of lack of water for the mine. The deposit occurs in a north-striking shear at the contact of schist and amphibolite. Drilling in recent years has shown narrow extensions of the lode. Scheelite is associated with the orebody in places.

Silver. In addition to nearly 20,000 ounces of silver obtained from copper-gold ores, two deposits of silver-bearing ore have been recorded. The larger is the Silver Phantom, seven miles west-south-west of Kuridala, which was discovered in 1953 and had yielded 129,138 ounces of silver to the end of 1958. The other, on the Duchess-Urandangi road, was found in 1918; 10,124 ounces of silver, in the mineral naummanite, were recovered.

Iron was mined from a limonitic body near Hematite railway siding as a flux for the Mount Elliott copper smelter before 1920; about 30,000 tons of ironstone were mined. Several small bodies of quartz-hematite also occur south-west of Selwyn and another occurs in the north-centre of the Sheet, near Mount Philp. They are generally too small and siliceous to be of economic interest.

Manganese forms low-grade supergene deposits along fractures in the Marimo Slate and farther south. Some of the deposits have been tested for use in the Mary Kathleen treatment plant and some ore has been mined. Minor deposits have been recorded in other formations.

Scheelite has been extracted from two small deposits, one north of Mount Cobalt and one in the Trekelano area. Total scheelite produced is only quarter of a ton.

Calcite ('Limestone') flux for Mount Isa Mines smelters has been quarried 4 miles south of Duchess (122,200 tons) and near Myubee railway siding (1,145 tons). Many other deposits probably occur as lenses in the higher-grade metamorphics of the Corella Formation and other beds that were originally rich in carbonates.

Uranium has been recorded in the Corella Formation (Pelican leases in north-centre of the Sheet area), in the Staveley Formation, south of Mount Dore, in the Lower Cambrian Mount Birnie Beds, and in the Cretaceous Toolebuc Member of the Wilgunyah Formation.

UNDERGROUND WATER RESOURCES

Underground water in the area occurs

1. in alluvial deposits,
2. in the Artesian Basin,
3. in the sedimentary sequence of the Burke River Outlier, and
4. in the rocks of the Shield.

Small supplies of drinking and irrigation water are available and exploited in wells and shallow bores in the alluvial valley fill of Wills Creek, and should be present in the valley of the Cloncurry River. The hydrology of the Artesian Basin is well known, and reasonable supplies should be expected on its fringe in the east of the area. For example, the Percal Plains bore, situated 5½ miles east from the eastern margin of the area, flows at a depth of 600 feet, but a salt water horizon was found at 190 feet. The eastern slope of the upland serves as a catchment of water that is taken into the basin along the contact of the Precambrian and Cretaceous rocks.

The distribution of groundwater in the pastorally important Burke River Plain is not well known, but appears to be discontinuous. Several bores are dry, or the supply is small, with a low quality of water. The existing bores are shallow, between 100 and 250 feet, and wells less than

100 feet. In the Burke River Plain the base of the unconsolidated cover rocks, including the Tertiary limestone, and the top of the Palaeozoic sequence, are aquiferous. Favourable structures like fracturing and faults (Roaring Bore, for example) in the Cambrian limestone contain local aquifers with a reasonable supply of water.

In the Precambrian, local aquifers should be present in fractures in limestone and calcareous formations, but no large supplies can be expected, and brackish water will be common.

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