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BMR Bulletin

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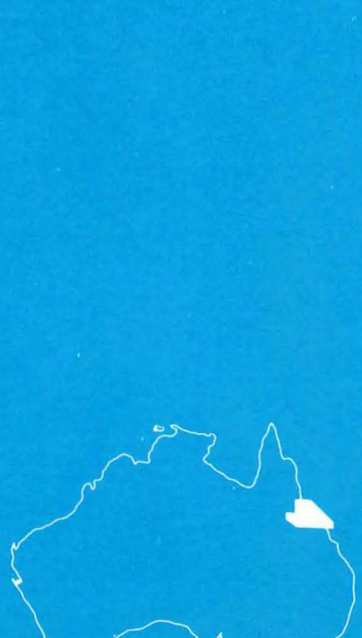

DEPARTMENT OF NATIONAL DEVELOPMENT & ENERGY
BUREAU OF MINERAL RESOURCES, GEOLOGY
AND GEOPHYSICS

BULLETIN 208

Geological evolution and economic geology of the Burdekin River region, Queensland

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ABSTRACT

This Bulletin summarises the results of regional mapping by teams of the Bureau of Mineral Resources and the Geological Survey of Queensland from 1961 to 1967 over an area of some 67 000 km^2 near Townsville.

Small areas of high-grade metamorphics may be Precambrian, or may be correlatives of the oldest dated rocks (Late Cambrian to Early Ordovician). These early strata occupied a major east-west basin which was destroyed by orogeny and granitic intrusion in Middle Ordovician time. A further period of granitic intrusion consolidated the Lolworth-Ravenswood Block as a major east-west structural high.

Of the Palaeozoic sedimentary basins, the Burdekin Basin received sediments from Givetian to Tournaisian times. Ranging in tectonic activity between a mildly unstable shelf and a yoked intracratonic basin, it presented an alternation of marine and continental conditions as it gradually expanded northwards. South of the Lolworth-Ravenswood Block, a miogeosyncline formed in the Middle Devonian. In the Tabberabberan Orogeny a geanticline rose in the geosynclinal belt, and the Drummond Basin formed on its western side. This transverse basin received sediments from Late Devonian to Middle Carboniferous times in three well-marked cycles, each beginning with torrential sediments and ending with mature ones. In its later life, it possibly emptied into the Burdekin Basin.

The Broken River Embayment received sediments more or less continuously from Silurian to Carboniferous times, but only the lowest and highest units occur in the map area. The lowest units are shelf and trough sediments, the highest is shallow-marine and lacustrine. At the latest stage in its development the Embayment reached its greatest extension to the southeast and may have connected with the Burdekin Basin.

The Late Devonian to Early Carboniferous sediments and volcanics near the coast represent the northern extremity of a basin probably connected with the Yarrol Basin.

These basins were destroyed in the Kanimblan Orogeny, and from Late Carboniferous to Early Permian times the area was dominated by igneous activity.

The Bowen Basin developed in the Permian volcanic episode, and passed through a series of marine incursions to a continental environment. Local coastal conditions during the first marine incursion produced the Collinsville Coal Measures. Possible correlatives of Bowen Basin units are widespread, although some of the relationships are tenuous.

Triassic orogeny ended deposition in the Bowen Basin, and was followed in the south coastal area by a period of igneous activity in the Early Cretaceous. Quiet conditions followed, and by the end of the Cretaceous the area was topographically mature.

In the early Cainozoic some earth movement continued, producing the Hillsborough Basin and resulting in erosion of much Triassic sandstone. The mature topography re-established by mid-Tertiary was the base for the subsequent lateritic episode, interrupted by further erosion and deposition. The evolution of the area was completed by Cainozoic volcanism followed by slight erosion.

The physiography of the coastal area is dominated by corridors between high ranges. Faulting can be reasonably suspected as a cause, and in some cases there is some evidence. The inland area is occupied mainly by the Burdekin catchment, which developed its present form by movements in the Cainozoic but still retains some northeasterly trends from Palaeozoic structures.

In the past the area was an important producer of gold, particularly from Charters Towers and Ravenswood, but little has been produced in the last fifty years. The deposits are attributed mainly to Webb's Ravenswood Epoch. Lode tin mining has also declined, although alluvial production has been more prominent in recent years. The lode tin deposits were formed in the Herberton Epoch. Future prospects of metal mining appear to rest mainly with alluvial tin, but the possibility of copper finds cannot be discounted.

Coal production from the Collinsville area has been gradually increasing in importance and appears likely to continue to do so. Petroleum exploration has so far been unsuccessful, although the possibility of discoveries cannot be completely ruled out.

Limestone makes an important contribution among the non-metallics and this can be expected to continue. There is also some potential for silica sand mining.

INTRODUCTION

The area covered by the Burdekin River Region 1:500 000 geological map lies between latitudes 18°30′S and 21°S, and between longitudes 144°30′E and 149°40′E. It encompasses the 1:250 000 sheets Townsville, Charters Towers, and Bowen and parts of Ingham, Ayr, Hughenden and Prosperine.

The main features and communication routes are shown in Figure 1. Principal towns, with populations as at the 1976 census, are Townsville (78 653), Charters Towers (7914), Ayr (8606) Bowen (6707), Ingham (5868), Home Hill (3330), Prosperine (3012), and Collinsville (2403). State railways of 106-cm gauge are the main coast line through Townsville; the Townsville-Mount Isa line; the Bowen-Collinsville line; and the Yabulu-Greenvale line. A network of private 61-cm tramways services the sugar-growing areas. Sealed roads include the main highways and parts of the development road systems; the formed shire roads are gravel, trafficable except during the wet season; many minor tracks, often only suitable for 4-wheel drive, extend from these, particularly in the mining areas. Airports used by commercial flights are at Townsville, Ingham, Bowen, Prosperine, and Charters Towers, and many of the station properties have strips suitable for light aircraft. Townsville, Bowen, and Lucinda have port facilities.

The climate is tropical, with hot wet summers and mild dry winters. Isohyets are shown in Figure 1, and Table 1 shows other data for selected towns in the area and for Hughenden, just west of its margin. By far the greater part of the rainfall is in the period December-February, and flooding is common at this time. In general, the rainfall is most reliable on the wetter parts of the coast and least in the western parts of the area.

Frosts are virtually absent on the coast, and in most of the inland occur on an average only 2-3 times per year.

TABLE 1. SELECTED CLIMATIC DATA
(after Department of National Development, 1970)

Town	*Av. max. temp., Dec. °C*	*Av. min. temp., Dec. °C*	*Av. max. temp., July °C*	*Av. min. temp., July °C*	*Av. rel. humidity, 3 p.m. (%)*
Ayr	32.0	22.1	25.0	11.7	not available
Bowen	31.4	23.4	23.9	13.8	61
Charters Towers	34.8	20.9	24.4	10.9	44
Collinsville	33.6	20.7	24.7	8.0	43
Hughenden	37.3	21.5	25.1	8.1	30
Townsville	30.6	24.2	24.4	15.4	63

In the wetter parts of the coast is a dense cover of woodland, swamp vegetation, and mangroves; the drier parts are open eucalypt forest. The coastal ranges and adjacent parts of the highlands carry dense rainforest, grading westward into high-rainfall eucalypt forest and finally savannah woodland, which covers by far the greater part of the area. Spear-grass (*Heteropogon*) is the dominant grass in these drier areas.

Sugar cane is grown on the wetter parts of the coast, and in the Burdekin delta where ground water is available for irrigation. Elsewhere on the coast fruit, vegetables and beef are the principal products. Beef is the major product in the inland areas. Only Collinsville and its neighbour Scottville exist purely to serve the mining industry. Timber is obtained from parts of the coastal range and inland areas.

The main secondary industries are cement manufacture and copper-refining at Townsville, nickel extraction at Yabulu, and coke-making at Bowen.

Tourism, particularly in the coastal belt, is now one of the most important and fastest-growing industries in the area.

PREVIOUS INVESTIGATIONS

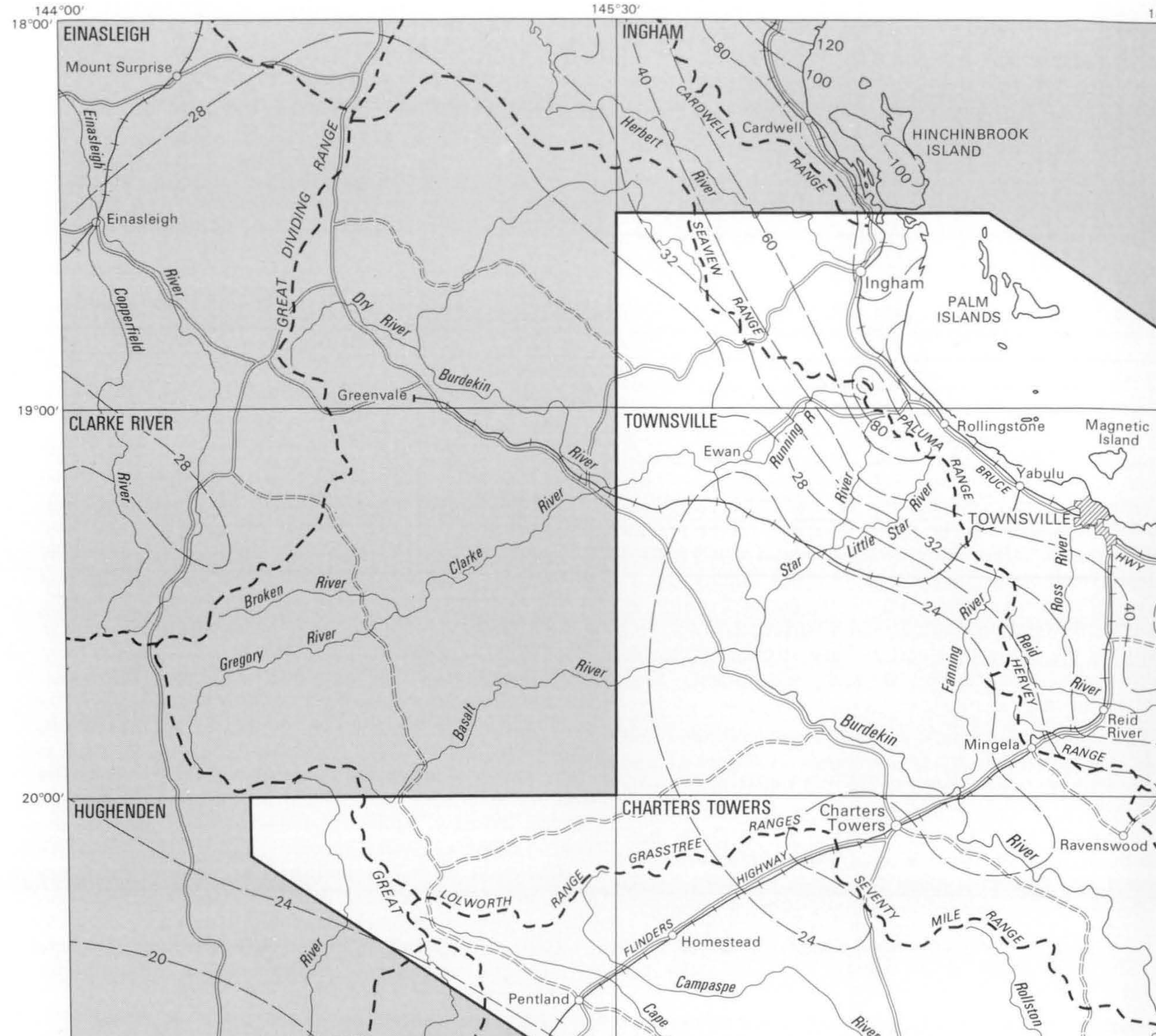
Preliminary observations in geology and geomorphology were made by Leichhardt (1847), who traversed the central part of the area in 1845, and by Jukes (1847), who examined part of the coast. A more systematic and widespread reconnaissance was made by Daintree (1868, 1870a, b, 1872) who produced the first geological map of Queensland. From Daintree's fossil collections Etheridge (1872) produced a stratigraphic column, which included *inter alia* the present Mount Wyatt Formation and Star Beds.

Robert Logan Jack was appointed Government Geologist of North Queensland in 1877, and of the whole of Queensland in 1879, and established the Geological Survey of Queensland. Jack was a capable and energetic geologist, and from the time of his arrival the pace of geological work quickened considerably. He described parts of the Burdekin Basin and Charters Towers area (1879a), the Bowen River Coalfield (1879b), the Normanby and Marengo Goldfields (1879b, 1887a), coal measures near Stuart, and sediments and coal near Prosperine (1887b). Maitland dealt with parts of the Prosperine and Bowen areas (1889), and the upper Burdekin (1891). Rands (1891) described the Cape River Goldfield and a traverse from there to Mount Wyatt.

The results of this period were consolidated by Jack and Etheridge in 1892. Their map shows in general form the outlines of the northern part of the Bowen Basin, the Burdekin Basin, and the Lolworth-Ravenswood Block, but gives no hint of the overall complexity of the area as revealed by later mapping.

Between 1892 and 1930 the work of the Geological Survey was more strongly oriented towards the investigation of metalliferous deposits, although surveys of potential coal-bearing areas yielded much stratigraphic information. In this period Cameron (1903) made additions to the geology of the coastal area and Morton (1920, 1921) described the Normanby Field. Reid produced his important economic work on Charters Towers (1917), and many additions to the Palaeozoic stratigraphy in his study of the Isaacs River Basin (1928), the Mackay area (1929a), and the Bowen River Coalfield (1929b). Some of the results of this period were discussed by Reid (1930).

During the same period Poole and Stanley were among a number of workers who dealt with various problems of the Great Barrier Reef and coastal geomorphology. Bryan (1925) discussed the available knowledge of earth-movements.



From 1930 until 1950 work was confined to purely economic studies, mainly by Reid and Morton. Exceptions were the specialised studies of Devonian corals by Hill (1942), and of the Great Barrier Reef by Fairbridge (1950). Available knowledge at that time was summarised by David (1950), Hill (1935), and Hill & Denmead (1960).

Since 1950 there has been a considerable upsurge of geological activity in the area. Mining and exploration companies, particularly those interested in coal and petroleum, carried out stratigraphic studies, often detailed; land use studies by the CSIRO included geological reconnaissances; and joint parties of the Bureau of Mineral Resources (BMR) and the Geological Survey of Queensland (GSQ) carried out systematic regional mapping of standard 1:250 000 sheet areas. During this period Traves (1953) made a reconnaissance of the Townsville-Bowen region; geological maps were prepared of petroleum prospecting areas near Prosperine (Lawrence, 1956; White & Brown, 1963; Brown, 1963) and a detailed study of the northern part of the Bowen Basin was made by Webb & Crapp (1960).

Regional mapping by BMR and GSQ is summarised in Table 2.

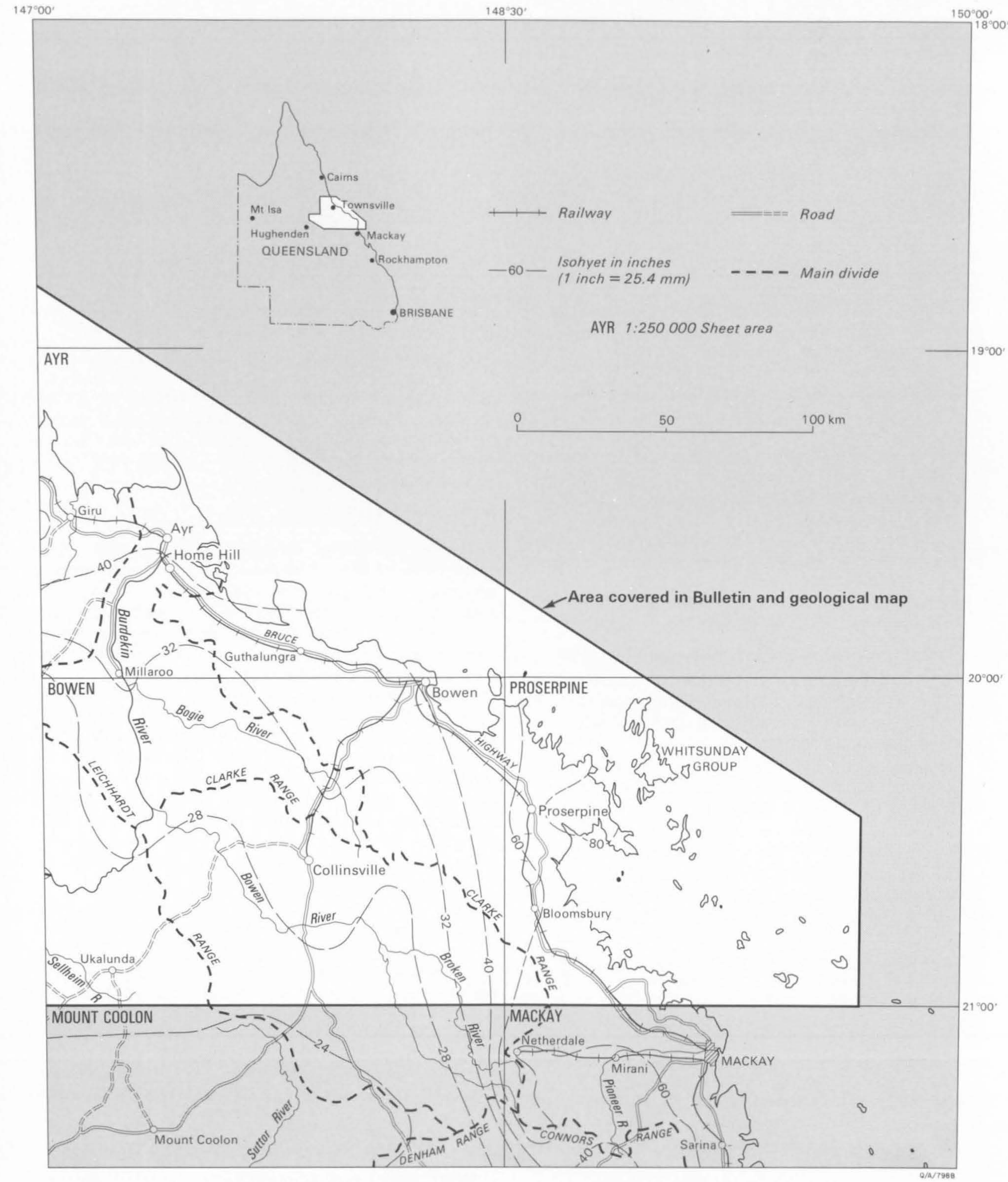


Fig. 1. Burdekin River Region, showing location, access, and main features.

GEOLOGICAL HISTORY

Precambrian to Early Devonian (Table 3)

Precambrian

Although the Precambrian shield lies beyond the western edge of the map area, it has to be considered in any account of the geological history of the area. This portion of the shield (neglecting its northerly extension into Cape York Peninsula) consists of the *Georgetown Inlier* of White (1965) which is believed to be continuous with with the Precambrian of northwestern Queensland along the *Euroka Ridge,* a basement ridge beneath the sediments of the Great Artesian Basin (Hill, 1951). This block has been relatively stable since the close of the Precambrian, and the northeast trend of its southern margin has had a considerable influence on later structures.

TABLE 2. BMR-GSQ REGIONAL MAPPING

1:250 000 Sheet Area	*When mapped*	*References*
Ayr	1964	Gregory, 1969; Paine & others, 1969
Bowen	1961, 1964–65	Malone & others, 1966; Paine & Cameron, 1972; Paine & others, 1974
Charters Towers	1963–64, 1966–67	Wyatt & others, 1971; Clarke & Paine, 1970; Clarke, 1971; Levingston, 1972
Hughenden	1962–63	Vine & Paine, 1974; Paine & others, 1971
Ingham	1962–63	de Keyser & others, 1964; 1965
Proserpine	1962, 1965–66	Clarke & others, 1971; Paine, 1972a
Townsville	1960–63	Wyatt, 1968; Wyatt & others, 1970; Levingston, 1971

White (1965) discussed rocks of the Georgetown Inlier to which previous workers had assigned ages from Precambrian to Ordovician, and concluded that Precambrian was the most likely age for all of them; a factor leading to this conclusion, apart from the degree of metamorphism and absence of fossils in the rocks, was the relations with a large granite body (the Forsayth Batholith) which was assumed to be all of Precambrian age; he may also have been influenced by the resemblance of some of the rocks to those in a sequence later called the Cape River beds, which were at that time assigned to the Precambrian. Later isotopic dating has shown that some of the plutons making up the Forsayth Batholith are of Late Silurian or Early Devonian age, and that much of the Cape River beds is Late Cambrian to Early Ordovician.

Precambrian to Early Ordovician (Fig. 2)

The Cape River beds, the Argentine Metamorphics, and the Running River Metamorphics each comprise more than one rock unit, although generally subdivision has not been attempted.

Lithological resemblances between various parts of these units and rocks of the Georgetown Inlier have been noted by Wyatt & others (1970), who proposed a number of correlations. Possible correlations suggested by these resemblances are given in Table 4.

The Charters Towers Metamorphics and the Kirk River beds, two units of small outcrop area, are considered to be equivalent to parts of the Cape River beds.

Evidence of age has been obtained only from the Cape River beds. It comprises isotopic ages of 510 ± 100 m.y. (Late Cambrian*; A. W. Webb, in Paine & others, 1974, p. 15 and appendix) from the Mount Windsor Volcanics in the Bowen 1:250 000 Sheet area, and tentatively 483 ± 25 m.y. (Early Ordovician; A. W. Webb, R. Bennett, & J. A. Cooper in Paine & others, 1971, p. 15) from Cape River beds in the Hughenden 1:250 000 Sheet area. An early Ordovician age is also indicated by graptolites in sediments overlying Mount Windsor Volcanics south and southwest of Ravenswood (Dear, 1974; McClung, 1976).

The (?)Cambrian-Early Ordovician exposures are the scattered remnants of a major area of deposition extending a considerable distance along the southeastern edge of the Precambrian shield. The full extent of this basin is not known, but in the Late Cambrian and Early Ordovician it was possibly connected with the Georgina Basin of northwestern Queensland. Some support for this suggestion is given by the presence of Late Cambrian rocks in A.A.P. Fermoy No. 1 well, 80 km south of Winton (Casey, 1970).

A possible extension to the south is represented by the Anakie Metamorphics, where the metamorphism is assigned to the Middle Ordovician (Olgers, 1972), but the Mount Windsor Volcanics, with their small amount of associated sediments, suggest that the general southern limit was close to the southern edge of the present exposures.

Middle Ordovician (Fig. 2)

During the Middle Ordovician the intrusion of the main body of the Ravenswood Granodiorite Complex and accompanying orogeny destroyed the existing basin and produced a structural high which dominated subsequent deposition. This Middle Ordovician orogeny was coeval with a major movement affecting Ordovician rocks from northwestern Queensland to Western Australia (Öpik, 1960). Strong foliation near the contacts, in both intrusive and country rocks, suggests considerable intrusion stress; however, the foliation usually disappears within a few kilometres from the contact, and many of the sediments are but slightly deformed. The overall pattern is of rather gentle doming with little horizontal stress except in the Cape River area, where northeast compression was apparently severe. This compression, however, was possibly epi-Silurian.

Isotopic dating has shown that the Ravenswood Granodiorite Complex is composite, including intrusives of Middle Ordovician and epi-Silurian (Bowning) age. The earlier intrusion includes the main part of the batholith (mainly granodiorite) and a marginal late, acid phase. The epi-Silurian intrusives are smaller bodies of which so far only one has been mapped—the Barrabas Adamellite. These later intrusives are virtually identical in age with the Lolworth Igneous Complex to the west, and may be co-magmatic with it (Table 5).

Late Ordovician to Early Devonian (Fig. 2)

When sedimentation resumed in the area, probably towards the end of the Ordovician, the main structural element was the NNW-trending Tasman Geosynclinal Zone, which dominated eastern Australia's geological evolution until the Mesozoic. However, the northeasterly trends of the early Palaeozoic structures, particularly the southern edge of the shield, still continued to exert an influence.

No Late Ordovician to Early Devonian sediments are known from the southern part of the area, and it appears that the Lolworth-Ravenswood Block was the nucleus of a land area which completely interrupted the course of the Tasman Geosynclinal Zone.

* The time scale used in this report is that of Harland & others (1964). For a summary of all isotopic age determinations in the area see Table 20.

TABLE 3. SUMMARY OF PROTEROZOIC TO EARLY DEVONIAN UNITS

Formation name or symbol	*Thickness, m*	*Environment of deposition/intrusion*	*Relationship*	*Remarks*
LATE SILURIAN TO EARLY DEVONIAN				
Kangaroo Hills Formation SDk	10 500–12 000 (W of map area)	Trough adjacent to tectonic land	Unconformable on Greenvale Formation	
Tribute Hills Sandstone SDt	1000–1500	Stable shelf	Uncertain—see notes	
Dumbano Granite SDd	—	Late syn-orogenic and post-orogenic	Intrudes Cape River Beds	Au, Ag at Mount Emu Plains
Lolworth Igneous Complex SDl	—	Post-orogenic batholith	Intrudes Ravenswood Granodiorite Complex	Au at Old Homestead, Lolworth, and Fern Springs diggings
Barrabas Adamellite SDb	—	Composite intrusive	Intrudes Ravenswood Granodiorite Complex	Cu-Mo mineralisation (Kean's prospect)
SILURIAN				
Greenvale Formation Sg	9000 (W of map area)	Trough adjacent to craton	Unconformable under Kangaroo Hills Fm	
LATE ORDOVICIAN TO SILURIAN				
Wairuna Formation Slw	1500 (W of map area)	Shelf adjacent to craton	Unconformable under Greenvale Formation	Late Ordovician-Early Silurian fossils
Ewan Beds Se	1500–3000	Unknown, possibly shelf	Unconformable on Running River Metamorphics	Sn, Cu deposits near Ewan
ORDOVICIAN AND EPI-SILURIAN				
Ravenswood Granodiorite Complex ODa, ODo, ODn, ODr	—	Syn-orogenic and post-orogenic	Intrudes Cambrian-Ordovician strata	Important Au deposits in Charters Towers-Ravenswood area
CAMBRIAN TO ORDOVICIAN				
Charters Towers Metamorphics ЄOf	?>2000	Unknown	Intruded by Ravenswood Granodiorite Complex	Minor gold deposits
Cape River Beds ЄOc	Unknown	Unknown, possibly deep water in part	Intruded by Ravenswood Granodiorite Complex	Au, Ag, Pb, Cu at Liontown, other minor Au deposits
ЄOq				
Mount Windsor Volcanics ЄOw	3000–4500	Unknown, possibly some volcanic piles	Intruded by Ravenswood Granodiorite Complex	
Kirk River Beds ЄOk	?>3000	Unknown	Intruded by Ravenswood Granodiorite Complex	Minor Au at Bunkers Hill
ЄOu				
PROTEROZOIC?				
Running River Metamorphics Ᵽr	Unknown	Unknown	Unconformable under Ewan Beds	Sn mineralisation
Argentine Metamorphics Ᵽa	Unknown	Unknown	Intruded by Ravenswood Granodiorite; beneath Dmf, Dud, DCs, DCg	Ag and minor Au, Argentine area

TABLE 4. POSSIBLE CORRELATIONS, PROTEROZOIC TO ORDOVICIAN UNITS

CAPE RIVER BEDS		*ROCKS OF GEORGETOWN INLIER*		*ARGENTINE METAMORPHICS*		*RUNNING RIVER METAMORPHICS*	
Outcrop area	*Lithology*	*Formation*	*Lithology*	*Outcrop area*	*Lithology*	*Outcrop area*	*Lithology*
Central belt at western end	Quartzite	Paddys Ck Fm	Qtz phyllite, quartzite	Back Creek	Quartzite, quartz schist		
Upper Cape River	Variety of schist and gneiss	Lucky Ck Fm	Calcareous grewacke, actinolite schist, quartz-chlorite-epidote schist, thin impure marble	Boundary Creek	Actinolite schist, thin recrystallised limestone		
Morepork Creek	Mica schist, metamorphosed arenites	Halls Reward Metamorphics	Migmatite, quartz-mica-schist, garnet-mica-schist quarzite	Dinner Creek, Star Homestead White Springs	Migmatite SW and SE of Star Homestead; metamorphics in White Springs area.	N and W of Ewan	Quartzite, mica schist
Range Creek	Amphibolite	Stenhouse Creek Amphibolite	Thinly banded amphibolite, rare impure marble	Keirys Dam, Six mile Creek, White Springs	Amphibolite, serpentinite	NE of Ewan	Amphibolite, mica schist

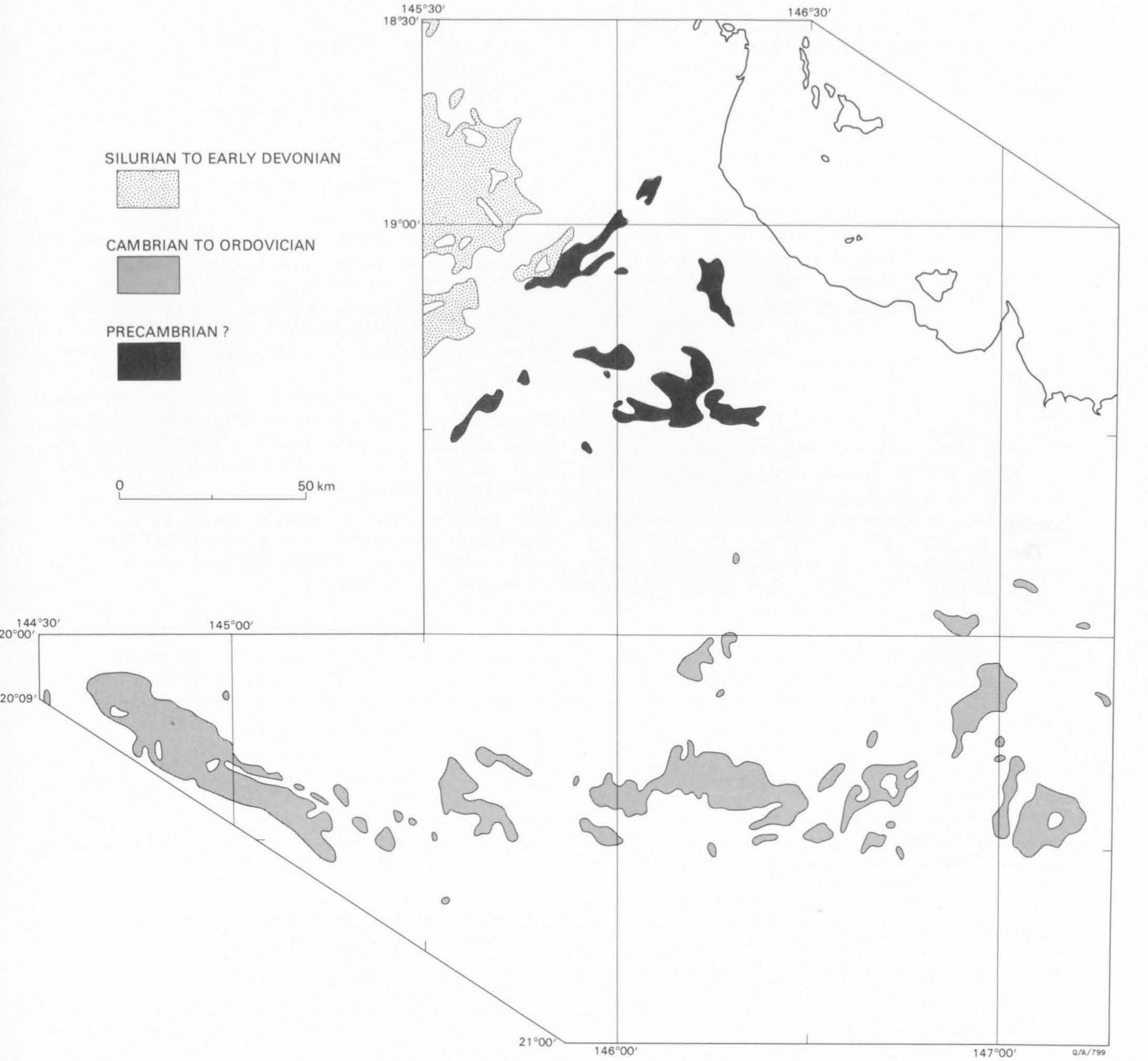


Fig. 2. Distribution of Precambrian(?) to Early Devonian strata.

In the north the Geosynclinal Zone projected into the craton in the Broken River Embayment, whose northwestern boundary was determined by northeast-trending faults. Only the most easterly deposits of the embayment extend into the map area—the Silurian to Early Devonian sequences and the Clarke River Formation (for details on the adjoining area see White, 1965).

The Ewan beds, separated by the Sybil Graben from other Silurian rocks, have not been placed exactly in the sequences. Possible correlations are with the Perry Creek Formation, or with the Carriers Well Limestone Member of the Wairuna Formation. The second is more likely, but neither is completely satisfactory.

A few miles south of the Burdekin River, near the western edge of the map area, is an area shown as

TABLE 5. GRANITIC BODIES ASSOCIATED WITH BOWNING OROGENY

Unit	*Age*	*Distribution*	*Remarks*
Lolworth Igneous Complex	395 m.y.	W end of Lolworth-Ravenswood Block	Probably co-magmatic
Ravenswood Granodiorite Complex, younger intrusives	395 m.y.	Throughout main body of R.G. Complex	
Barrabas Adamellite	395 m.y.	Small pluton SW of Ravenswood	
Dumbano Granite	380 m.y.	Joining Lolworth Igneous Complex to Georgetown Inlier	Mostly beyond sheet area

Greenvale Formation. The continuation of these rocks in the adjoining Clarke River Sheet area is shown as Kangaroo Hills Formation. This difference of interpretation is between Wyatt & others (1970) and White (1961, 1965). The critical point is the position of the overlying *Tribute Hills Sandstone* in relation to the Silurian to Early Devonian sequence, of which the four lowest formations are:

Perry Creek Formation (youngest)
Conformity
Kangaroo Hills Formation
Unconformity
Pelican Range Formation
Faulting
Greenvale Formation

White considered that the Tribute Hills Sandstone is largely equivalent to the Perry Creek Formation, and hence concluded that the beds in question were Kangaroo Hills Formation. Wyatt & others considered the Tribute Hills Sandstone to be very similar to the Pelican Range Formation, and the beds to the south to resemble the Greenvale Formation, and suggested correlation accordingly.

The emplacement of the Lolworth Igneous Complex and its contemporaries (Table 5) completed the consolidation of the Lolworth-Ravenswood Block. In the Cape River area and near Charters Towers deformation and alteration of the early Palaeozoic sediments suggest that severe northeast compression preceded the intrusions; and the Alex Hill Shear Zone may be a result of the same stress.

In the Broken River Embayment the movement (which can be correlated with the Bowning Orogeny) was possibly as late as Early Devonian.

The Late Silurian to Early Devonian sediments were folded, raised, and incorporated in a geanticline—the 'Wairuna Tectonic Land' of White. As a result the locus of sedimentation in the Broken River Embayment moved southwestward beyond the map area, not to return until the Carboniferous. Deposition of the Kangaroo Hills Formation in the far northwest of the map area continued into the Early Devonian. No other sediments of Early Devonian age have been found in the area.

Middle Devonian (Table 6, Fig. 3)

Apparently the next era of sedimentation was ushered in by the Middle Devonian orogeny, described by Hill (1951). No evidence of any movement associated with this orogeny has been found, but small areas of serpentinite (not shown on the map) in the Argentine Metamorphics may be part of the belt of serpentinites emplaced in eastern Queensland at that time.

Middle Devonian rocks were deposited in two areas: the Ukalunda beds, and other scattered areas extending as far south as Clermont, suggest a major basin of deposition south of the Lolworth-Ravenswood Block, probably dating from early Middle Devonian time; north of the Lolworth-Ravenswood Block, the 'Burdekin Basin' (see explanatory note below) received its first sediments in the Givetian. In both areas coral limestones are conspicuous elements.

The southern basin was miogeosynclinal, its eugeosyncline lying to the east. During the Tabberabberan Orogeny the miogeosyncline was deformed and a geanticline rose on its eastern edge to form the Drummond Basin. The Burdekin Basin, protected by the Lolworth-Ravenswood Block, was not deformed. However, deposition was interrupted and when it resumed, marine conditions had given way to continental conditions.

Use of the terms 'Burdekin Basin', 'Star Basin', etc.

Etheridge's (1872) 'Star Beds' were later expanded by correlation to include almost all strata in Queensland with Late Devonian to Early Carboniferous affinities, giving the original beds an importance far beyond that which they merited. This in turn led later writers to alter Jack's (1879a) 'Star Basin' beyond recognition.

To avoid further confusion, it is suggested that Etheridge's and Jack's terms be used in their original sense, and that the term 'Burdekin Basin' be used as by recent authors (e.g. Wyatt & others, 1970). These usages are as follows:

'Star beds': a sequence typically developed in Horse Creek, near Star outstation, and on the Star River at Corner Creek (Jack, 1879a). The term should not be applied to strata in other areas.

'Star Basin': the basin in which the Star beds crop out, and which forms an area of about 90 km^2 at the junction of the Great and Little Star Rivers (Jack & Etheridge, 1892). As thus defined, the Star Basin is a basin of erosion, not a basin of deposition.

'Burdekin Basin': the area between Laroona, Valpre, and Burdekin Downs in the west, and Speeds Creek, Calcium, and Fanning Rivers in the east, in which sedimentation commenced in the Givetian and ranged through to the Tournaisian (Wyatt & others, 1970). As thus defined it includes the Reid River area, but not the Broken River Embayment.

Late Devonian to Early Carboniferous (Table 6, Fig. 3)

Burdekin Basin

Remnants of strata indicate that the Burdekin Basin, following deposition of the Givetian Fanning River Group in the south, gradually expanded to the north to cover 4000–5000 km^2. This west-trending oval depression was bordered by a granitic and metamorphic terrain to the south, and a metamorphic terrain to the west and north. To the east was an opening to the sea.

The neritic, transitional, and continental sediments of the basin were deposited in a tectonic environment ranging from a mildly unstable shelf to a yoked intracratonic basin. In the southern and central portions of the basin, the strata are thickest and represent the whole Givetian-Tournaisian section. The basin expanded, particularly to the north, in the Famennian transgression, and still further in the Tournaisian transgression.

The Burdekin Basin has not been a target for oil exploration nor has any information been published on current directions, so palaeogeographical conclusions are generally rather speculative. The basin appears to have been of roughly constant size during the Middle Devonian (Fanning River Group). The change in environment displayed by the overlying Dotswood Formation was probably related to changes in the hinterland rather than in the basin itself. The Dots-

TABLE 6. SUMMARY OF MIDDLE DEVONIAN TO EARLY CARBONIFEROUS UNITS

Formation name and symbol	*Thickness, m*	*Environment of deposition/intrusion*	*Relationships*	*Remarks*
EARLY CARBONIFEROUS				
Cli	—	Syntectonic batholith	Intrudes Clarke River Formation	Rb/Sr age 330 m.y.
Clg	—	Stocks and sills	Intrudes Ukalunda Beds, Drummond Basin sequence	Possibly more than one intrusive episode
Clarke River Formation Cc	1500–2200	Emerging surface—marine followed by terrestrial	Unconformable on Late Silurian to Early Devonian	Only outliers in map area
Piccadilly Formation Ca	360–500	Fluvial-lacustrine	Conformable on Hardwick Formation	Burdekin Basin
Natal Formation Cln	300–1200	Fluvial-lacustrine	Conformable on Bulliwallah Formation	Drummond Basin
Bulliwallah Formation Clb	1800	Fluvial or lacustrine, some associated volcanism	Conformable on Raymond Formation	Drummond Basin
Star of Hope Formation Cls	up to 1800	Continental, torrential with ephemeral streams; associated volcanism	Conformable on Raymond Formation	Drummond Basin
Raymond Formation Clr	600–800	Fluvial	Conformable on Mount Hall Formation	Drummond Basin
Mount Hall Formation Clh	up to 3000	Fluvial	Underlies and interfingers with Scartwater Formation	Drummond Basin
Scartwater Formation Clc	1200	Piedmont alluvial plain	Disconformable on St. Anns Formation	Drummond Basin
Edgecumbe Beds Cle	6000	Shallow marine followed by terrestrial	Unconformable under Airlie Volcanics	Equivalent to part of Campwyn Beds
LATE DEVONIAN TO EARLY CARBONIFEROUS				
Star Beds DCs	700–820	Unstable between shallow marine and terrestrial	Unconformable under Tareela Volcanics	Burdekin Basin

TABLE 6. SUMMARY OF MIDDLE DEVONIAN TO EARLY CARBONIFEROUS UNITS *(continued)*

Formation name and symbol	*Thickness, m*	*Environment of deposition/intrusion*	*Relationships*	*Remarks*
DC	Not det.	Mixed	Varied	Burdekin Basin
Game Hill Beds DCg	750	Unstable between shallow marine and terrestrial	Unconformable or disconformable under St. James Volcanics	Burdekin Basin
Hardwick Formation DCh	300–360	Coastal to shallow marine	Conformable on Lollypop Formation	Burdekin Basin
Lollypop Formation DCl	300–820	Near shore, mostly terrestrial	Conformable on Myrtlevale Beds	Burdekin Basin
DCv	Unknown	Mainly volcanic	Possibly equivalent to Mount Wyatt & St. Anns Formations	Drummond Basin
St Anns Formation DCa	2100	Shallow marine and terrestrial	Unconformable on Ukalunda Beds	Drummond Basin
DCu	Unknown	—	Mainly roof pendants on late Palaeozoic granites	Ayr and Townsville Sheet areas
Connors Volcanics DCo	Unknown	Subaerial volcanism	Unconformable under Lizzie Creek Volcanics, Carmila Beds	Possibly partly equivalent to Campwyn Beds
Campwyn Beds DCc	3000?	Shallow marine to terrestrial, some associated volcanism	Probably unconformable under Permian units of Proserpine area	Mainly outside map area
LATE DEVONIAN				
Myrtlevale Beds Duy	300–450	Marine—advancing then retreating sea	Conformable on Dotswood Formation	Burdekin Basin
Dotswood Formation Dud	2400	Continental redbed	Overlapping, probably disconformable on, Fanning River Gp	Burdekin Basin
Mount Wyatt Formation Dum	1500+	Nearshore marine and paralic	Unconformable on Ukalunda Beds	Drummond Basins
MIDDLE DEVONIAN				
Fanning River Group Dmf	360	Shallow marine	Nonconformable on Ravenswood Granodiorite Complex	Burdekin Basin
Ukalunda Beds Dk	1200+	Marine, moderate depth	Probably infolded with Anakie Metamorphics	Basement to Drummond Basin

wood Formation is of markedly continental redbed type, suggestive of a subtropical upland supplying sediment to an environment ranging from piedmont to floodplain and shallow lacustrine.

The lower boundary of the Formation is marked in places by a conglomerate, which at one point contains pebbles of limestone, indicating that the Fanning River Group had been exposed to erosion by marine regression. However, there is no angular unconformity between the Fanning River Group and the Dotswood Formation, so any differential uplift must have lain beyond the basin. Probably the elevated source area was produced in the southern part of the Lolworth-Ravenswood Block by the Tabberabberan Orogeny.

The Famennian and Tournaisian transgressions were each succeeded by a period of continental deposition, but the conditions for redbed formation no longer prevailed. In these later times it is also probable that much more sediment was coming from the north.

In the far northern part of the basin the Famennian-Tournasian sequences are represented by the Star beds and the Game Hill beds, neither of which has been subdivided.

Drummond Basin

The Ukalunda beds had been laid down in a miogeosyncline; the eugeosyncline was to the southeast, beyond the map area. Following the Tabberabberan Orogeny, there arose a major geanticline trending north-northwest across the geosynclinal belt, forming the intracratonic Drummond Basin on its western side. Sediments of this basin now crop out over some 25 000 km^2 but the basin at its greatest extent may have been almost 125 000 km^2 in area. The first sediments do not appear to have been laid down until late in the Famennian, and are marine. However, continental conditions were soon established, and prevailed for the remainder of the life of the basin. Olgers (1972, p. 22) divided the sedimentary history into three cycles, as shown for the northern part of the basin in Figure 5.

In the first cycle, deposition was in a shallow sea, with sediment derived from the Lolworth-Ravenswood Block. This cycle came to an end with the deposition of acid flows and pyroclastics, both on land and in water, over most of the area.

In the second cycle, the locus of deposition was a long, narrow basin along the western flank of the geanticline. Much of the sediment was derived from the geanticline, but later in the cycle the southern margin of the basin became the dominant provenance. Transport was by a strongly-flowing river which ran northward through the basin, swinging to the east to the sea around the northern end of the geanticline. In the later stages of this cycle the Lolworth-Ravenswood Block was eroded to a sufficiently low level for the river to flow northeastward across it.

The third cycle was inaugurated by renewed epeirogeny and volcanism in the areas bordering the basin. Originally deposition was over roughly the same area as that of the previous cycle, but as the landscape matured, deposition extended to practically the limits of the basin.

Clarke River Basin

The Broken River Embayment continued to evolve steadily between the Middle Devonian and the Carboniferous, as the sediments of each phase were successively deformed and incorporated in the rising land mass in the centre. Deposition was all outside the map area until the Carboniferous, when the Clarke River Formation was deposited on an emerging land surface. Shallow marine conditions were followed by lacustrine, in parallel with the adjoining Burdekin Basin.

Coastal area

Along the coast in the southeast of the map area is the northern extremity of a sedimentary basin in which were deposited the Campwyn beds and Connors Volcanics (both Late Devonian to Early Carboniferous) and the Edgecumbe beds (Early Carboniferous). These sequences appear to be partly equivalent, and all involve volcanics, particularly the first two. Hill considered that this Basin was a northern extension of the Yarrol Basin, although there may have been a structural high separating the two depositional areas at times.

Correlations between sedimentary basins

Suggested correlations between the Middle Devonian to Late Carboniferous sequences are shown in Figure 5, and palaeogeographic outlines in Figure 6. It has been suggested (Hill, 1951) that the Drummond, Burdekin (then known as 'Star'), and Hodgkinson Basins may belong to one major structural unit, but this seems to be a false simplication. Although the Tasman Geosynclinal Zone was fully developed at that stage as a NNW-trending belt of depression, the Burdekin Basin was still largely dominated by the east to northeast lineaments inherited from earlier times. The Lolworth-Ravenswood Block not only formed a topographic barrier until well into the Carboniferous, but functioned as a stable cratonic block during deformation. To the north, the extremity of the Broken River Embayment had developed into the Broken River Rift, a northeast-trending rift which was the locus of sedimentation from Middle Devonian to Early Carboniferous. To the north and probably also to the south, it was bounded by geanticlines. The Hodgkinson Basin probably did not extend into the map area; de Keyser & Lucas (1968) considered that 'the present south-western boundary corresponds roughly to the original boundary of the Hodgkinson Basin' and 'the composition of the coarse detritus also suggests the presence of a nearby land mass to the south and west'.

The Clarke River Basin represents the latest stage of development of the Broken River Embayment, and its greatest extension to the southeast. The Clarke River Formation is similar to parts of its contemporaries, the Hardwick and Piccadilly Formations and the Star beds, suggesting that connection between the Burdekin Basin and the Broken River Embayment was achieved in the Tournaisian. There is no evidence of a previous connection; up to that time the history of the two basins had been completely different.

Deposition in the Drummond Basin did not begin until very late in the Devonian, and current directions suggest that during the Basin's earlier stages its river system discharged on the southern side of the Lolworth-Ravenswood Block. Towards the end of the second depositional cycle it breached the Block, and sediment was probably discharged into the Burdekin Basin until late in the life of both basins.

The sediments and volcanics along the present coast appear to have been deposited in a marginal basin, separated from the Drummond Basin by the geanticline. In the early stages it is possible that the two were connected around the nose of the geanticline.

Kanimblan Orogeny

The Viséan Kanimblan Orogeny was variable in its effect throughout the area. The main stress was compression from the east. This was largely relieved by faulting, so folding was generally gentle and open except near the faults. The fold pattern in many places was partly developed before the orogeny, and was moulded by the form of the underlying basement. In the Drummond Basin severe folding and faulting occurred at the northern end, where the beds were sheared between the northern end of the west-moving Anakie Inlier (see section AB on geological map) and the southern edge of the Lolworth-Ravenswood Block. In the coastal area the Campwyn beds are only moderately folded, but the Edgecumbe beds have been titled as a block through 90° to the east, and in places are folded and complexly faulted.

Accompanying igneous intrusions include the western portion of the Oweenee Granite, northwest of the Burdekin Basin, and a number of irregular granodiorite plutons at the northern end of the Drummond Basin. The boundary between the Oweenee Granite and younger granites to the east is based on the results of isotopic dating rather than mapping, and for that reason it has been shown on the map as a smooth, rather arbitrary line.

Late Carboniferous to Early Permian (Tables 7, 8, 9; Fig. 7)

This time-span cuts across the geological history to some extent, in that the formation of the Bowen Basin began in and extended beyond it; but otherwise it possesses a strong unity of character. The Kanimblan Orogeny had produced complete regression of the sea,

and it is probable that uplift continued in most of the area throughout the period. Magma was high in the crust, and at regular intervals was emplaced and/or extruded. Some relatively low-lying areas received continental sediments, usually derived from the volcanic terrain. Except for the northern portion of the Urannah Igneous Complex and the Lizzie Creek Volcanics, acid and intermediate rocks overwhelmingly predominate.

Neither in composition nor in position does the activity show any systematic variation in time. Intrusion by an intermediate-to-basic batholith in the southeast of the area ushered in the period of activity, but thereafter basic rocks are exceptional (e.g. Lizzie Creek Volcanics). The distribution of the various formations, individually and collectively, shows the influence of the strong northwest trends associated with the Tasman Geosynclinal Zone, although this pattern may be somewhat exaggerated by the masking effects of later formations in the western part of the area.

This igneous activity extended far beyond the north and northwestern edges of the area. In the Georgetown Inlier it has been the subject of an extensive study by Branch (1966), who reached the following conclusions:

1. The main events were vast outpourings of rhyodacitic pyroclastics, followed by ademellite intrusions into the base of the pyroclastic flow fields. These events were preceded and succeeded by the extrusion of small amounts of calc-alkaline lavas.
2. Most of the pyroclastic flows are preserved in cauldron subsidence areas.
3. Ring complexes were formed at the intersection of major basement fractures.

In the Burdekin region the pattern is similar in that rhyodacitic extrusives and adamellite intrusives predominate. However, definite cauldron subsidence areas are absent, with the possible exception of the area occupied by the Bulgonunna Volcanics. There is only one mapped ring complex—the Rangeview Ring Fracture (20°18′S, 147°07′E)—although some circular stocks may represent the roots of subsidence areas associated with ring fractures.

The Lizzie Creek Volcanics were the first deposits in the newly formed Bowen Basin. Their relation to later deposits and the further development of the basin are discussed below.

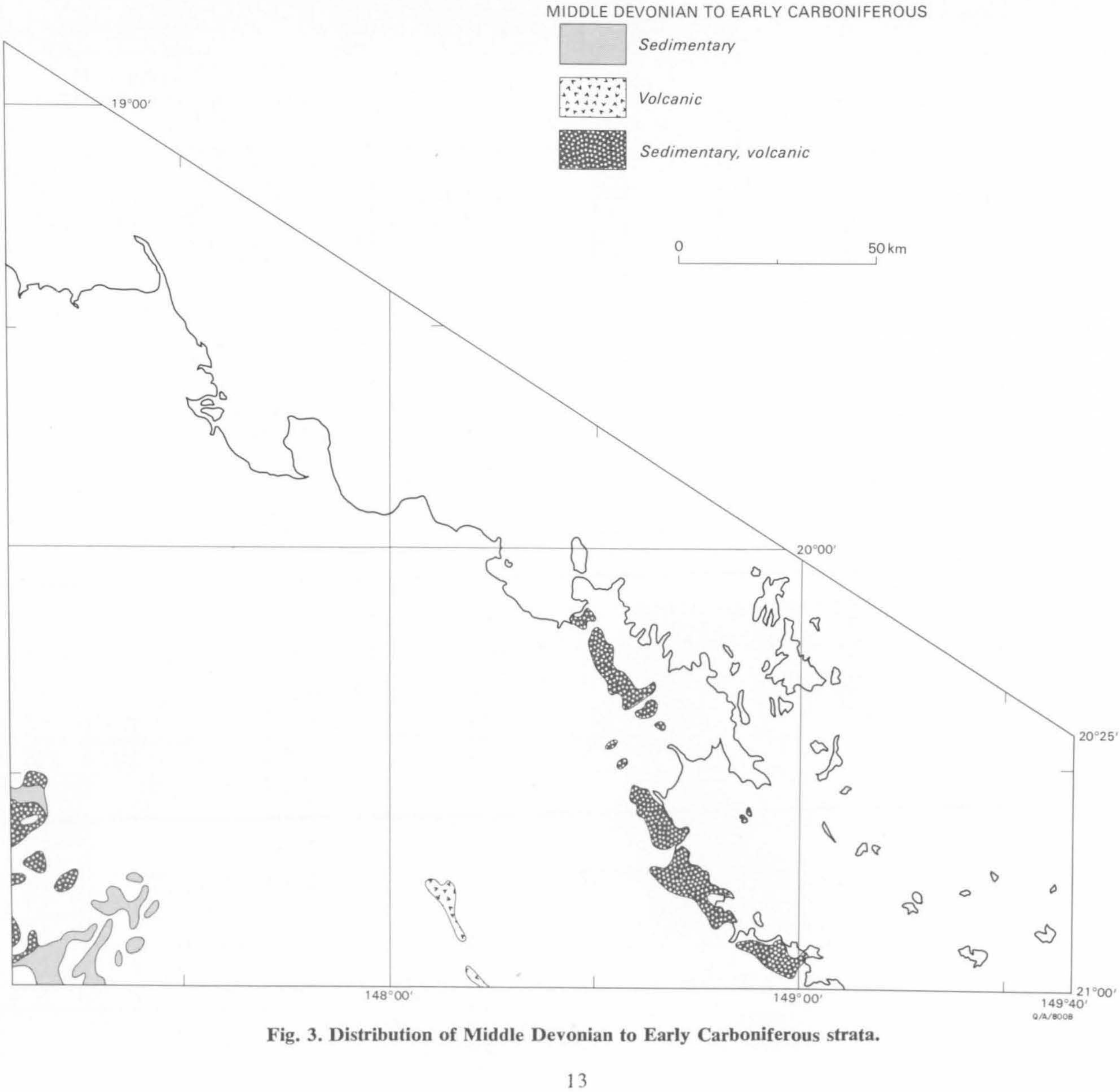
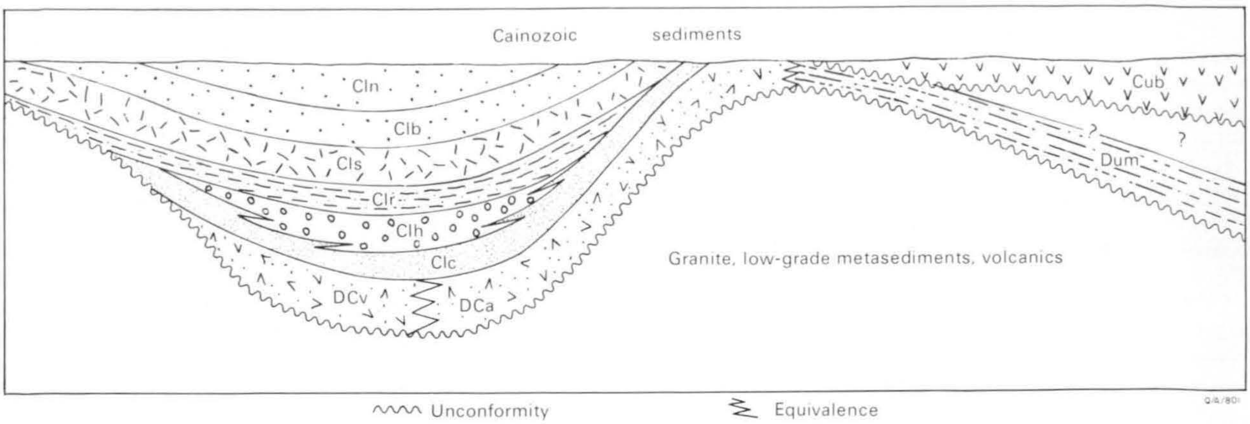


Fig. 3. Distribution of Middle Devonian to Early Carboniferous strata.



Cub	*Bulgonunna Volcanics*	Clh	*Mount Hall Formation*
Cln	*Natal Formation*	Clc	*Scartwater Formation*
Clb	*Bulliwallah Formation*	DCv	*Volcanics and sediments*
Cls	*Star of Hope Formation*	DCa	*Saint Anns Formation*
Clr	*Raymond Formation*	Dum	*Mount Wyatt Formation*

Fig. 4. Relationships in the northern Drummond Basin (from Olgers, 1972, fig. 7).

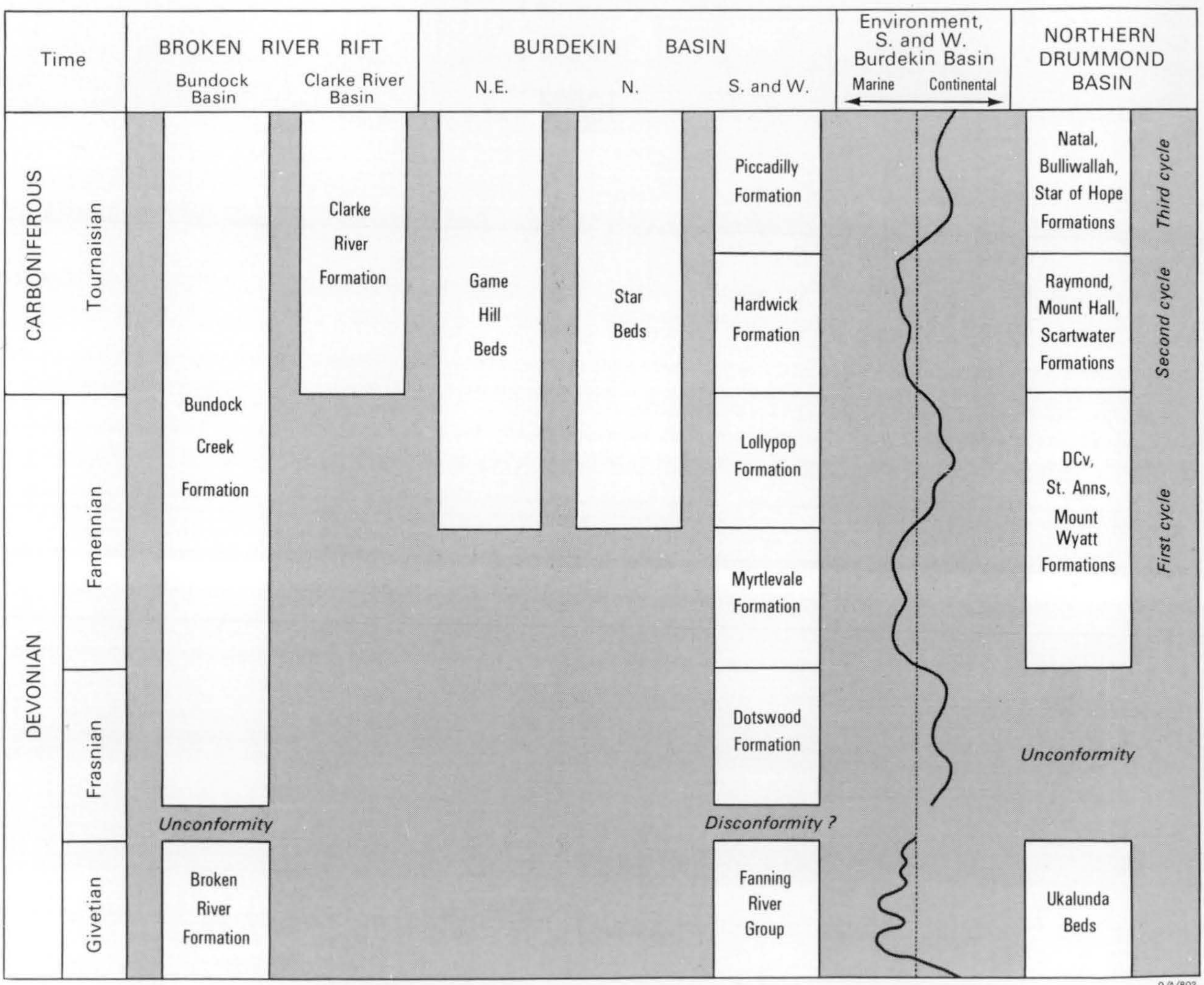


Fig. 5. Suggested correlations, Middle Devonian to Early Carboniferous units.

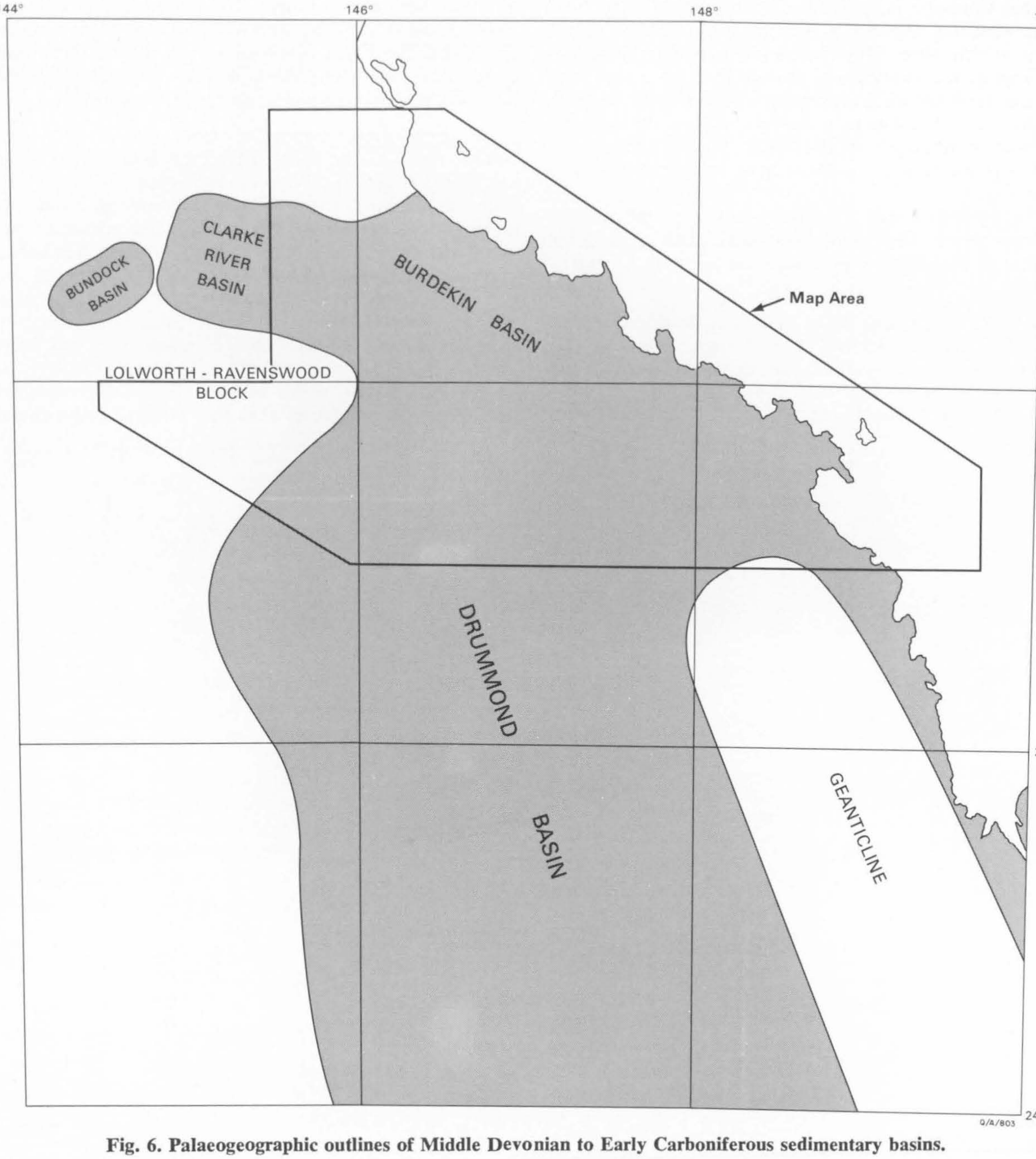


Fig. 6. Palaeogeographic outlines of Middle Devonian to Early Carboniferous sedimentary basins.

Early Permian to Triassic
(Tables 10, 11; Fig. 8)
Bowen Basin

The Bowen Basin was the last major structural feature developed within the Tasman Geosynclinal Zone in eastern Queensland. Only the northern extremity extends into the map area, and it is simple in structure compared with sections farther south. The first significant downwarp probably began early in the Permian, during the volcanic episode just described, and the first deposits were predominantly volcanic—the Lizzie Creek Volcanics. The basin was asymmetrical. On the western side the Bulgonnunna Volcanics formed a stable block from which a shallow shelf sloped to the east, and only a thin layer of volcanics and sediments was deposited there. In the east was a trough, possibly rimmed on its eastern side by a line of volcanic highlands trending north-northwest. Volcanics and sediments accumulated in the trough, which was invaded by the sea towards the end of the Lizzie Creek episode. The terrestrial portion of the volcanics was the source of most of the sediments.

With the cessation of volcanism, sedimentation proceeded in the moderately deep-water conditions produced by the marine incursion (Tiverton Subgroup). Later movement extended the area of the basin to the east and the north but produced an overall shallowing. The Gebbie Subgroup was deposited under shallow marine conditions in the main part of the basin while near the northern and western shore a deltaic or paludal environment, with occasional marine incursions, produced the Collinsville Coal Measures. The next incursion extended the limits of the basin again, as a shallow transgressive sea (Blenheim Subgroup). All these units belong to the Back Creek Group.

The Connors Arch, later an important structural high, probably showed its first signs of upward movement at this time. This rise resulted in a reduction in the size of the basin and a change through a restricted marine or brackish environment (Blackwater Group) in the Late Permian to a fluviolacustrine environment (Rewan Formation) in the Early Triassic. The rising arch was the main provenance area, and deposition was often rapid.

This episode ended with the cessation of uplift in the Connors Arch; less rapid deposition, with a probable change of provenance, produced the Clematis Group.

Other areas

Beyond the present limits of Bowen Basin sediments are correlatives indicative of its former extent. In the Townsville area volcanics and minor coal measures extend as far north as 19°05′S, and there appears little doubt that the Lizzie Creek depositional area was continuous over this distance. To the east, the Carmila beds, Airlie Volcanics, and Calen Coal Measures indicate that the basin extended across the northern end of the Connors Arch, although full continuity between the two areas was probably, at most, intermittent.

An even more important extension is with the Galilee Basin in the west, where the Betts Creek beds are overlain by the Warang Sandstone. The present connection here is south of the Drummond Basin, far to the south of the map area. The unconformity between the Betts Creek beds and the Warang Sandstone suggests a tectonic regime different from that of the Bowen Basin proper, and it is probable that this was first an independent depositional area. However, by Triassic times it appears that a connection had been formed, if only intermittently. The two outliers of Collopy Formation north of the Mingela-Ravenswood road prompt speculation that the Triassic depositional

area may have been much more widespread than otherwise suggested, but no conclusions can be drawn.

There were some earth movements in the coastal area in the Permian, but the main phase was not felt until the Triassic. The principal movement was the rise of the Connors Arch, raising the eastern limb of the Bowen Basin and stamping on the basin the asymmetrical synclinal form it now possesses. Movement between the two was largely accomplished by faulting. Following this episode the locus of deposition moved to the west, so that it marks at once the end of the Bowen Basin and the beginning of the Eromanga Basin.

Cretaceous (Table 12)

Following the Triassic orogeny the coastal area entered an important period of igneous activity similar to that of the Late Carboniferous, except that a smaller area was involved. Two distinct episodes have been recognised, both in the Early Cretaceous, as follows:

(i) A relatively deep-seated plutonic phase, represented by a group of granitic rocks with average isotopic age of 125 m.y. Included in this group are the Hecate Granite, a batholith now exposed over at least 1250 km^2, a granite at Eungella just southeast of the map area, and part of the Urannah Igneous Complex.

(ii) About 10 million years later there was a volcanic phase (Prosperine and Whitsunday Volcanics), waning to sub-volcanic (high-level stocks of leucocratic granite and rare syenite, Kg). The Proserpine Volcanics (mainly rhyolite) probably erupted on a stable terrestrial block, while the Whitsunday Volcanics, a thicker sequence of water-laid ash-fall pyroclastics and minor flows, were being deposited in an unstable landlocked basin close by to the east.

Cainozoic (Table 13, Fig. 9)

At the opening of the Cainozoic the area had reached a stage of topographical maturity. The main divide still lay to the east of its present position, probably near the coastal ranges, and there was a considerable extension of Triassic sediments to the east of their present exposures.

Block faulting and uplift produced changes in the southern portion of the area. In the east the Hills-

Fig. 7. Distribution of Late Carboniferous to Early Permian strata (excluding Back Creek Group and equivalents).

TABLE 7. SUMMARY OF LATE CARBONIFEROUS TO EARLY PERMIAN UNITS

Formation name and symbol	*Thickness, m*	*Environment of deposition/intrusion*	*Relationships*	*Remarks*
EARLY PERMIAN				
Plr	—	Dykes of Rangeview Ring Fracture	Cut Plg, postdate Cuv	Essentially same age as some Plg
Plg	—	Isolated stocks	—	
Thunderbolt Granite Plq	—	Post-tectonic batholith	Intrudes Cud; intruded by Hecate Granite	Possibly slightly younger than Lizzie Creek Volcanics
Plv	300–500	Terrestrial volcanics	Intruded by Plg, Mt. Abbot Complex, Hecate Granite	Mainly in Townsville district; also includes Mt. Aberdeen Volcanics, Kurungle Volcanics
Lizzie Creek Volcanics Plz	up to 6000	Volcanism in marine basin	Nonconformable on Cug, CPg; overlapped disconformably by Collinsville Coal Measures	Formerly named Lower Bowen Volcanics
Carmila Beds Pla	7500(?)	Terrestrial volcanics	Intruded by Hecate Granite	Probably same age as Lizzie Creek Volcanics
Airlie Volcanics Pll	6000(?)	Terrestrial volcanics	Probably unconformable on Campwyn Beds; intruded by younger phases of Urannah Igneous Complex	Age in doubt
LATE CARBONIFEROUS TO EARLY PERMIAN				
CPg	—	Several separate bodies	—	Probably more than one age; includes Pall Mall Adamellite, parts of Oweenee and Almaden Granites
Tuckers Igneous Complex CPt	—	Epizonal pluton	Intrudes late Carboniferous volcanics	Probably coeval with Boori Igneous Complex
CPp	—	Small bodies of porphyry related to CP granites	—	Possibly more than one age
Boori Igneous Complex CPb	—	Epizonal pluton	Intrudes Ravenswood Granodiorite Complex, Cur	Probably coeval with Tuckers Igneous Complex
CPi	—	Small irregular plutons	Intrude C in Burdekin Basin; intrude Drummond Basin sequence	Possibly more than one age

TABLE 7. SUMMARY OF LATE CARBONIFEROUS TO EARLY PERMIAN UNITS *(continued)*

Formation name and symbol	*Thickness, m*	*Environment of deposition/intrusion*	*Relationships*	*Remarks*
LATE CARBONIFEROUS				
Marshs Creek Beds Cm	1200	Freshwater or estuarine	Conformable on Hells Gate Rhyolite	With Hells Gate Rhyolite forms Sybil Group
Hells Gate Rhyolite Ch	900	Terrestrial, many local volcanic piles	Unconformable on Clarke River Formation	With Marshs Creek Beds forms Sybil Group
Tareela Volcanics Ct	3000	Volcanics	Overlie Star Beds, probably disconformably	
Insolvency Gully Formation Ci	1050	Terrestrial, fairly rapidly subsidising basin	Intruded by CPg	Similar to parts of Ellenvale Beds
St. James Volcanics Cs	900–1050	Terrestrial, mainly volcanic	Probably unconformable on Game Hill Beds	Probably equivalent to C and Tareela Volcanics
Ellenvale Beds Ce	3000	Terrestrial, mainly volcanic	Possibly conformable with C; intruded by CPg	Probably equivalent to Sybil Group
C	1000	Terrestrial sediments and volcanics	Unconformable on Percy Creek Volcanics; intruded by CPi and CPg	
Percy Creek Volcanics Cp	180	Volcanics, probably terrestrial	Unconformable on Hardwick Formation	Similar to parts of Tareela and St. James Volcanics
Cuv	—	Acid volcanics in several areas	Various	Includes Glen Gordon Volcanics
Cur	—	Isolated dykes, sills, volcanic plugs	Intrudes various rocks, Early Carboniferous and older	May be related to Bulgonunna Volcanics
Cug	—	Post-tectonic epizonal batholith	Intrudes Late Carboniferous volcanics; overlain by Lizzie Creek Volcanics	Probably related to Bulgonunna Volcanics
Bulgonunna Volcanics Cub	Unknown	Volcanism at several centres; terrestrial	Unconformable on Early Carboniferous formations; unconformable under Lizzie Creek Volcanics	Probably comagmatic with Cug
Cud	—	Composite mesozonal batholith	Intruded by Thunderbolt Granite; unconformable under Lizzie Creek Volcanics	Equivalent to earlier parts of Urannah Igneous Complex

TABLE 8. POSSIBLE CORRELATIONS OF MIDDLE CARBONIFEROUS TO EARLY PERMIAN IGNEOUS EVENTS BETWEEN BURDEKIN RIVER REGION AND AREA TO THE NORTH

Age (m.y.)	*Burdekin River Region*	*Area to north (after Branch, 1966)*
265	Thunderbolt Granite	Mareeba Granite
270	Lizzie Creek Volcanics, Carmila Beds, Airlie Volcanics, Plg, Plr, Plv, part of Urannah Igneous Complex	*Third volcanic episode:* Agate Creek Volcanics, volcanics of Mitchell River
280	Tuckers Igneous Complex, Boori Igneous Complex, Cpg, CPp	*Intrusive events:* Elizabeth Creek Granite, Herbert River Granite
290	Bulgonunna Volcanics, Percy Creek Volcanics, Ellenvale Beds, Hells Gate Rhyolite, Marshs Creek Beds, St James Volcanics, Insolvency Gully Formation, Tareela Volcanics, Cug, Cur, Cuv	*Second volcanic episode:* Butlers, Warby, Claret Creek, Boxwood, Newcastle Range, Featherbed, Scardens, Glen Gordon, Walsh Bluff, Kallon,
305-310	Cud, part of Urannah Igneous Complex	Gingerella, Cumberland Range, and Galloway Volcanics
330	Oweenee Granite	*First volcanic episode:* Nychum, Nanyeta and Sunday Creek Volcanics; Doolan Creek Rhyodacite

TABLE 9. AGES OF SOME UPPER CARBONIFEROUS-LOWER PERMIAN FORMATION UNITS

Age, m.y.	*I* Units assigned to age by isotopic dating	*II* Units assigned to age by correlation with those of Column I
265	Thunderbold Granite	
270	Urannah Igneous Complex (part), Lizzie Creek Volcanics, Plg (at least in part)	Carmila Beds, Airlie Volcanics, Plr, Plv
280	Tuckers Igneous Complex, Boori Igneous Complex, CPg (part)	CPp
290	Urannah Igneous Complex (part) Bulgonunna Volcanics, Cug	Ellenvale Beds, Hells Gate Rhyolite, St James Volcanics, Tareela Volcanics, Percy Creek Volcanics, Marshs Creek Beds, Insolvency Gully Formation, Cur, Cuv
305-310	Urannah Igneous Complex (part—possibly most), Cud	
Unknown	CPi	

borough Basin was formed as a graben in the Oligocene, receiving terrestrial sediments and volcanics, while a small intrusive complex was emplaced nearby. Farther west, mature topography was again achieved with the removal of much of the Triassic sandstone and the deposition of disconnected areas of river and lake deposits.

This mature land surface was apparently continuous with a similar surface over most of Queensland, on which formed the great mid-Tertiary laterite sheet. This lateritic period has been used by many writers as the most important basis for division of the Cainozoic, although there are two problems still associated with it: there is some divergence of opinion as to the exact age of its formation, and in places more than one period of lateritisation is indicated. In view of the vast area involved, it would be unlikely that the sequence of events coincided at all places, so the difference in assigned ages may be real. The general sequence appears to have been as follows:

1. A major episode of lateritisation, which affected the whole area concerned. This began in different places at times ranging from Oligocene to Miocene, and was completed from Early to Late Miocene.
2. An episode of renewed erosion and deposition.
3. A minor episode of lateritisation, producing a thin ferricrete profile.
4. In places a further erosion/deposition period followed by minor lateritisation. The latest of these episodes may reach to the present day.

Within the map area the first three episodes can be positively identified. The formation of the main laterite sheet probably coincided more or less with the Miocene. Laterite formed on rocks of several ages, but mostly on earlier Tertiary sediments. The second and third episodes are represented by the Campaspe beds and their mantle of ferricrete.

Within the map area the first three episodes can be positively identified. Whether there was any further lateritisation in the area is uncertain. Certain ferricrete areas appear to be younger than the Nulla Basalt, which in turn appears younger than the Campaspe beds, but the Nulla Basalt itself includes flows ranging in age from Pliocene to Pleistocene, and the relationships are not fully established. It is possible that the earliest basalt eruption took place between the deposition of the Campaspe Beds and the formation of ferricrete upon them.

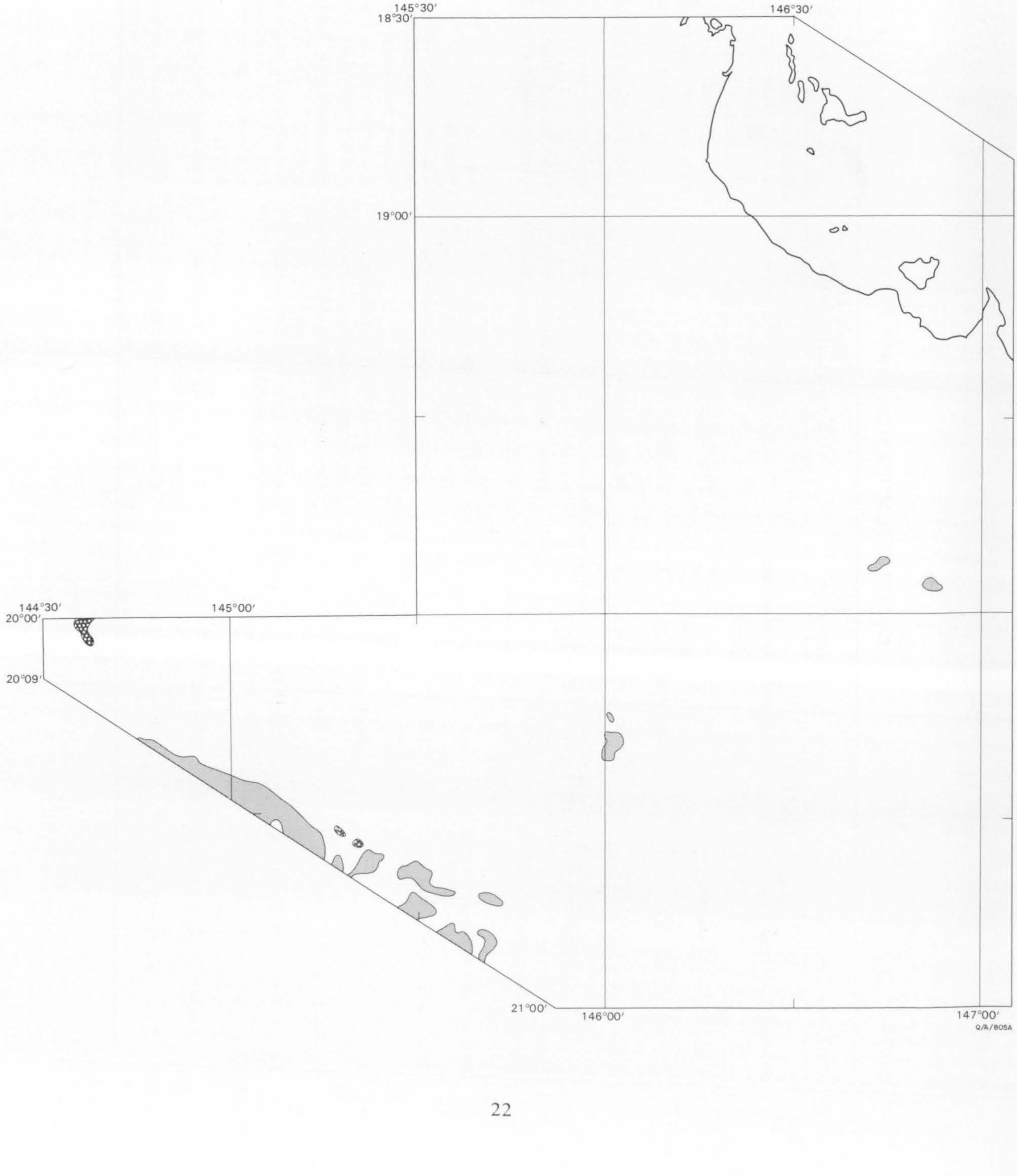
The basalt flows belong to the Nulla, Sturgeon, and Toomba Provinces. Flows in the Nulla Province have yielded ages ranging from Upper Pliocene to Pleistocene. This period is comparable to those of the McBride and Atherton Provinces to the north, indicating the essential unity of the extrusuve episode. The Sturgeon

TABLE 10. SUMMARY OF EARLY PERMIAN TO TRIASSIC UNITS

Formation name and symbol	*Thickness, m*	*Environment of deposition/intrusion*	*Relationships*	*Remarks*
TRIASSIC				
Warang Sandstone R̄w	200 (outside map area)	Fluvatile, possibly torrential	Unconformable on Betts Creek Beds; unconformable under presumed Upper Jurassic	Equivalent to Clematis Sandstone
Collopy Formation R̄c	150	Freshwater	Unconformable on Ravenswood Granodiorite Complex	May be equivalent to Warang Sandstone
Clematis Group R̄e	160–450	Fluviatile	Conformable on Rewan Formation	Equivalent to Warang Sandstone
Rewan Group R̄r	800 (outside map area)	Shallow water	Conformable on Blackwater Group	
LATE PERMIAN TO EARLY TRIASSIC				
Mount Wickham Rhyolite PR̄r	200 (flows)	Flows, plugs, dykes	Intrudes and unconformably overlies Lizzie Creek Volcanics	
PERMIAN				
Mundic Igneous Complex Pum	—	Small stocks, bosses, etc.; epizonal	Intrudes Lolworth Igneous Complex	Minor Au mineralisation
Betts Creek Beds Pub	150	Continental, at times swampy; occasional volcanicity	Unconformable on Cape River Beds; unconformable under Warang Sandstone	
Puv	60	Terrestrial, near shoreline of inland sea; intermittent volcanicity	Unconformable on Dumbano Granite and older rocks	Probably equivalent to Betts Creek Beds
Blackwater Group Puw	2500	Lacustrine, fluviatile, and paludal	Conformable on Back Creek Group	See Table 11
Back Creek Group Pb	400–1800	Ranges from moderately deep marine to deltaic	Possible slight unconformity on Lizzie Creek Volcanics, conformable under Blackwater Group	Includes Tiverton, Gebbie, and Blenheim Subgroups and Collinsville Coal Measures
Collinsville Coal Measures Plc	250–420	Deltaic or paludal, occasional marine transgression	Part of Back Creek Group	Includes 11 named coal seams
Calen Coal Measures Ple	300	Continental or near-shore	Unconformable on Lizzie Creek Volcanics, Carmila Beds	Probably equivalent to Collinsville Coal Measures

TABLE 11. NOMENCLATURE OF BOWEN BASIN SEDIMENTS

Older nomenclature (Malone & others, 1966)	*Present nomenclature* (Dickins & Malone, 1973; Jensen, 1975)	
Carborough Sandstone	Clematis Group	
Upper Bowen Coal Measures	Rewan Group	
	Blackwater Group	
Middle Bowen Beds	Blenheim Subgroup Collinsville Coal Measures Gebbie Subgroup Tiverton Subgroup	Back Creek Group
Lower Bowen Volcanics	Lizzie Creek Volcanics, Carmila Beds	



Basalt, lying on the opposite side of the Great Dividing Range to the Nulla, also represents a similar time span. The Toomba Basalt, on the other hand, is one of the youngest flows in Queensland, and appears to have no correlative except the Kinrara Basalt, just beyond the northwestern edge of the map area.

Such analytical and petrological work as has been done shows these rocks to be of the olivine-basalt family. Their extrusion is roughly contemporary with, and almost certainly related to, the uplifts that marked the emergence of the Recent epoch.

PHYSIOGRAPHY

LANDFORMS (Fig. 10)

The *coastal highlands* comprise residuals of resistant rock forming steep, often rugged hills and mountains. These may form isolated masses rising from the coastal plain (e.g. Mount Stuart, and Mount Elliot), rocky headlands and capes (Cape Cleveland, Cape Upstart, and the Conway Range) or rocky islands (all the larger islands in the map area). The resistant rocks forming these features are virtually all Early Carboniferous to Early Cretaceous intrusives and volcanics.

The *coastal plains* include deltaic, clay, and piedmont plains, saline land, mangrove areas, and beach ridges and sand dunes. All are formed on Quaternary deposits, usually superficial. Elevations rarely exceed 80 m.

The *eastern highlands* are a complex system of rugged mountains and hills and dissected plateaux separating the coastal plains from the inland areas. Elevations of 900-1000 m are reached in the northern part of the area (Paluma and Coane Ranges) and the southern part (Clarke Range). In the central part the Leichhardt Range is mostly under 500 m. A conspicuous break in this belt of high ground is the deeply incised gorge through which the Burdekin River traverses the Leichhardt Range.

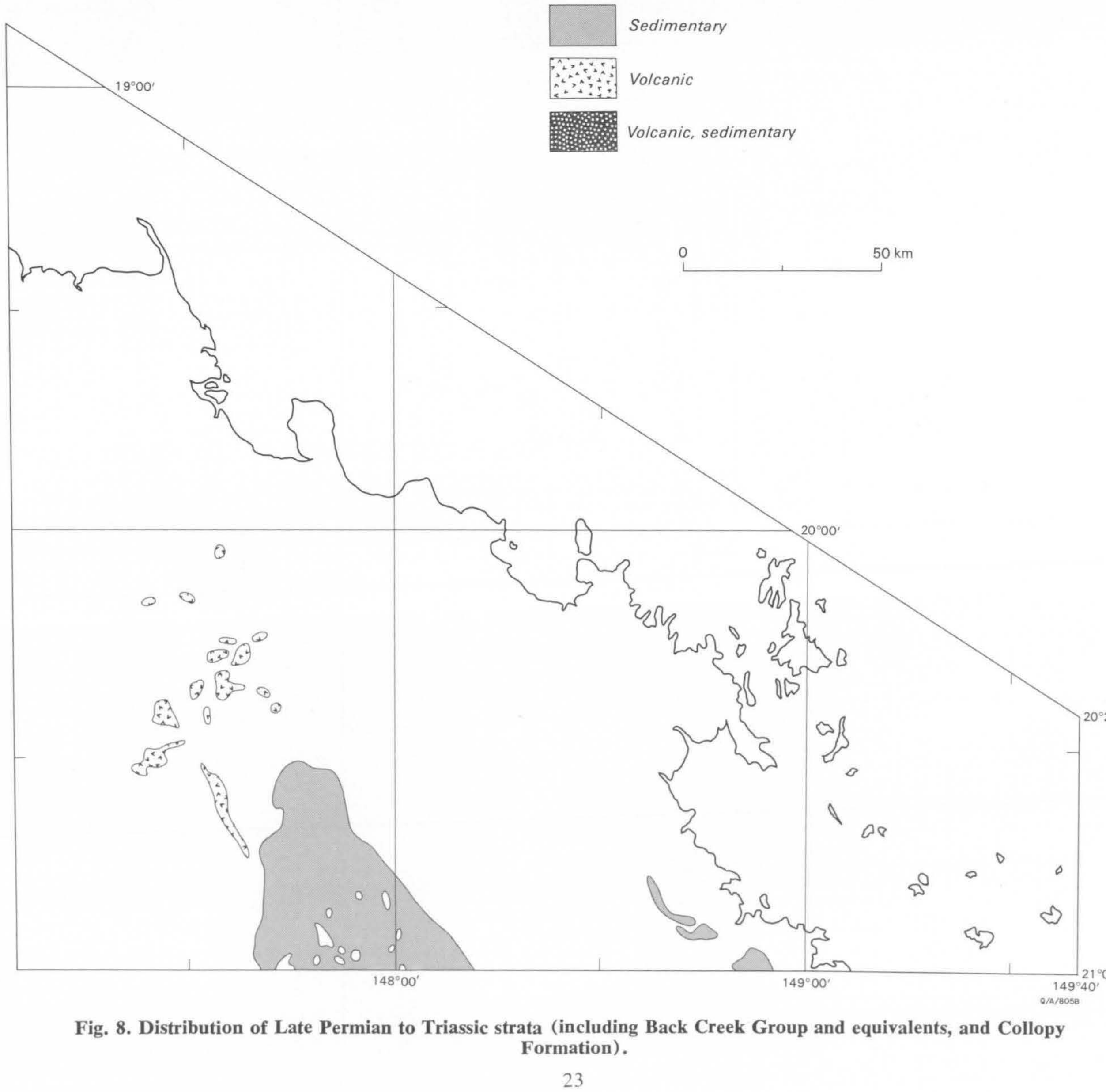


Fig. 8. Distribution of Late Permian to Triassic strata (including Back Creek Group and equivalents, and Collopy Formation).

TABLE 12. SUMMARY OF CRETACEOUS UNITS

Formation name and symbol	*Thickness, m*	*Environment of deposition/intrusion*	*Relationships*	*Remarks*
Mount Abbot Igneous Complex Ka1, 2	—	Epizonal stocks	Intrudes CPg	
Kg	—	Subvolcanic intrusives	Intrudes Whitsunday Volcanics, and comagmatic with them	Several separate bodies, mostly on islands
Proserpine Volcanics Kp	900	Terrestrial volcanics	Unconformable on Edgecumbe Beds, Airlie Volcanics	Terrestrial equivalents of Whitsunday Volcanics
Whitsunday Volcanics Kw, Kc	1500	Volcanics, intramontane basin	Intruded by Kg	Equivalent to Proserpine Volcanics
Ki	—	Separate small stocks, laccoliths, etc.	Intrudes Bowen Basin sequence	Very minor gold mineralisation
Hecate Granite Kh	—	Mesozonal batholith	Intrudes Urannah Igneous Complex, Thunderbolt Granite, Carmila Beds, Plv, Cud, CPg	Responsible for 'Duffer' vein and some minor gold mineralisation

TABLE 13. SUMMARY OF CAINOZOIC UNITS

Formation name and symbol	*Thickness, m*	*Environment of deposition/intrusion*	*Relationships*	*Remarks*
PLEISTOCENE TO RECENT				
Qa	Up to at least 33 on coast	Alluvial, colluvial	Overlies many other formations	Deposition still proceeding on coast
Qr	?	Beach ridges, coastal dunes	Superficial	
Qs	?	Residual	Superficial	Mainly soil
Ql	?	Lacustrine	In lakes dammed by Toomba Basalt	
Toomba Basalt Qt	?	Terrestrial volcanic	Superficial	
Qn	3–4.5	Fluviatile and lacustrine	Overlies pre-Pleistocene formations	Probably essentially Pleistocene
PLIOCENE TO PLEISTOCENE				
Sturgeon Basalt Czm	?	Terrestrial volcanic	Superficial	Probably equivalent
Nulla Basalt Czn	?	Terrestrial volcanic	Superficial	
Czb	?	Terrestrial volcanic	Superficial	Remnants of possibly more than one flow
TERTIARY				
Tu	Up to 45	Fluviatile and lacustrine	Overlies Palaeozoic	Possibly contemporaneous with Czb
Tf	Usually < 1.5	Weathered zone	Seems confined to Campaspe Beds	Represents weak episode of lateritisation
Tx	< 10	Torrential	Overlies pre-Tertiary formations	Later than main episode of lateritisation
MIOCENE OR OLDER				
Tl	10	Weathered zone	Overlies many formations	Main episode of lateritisation
Tn	36	Lacustrine, fluviatile	Overlies several formations	
Tb	2	Terrestrial volcanic	Overlies Star of Hope Formation	
OLIGOCENE				
Mount Jukes Syenite Complex Tj	—	Epizonal stocks	Intrudes Carmila Beds, Calen Coal Measures	Same age as Cape Hillsborough Beds (McDougall & Slessar, 1972)
Cape Hillsborough Beds Th	500	Terrestrial	Unconformable on Carmila Beds, Campwyn Beds	Probably equivalent to lower part of Tz
Tz	3000	Intramontane basin	Faulted against older rocks	Mainly subsurface

Igneous rocks, both volcanic and intrusive, are overwhelmingly predominant in these highlands. They range in age from the Ordovician phases of the Ravenswood Granodiorite Complex to the Cretaceous intrusives in the southeastern part of the area.

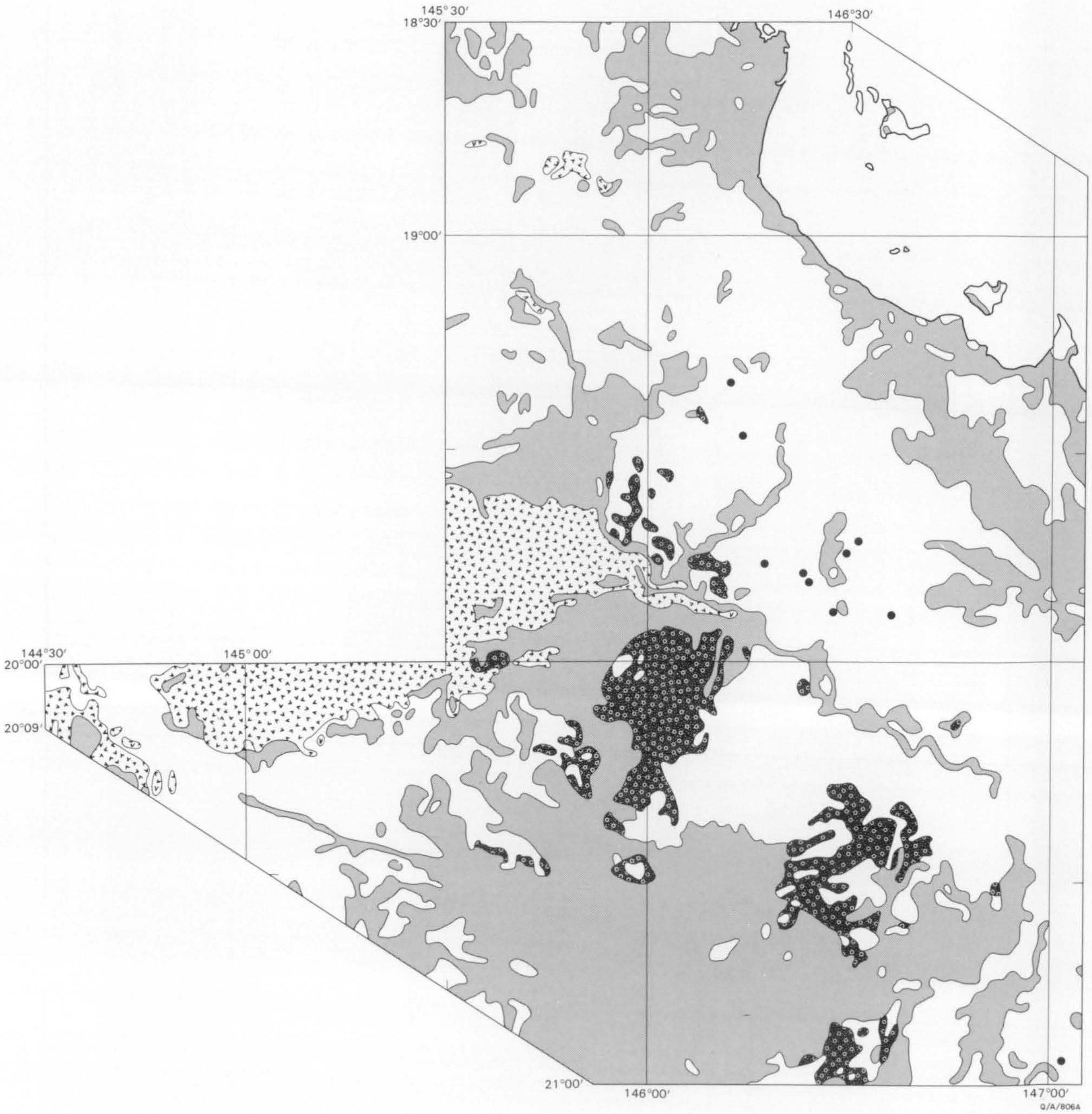
The *central hills and tablelands* are a complex of low undulating hills with some steeper ridges, and dissected tablelands, mesas, and buttes. Elevations are usually 200-500 m above sea level.

Granitic rocks underlie the hilly areas near Charters Towers and in places farther north to the Coane Range. Elsewhere Palaeozoic sediments are predominant, particularly those of the Burdekin and Drummond Basins. The tablelands are formed mainly on Tertiary sandstone, laterite, and ferricrete. Dissection of these has formed broken scarps, mesas and buttes, and in places where harder underlying rocks have been exposed, low hills and ranges.

The *central plains and lowlands* in the area southwest of Charters Towers consist of gently undulating clay plains and level to undulating sandy or loamy plains. Alluvial plains are present near many streams, which frequently form braided channels. Underlying rock types are mainly Cainozoic clayey sandstone with ferricrete cappings, and superficial formations.

In the Bowen River valley the lowlands are undulating plains with minor cuestas and strike ridges, found mainly on the Lizzie Creek Volcanics. Those nearby on the lower Burdekin are similar, grading in the north towards the coastal plains.

The *western plateaux and high plains* comprise the eastern extremities of the Burdekin Upland, the Nulla Plateau, and the Alice Tableland (southern part). The Burdekin Upland consists of undulating dissected plateaux and plains about 400 m in altitude at the southern end and increasing to the north. The under-



lying rocks in the map area are predominantly Palaeozoic sediments, with subordinate granites.

The Nulla Plateau is a broad, slightly domed plateau formed by accretion of lava flows (Nulla Basalt). The small part of it extending into the map area comprises plains about 300 m above sea level, terminating to the east and south in stepped scarps representing the extremities of individual flows. A conspicuous feature in the south is the 'Great Basalt Wall', an irregular scarp 15–30 m above the surrounding plain, representing the edges of the Toomba Flow.

The Alice Tableland is an extensive plateau developed on Mesozoic and Cainozoic sediments. The small part of it within the map area is the highly dissected northeastern extremity which grades into the central plains.

The *western highlands* include part of the Great Dividing Range, here trending southwest, and the Lolworth and Grasstree Ranges, which extend from the Great Dividing Range to the north-northeast. The Great Dividing Range section consists of dissected hilly country largely on early Palaeozoic metamorphic rocks. Elevation decreases from over 750 m in the north to 450 m near Pentland. The Lolworth and Grasstree Ranges are rugged hills and ridges of early Palaeozoic granite, rising in places to over 750 m above sea level.

Physiographic history

The predominant geological elements in forming the present land surface were:

1. Pre-Mesozoic faults.
2. The presence of resistant Palaeozoic and Mesozoic igneous rocks.
3. An early Tertiary surface of erosional maturity and lateritisation.
4. Cainozoic basalt extrusions.
5. Cainozoic earth movements.

Their effects are often so intertwined as to be inseparable.

The North Queensland coastal plain and its bounding scarps and corridors have been frequently discussed. Much of the disagreement in interpretation arises from treating the long coastline of eastern Australia as a unit, with similar origin at all places. To avoid this,

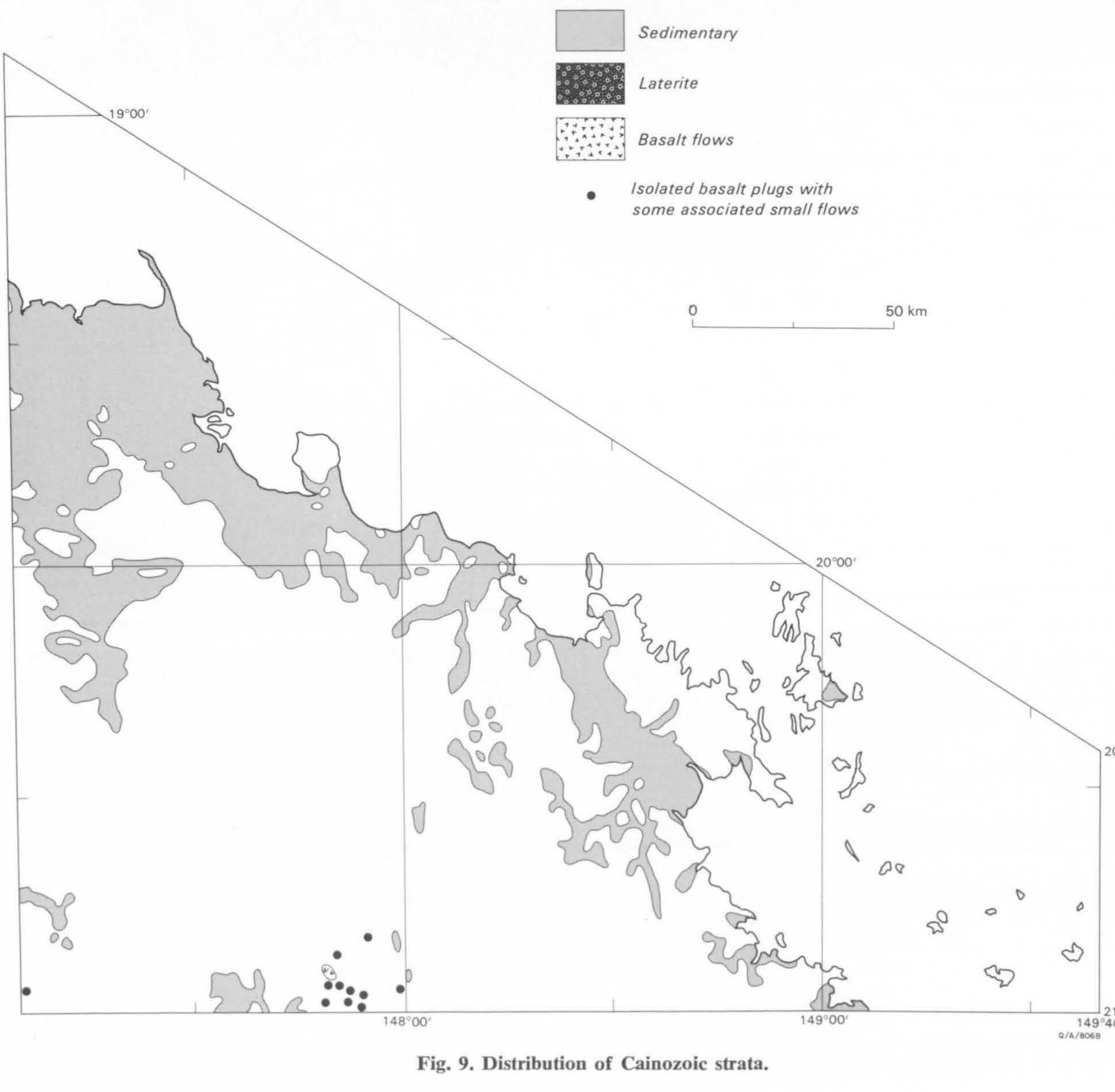


Fig. 9. Distribution of Cainozoic strata.

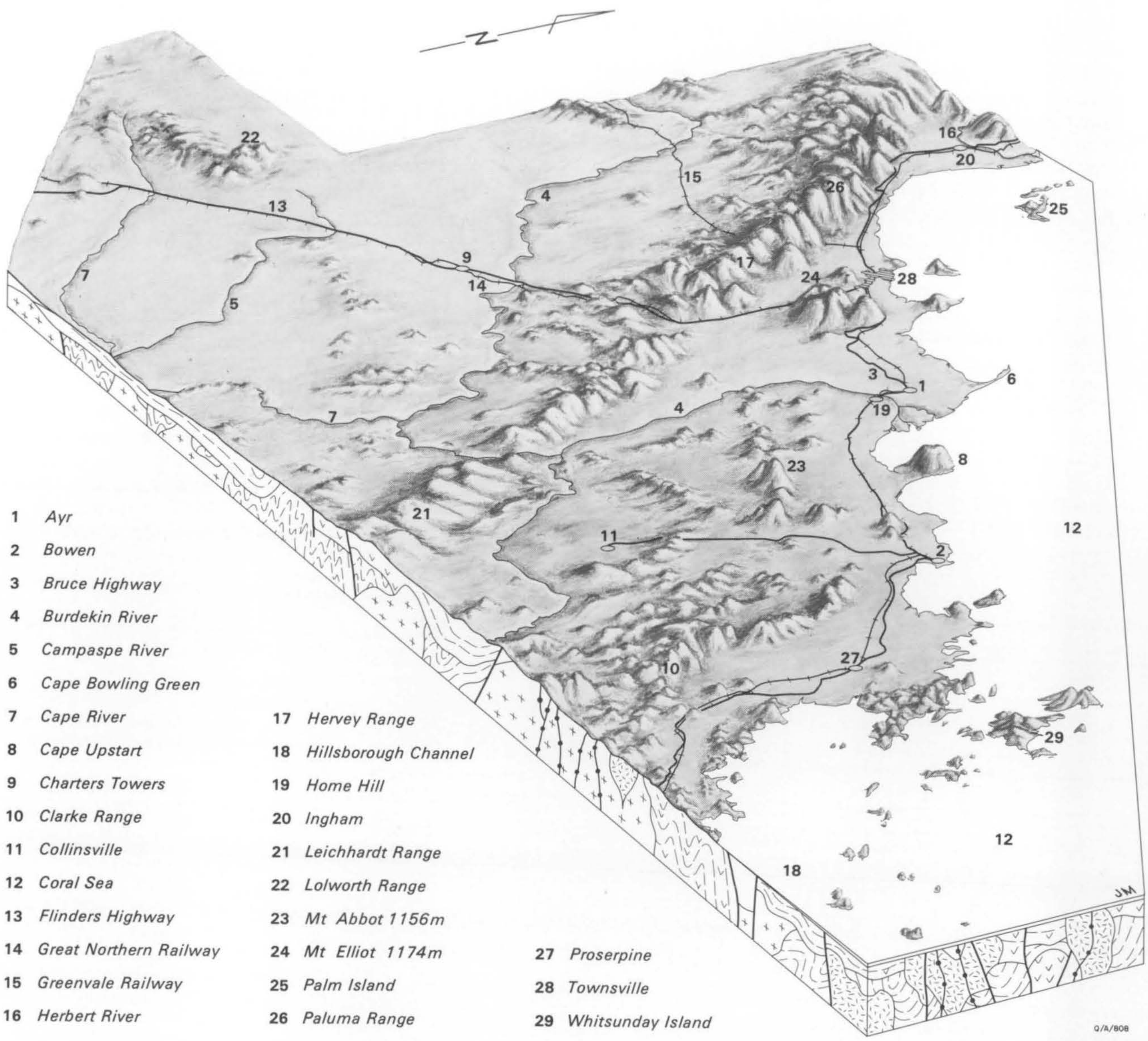


Fig. 10. Physiographic block diagram (geology schematic).

individual parts of the coast are best considered separately.

Near Ingham, de Keyser & others (1965) showed the Palmerville Fault as controlling part of the Herbert Gorge and extending thence to Halifax Bay. The coastal plain, straddling the fault line, lies between highland blocks over 900 m high in places. The influence of the fault obviously results not from differential uplift, but from differential erosion along a pronounced line of weakness, so the scarps are fault-line scarps not fault scarps.

Farther south, the coastal plains of Townsville lead to a corridor past Woodstock which continues, intermittently, to the Bowen River valley southwest of Collinsville. No direct evidence of faulting has been found in the northern part of this corridor, but the southern end coincides with the Millaroo Fault Zone, so here also there is evidence of a pronounced line of weakness finding topographic expression.

Between Bowen and Proserpine is a narrow corridor, the Bowen-Proserpine Lowland. This is a graben containing Tertiary sediments (Clarke & others, 1971).

The importance of faulting suggests that it may have been an operative factor in other parts of the coast, for instance in the Burdekin delta region, but in the absence of any direct evidence this is only conjecture.

West of the coastal divide most of the area is occupied by the drainage basin of the Burdekin River, and much of its present form is tied to the evolution of that system. The principal stages were:

1. Pre-Tertiary. The distribution of Mesozoic rocks indicates a divide farther east than the present Great Dividing Range, probably near the present coastal ranges. Plateau-like remnants, mainly beyond the map area to the north and west, suggest that a mature surface was achieved before the end of the Cretaceous although some harder rocks would present considerable local relief. At this stage the drainage was probably in three basins. The upper Burdekin, together with part of the Herbert, may have been part of the Einasleigh River system (de Keyser & others, 1965) either directly or via the Clarke and Copperfield Rivers. To the south the Coane Range represents the most likely boundary of this basin, separating it from a basin draining via

Lolworth and other creeks into the Flinders. The Cape and Campaspe Rivers have also beheaded originally west-flowing streams (Paine & others, 1971) but whether these were Gulf or Lake Eyre streams is not known. Probably the Lolworth Range was a major watershed past Charters Towers to the main divide.

2. Eocene-Miocene. During this period the main divide moved westward, rejuvenating parts of the previously mature surface. Maturity was again achieved, and the laterite sheet developed. The drainage at the close of this period was probably poorly developed, with many ephemeral lakes. Some discharge to the sea, through the coastal ranges, may have taken place through the present Burdekin Gorge, and also through Reid Gap, presently occupied by the upper Haughton River.

3. Miocene-Recent. The basalt eruption period was accompanied by differential uplift, not only in the northern part of the Burdekin catchment, but also in its extreme south beyond the map area (Whitehouse, 1955). The higher energy levels imparted to the drainage resulted in a pattern approximating the present. The three original drainage areas of the pre-Tertiary were combined by breaching two divides—the Coane Range through the softer rocks of the Sybil Graben, and the Lolworth Ranges through the more readily weathered granodiorite phase of the Ravenswood Granodiorite Complex. The breach in the coast range, the Burdekin Gorge, is through highly resistant rocks of the Bulgonunna Volcanics, and cannot be explained simply by differential erosion. This lies at a point of minimum uplift of the coast range, and represents a structural pass.

Although the Great Dividing Range has probably not altered substantially since the close of the Miocene, there would be differences in detail. Stream capture has purshed it westward, both to the north and to the south of the Lolworth Range (Paine & others, 1971), the eastern streams incorporating part of the Flinders headwaters and drainage which obviously passed west through Lakes Moocha and Buchanan. Some later modification was probably from the basalt flows forming a high plateau straddling the divide.

The present catchment within the sheet area can be regarded as a wide shallow inland corridor, parallel to the dominant northwest structural trend and broken by residual ridges following the older northeast trends. Relief is mature over most of the area, except close to the bounding ranges and transcurrent ridges. The Tertiary surfaces of lateritisation still occupy large areas, and in the northwest there are extensive high-level basalt plains. The average slope from the northern, elevated, extremity to the low 'hinge' near the Burdekin Gorge, is less than 0.2 percent.

ECONOMIC GEOLOGY

METALLOGENIC EPOCHS (Fig. 11)

The association of ore deposits with igneous rocks in eastern Queensland was comprehensively studied by Jones (1947) who defined several epochs of metallogenic activity. Jones's classification was revised by Jones & Carruthers (1965) and more extensively by Webb (1969). Webb made use of isotopic age determinations to delete one of Jones's epochs and introduce a new one. His classification is:

1. Ravenswood Epoch, Ordovician to Early Devonian. (455-395 m.y.)
2. Herberton Epoch, Carboniferous (Phase I: 330 m.y., Phase II: 300-280 m.y.)
3. Gympie Epoch, Late Permian to Middle Triassic. (Phase I: 235 m.y., Phase II:220 m.y.).
4. Mackay Epoch, Early Cretaceous (125 m.y.)

Within the Burdekin region, it seems unlikely that further major alterations will be required, although changes can be expected as more information is obtained (as in the Ravenswood Epoch—see below).

Ravenswood Epoch

The Ravenswood Epoch was defined by Webb as extending between 455 and 395 m.y. When he wrote, it was clear that the Ravenswood Granodiorite Complex included intrusions of two distinct ages, and that the country of the Ravenswood gold lodes was of the younger age. However, there was still some apparent conflict between field evidence and the isotopic ages, and nothing was known of the ages of the other orebodies within the Complex. Since then, field observations have been shown to accord with the isotopic dating, and it has been found that part, at least, of the Charters Towers productive area is in a body of the younger age. This gives to the younger intrusive event an importance far greater than previously recognised, and raises the question whether all gold deposition in the Charters Towers-Ravenswood area may be associated with it.

Paine & others (1971) related the deposits at Mount Emu to the Dumbano Granite, which is younger than any part of the Ravenswood Graniorite Complex (380 m.y., admittedly only a minimum, K-Ar, age). Webb did not mention this episode, but it is apparent that it belongs to the Ravenswood Epoch. Thus two definite phases, and tentatively a third, can be distinguished within the Ravenswood Epoch as now defined:

Phase I—Ravenswood Granodiorite Complex of earlier age—455 m.y.

Phase II—Lolworth Igneous Complex, Barrabas Adamellite, Ravenswood Granodiorite Complex of later age—395 m.y.

Phase III—Dumbano Granite—380 m.y.

So far as is known, the first two phases are distinct, and no intrusions have been found with ages between. However, because of the complicated relations between the various intrusive bodies, it is often impossible to assign a particular deposit to a particular phase.

Phase I. No orebodies can be positively assigned to this phase, but some possibilities suggest themselves. The antimony deposits near Ravenswood are isolated occurrences in the Millaroo Granite, one of the 455 m.y. (Phase I) intrusives. Gold deposits apparently related to similar early phases are those at Bunkers Hill, Hillsborough, and Kirk. The gold deposits at the Bluff and Seventy-Mile, on the southern contact of the batholith far from any known 395 m.y. intrusives, probably also belong here.

The silver-lead deposits at Liontown, whose origin is in doubt, may have reached their present form during the metamorphic episodes associated with the intrusion of the Ravenswood Granodiorite Complex, and could therefore belong to Phase I.

Phase II. This is the most important phase of the Ravenswood Epoch. The gold deposits at Charters Towers can be confidently assigned to it, and those at Ravenswood with only slightly less confidence. Smaller gold mining areas are Allandale, Brookville, Cape River, Mount Clearview, Mount Pleasant, Mount Remarkable, Newhaven, and Sandy Creek. In addition there are many small mining areas between Charters Towers and Ravenswood which cannot be assigned but are likely to belong to this phase: Broughton, Fanning, Dreghorn, Grass Hut, Puzzler, Rishton, Rochford, Trieste, and Windsor.

Base metal deposits are closely associated with the Barrabas Adamellite, and the silver-lead deposits of Totley are in a similar context to the gold deposits of Ravenswood.

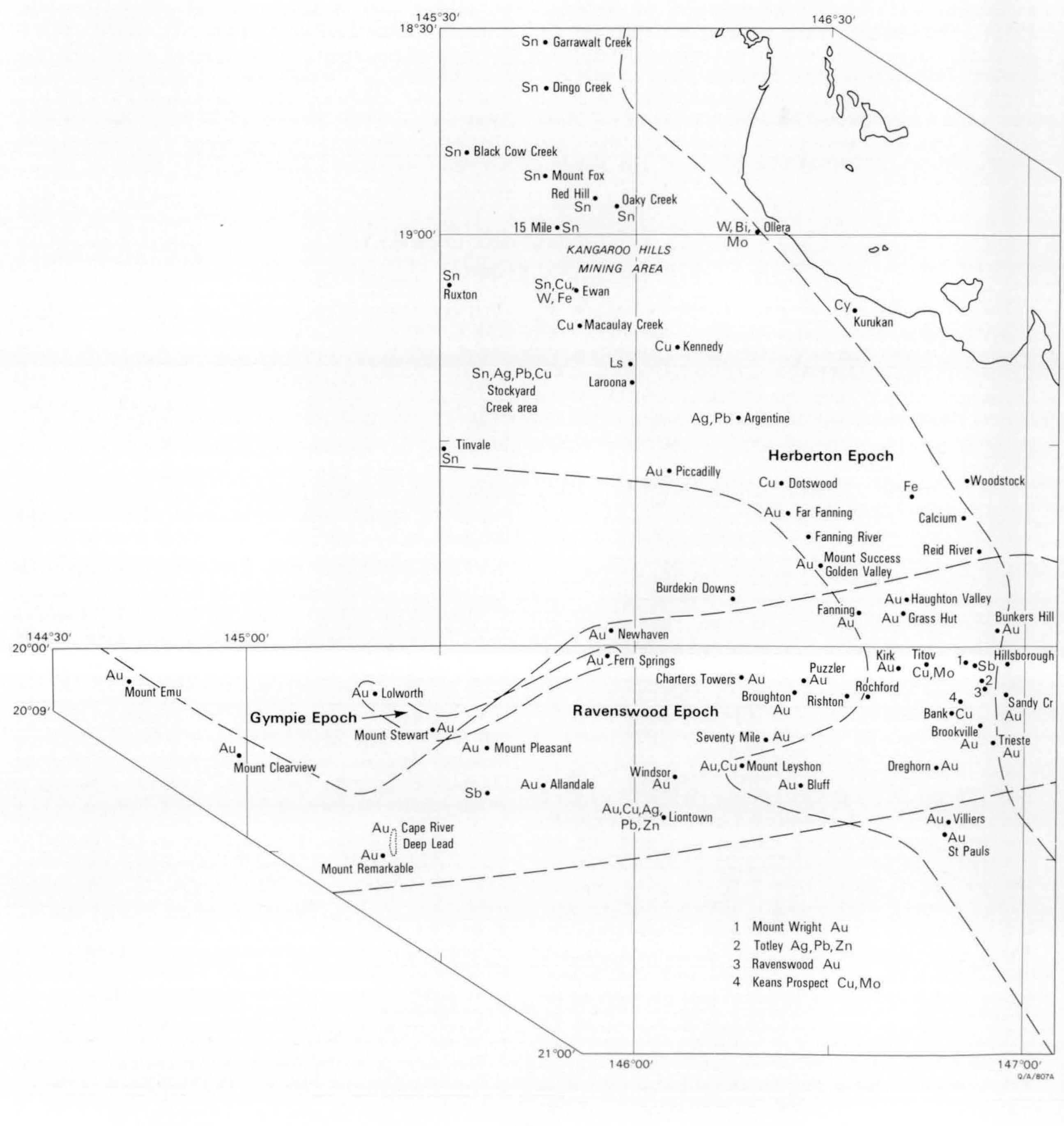
Phase III. So far only the gold deposits of Mount Emu have been assigned to this phase.

Herberton Epoch

The mineralisation of the Herberton Epoch falls into two distinct phases, the first accompanying the Kanimblan Orogeny, the second post-orogenic. In general it is in sharp contrast with that of the Ravenswood Epoch.

Phase I. The most important deposits of this phase are the tin lodes in the western portion of the Kangaroo Hills field, associated with the Oweenee Granite. This represents the earliest period of tin deposition in North Queensland—in the Herberton area to the north, tin deposits are associated with the post-orogenic Elizabeth Creek Granite (Phase II).

Other mineralisation of this phase lies to the south of the Lolworth-Ravenswood Block: gold deposits at Mount Wyatt, silver-lead and gold-bismuth deposits at



Ukalunda, and possibly the magnesite-chromite-asbestos occurrences near Bowen.

Phase II. Many of the copper showings of the area belong to this phase: Dotswood, Kennedy, Copper Pinnacle, St Pauls, and Villiers, and by analogy it is very likely that others—Stockyard Creek, Ewan, and Macaulay Creek—belong here also.

Gold was deposited at Argentine, Far Fanning, Golden Valley, Haughton Valley, Mount Success, Piccadilly, and possibly also at Mount Leyshon and Mount Wright; silver-lead at Argentine and probably that at Ewan; and iron at Ewan and Woodstock.

The molybdenite-wolfram-bismuth pipes at Ollera belong to this phase, but other wolfram deposits on the Kangaroo Hills field are less certain, as they appear to be associated with granites of both ages. In the same way tin occurs in possibly younger granites on the eastern side of the field. It appears that deposits of these metals belong to both phases and possibly the later granites assimilated and redistributed deposits originally associated with the first phase.

Gympie Epoch

The gold deposits at Fern Springs, Lolworth, and Mount Stewart have been assigned to Phase I of the Gympie Epoch. However, this conclusion depends on the age of the Mundic Igneous Complex, which could well belong to the Herberton II episode. If this alternative is correct the Gympie Epoch is not represented in the area.

Mackay Epoch

The minor copper mineralisation at Mount Aberdeen belongs to this epoch, as do the gold deposits at Longford Creek and Dittmer. The gold deposits of Normanby and Marengo probably also belong here.

METALS

Antimony

Small antimony lodes (possibly of Ravenswood I age) occur in granite (Ravenswood Granodiorite Complex) northeast of Ravenswood. In 1906-7, a period of high prices, 58 t of picked ore and hand-dressed

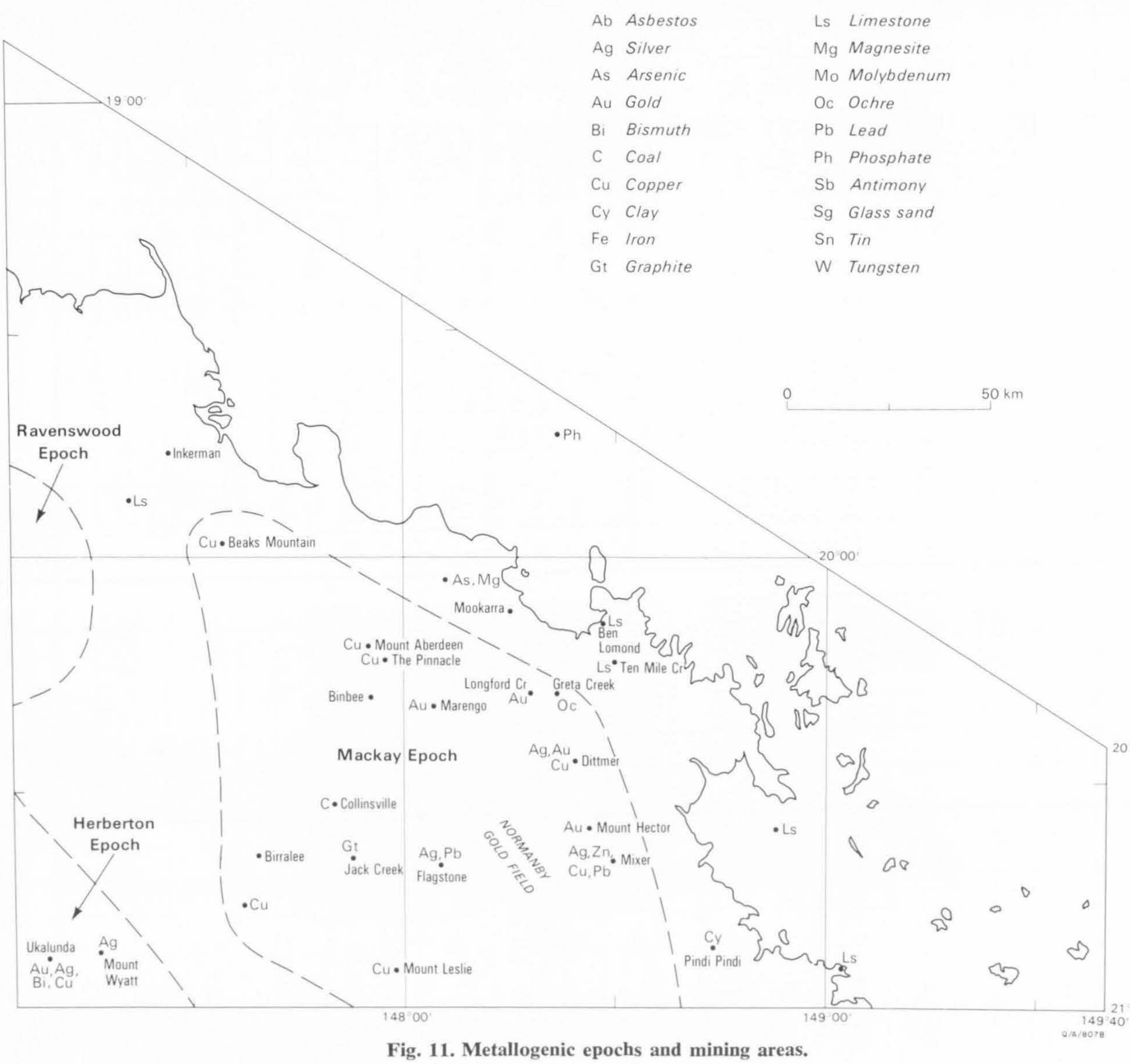


Fig. 11. Metallogenic epochs and mining areas.

TABLE 14. PRINCIPAL COPPER DEPOSITS IN THE AREA

Name	Location: General	Location: Grid Ref.	Metallogenic epoch	Nature	Ore and Gangue	Length m	Width m	Depth Mined m	Production: Ore t	Production: Cu t	Production: Ag kg	Remarks
Carrington	Liontown	402400 E 7741000 N	Herberton II ?	Vein in Mount Windsor Volcanics	Quartz, pyrite chalcopyrite	280	?	206	39 486	?	?	Au c. 400 kg Conc. etc. $45 236
Keelbottom	Dotswood	434200 E 7833700 N	Herberton II	?	Native copper, carbonates, chrysocolla	?	?	<60	?	?	?	Probably no production.
Kennedy	Upper Star River	405600 E 7869400 N	Herberton II	Lode between Ewan Beds and porphyry dyke	Oxidised Cu minerals, chalcopyrite	90	1.2	38	?	?	?	Abandoned before 1878
MACAULAY CREEK GROUP	Macaulay Creek	378800 E 7874800 N	Herberton II	Pipes in sheared and altered granite (Cli) along fissures	Altered granite, copper sulphides, galena, sphalerite							
Copper Knob						60	<5	8	472	17.3	376	
Mount Long						60	?	46	187	8.3	178	
Prospecting area						230	?	9	379	17.9	235	
Western						? 15	3 4	21 16	276	34.1	975	Two fissures 12 m apart
Mixer	11 km NW of Bloomsbury	656200 E 7713200 N	Gympie	Erratic filling of fissures and alternation of country	Complex mixture Cu, Pb, Zn minerals, siderite, barytes, rhodochrosite	?	1.2	23	?	?	?	
Mount Aberdeen	40 km SW of Bowen	600000 E 7763400 N	Mackay	Irregular on joint planes in granite	Copper carbonates, oxides	–	–	?	?	?	?	
Mount Thekla	Ewan	372200 E 7890400 N	Herberton II	Impregnation of conglomerate	Chalcopyrite, galena, sphalerite, pyrite	45	1-3.3	38	352	78	389	14 t Pb
St. Pauls	40 km SSW of Ravenswood	479000 E 7738300 N	Herberton II	V-shaped siliceous lode	Quartz, hematite, magnetite, Cu minerals	120	2.5	16	213	13.6	12	4.8 kg Au
STOCKYARD CREEK GROUP	30 km SW of Ewan	? 365800 E	Herberton II	3 lodes								
Ambrose					Cu, Ag, As	?	0.1-1	55 21 34 Max.	105	?	?	Ore worth $5968
Rio Tinto		786300 N		3 lodes	Kaolin, Cu, Pb.	<60	?	46 Max.	?	?	?	
Stockyard Creek				2 lodes	Quartz, kaolin, Cu, Pb	?	0.3	20	68	?	150	Possibly included in Rio Tinto
Villiers	36 km SSW of Ravenswood	478300 E 7742200 N	Herberton II	Lode controlled by fissuring	Secondary enrichment important	40	?	60?	2000?	?	?	Value about $36 000

concentrate was produced. The shoots invariably wedged out with depth. Thin veins of antimony ore also occur among the silver-lead lodes at Mount Wright.

A total of 32 t is recorded from the Charters Towers area, believed to be from deposits in the Cape River beds near Homestead. Antimony-bearing veins in the Kangaroo Hills Formation near Kangaroo Hills homestead have produced a negligible quantity of ore .

None of these occurrences possesses any great potential.

Arsenic

Arsenic is present in many ores of the area, but has never been extracted.

Bismuth

See 'Tungsten, molybdenum, bismuth'

Copper

Copper deposits are widespread throughout the area, but most are small, and few have produced to any extent. The most important are shown in Table 14. Usually workings are confined to the zone of oxidation and slight secondary enrichment.

The widespread occurrence of high-level intrusives suggests that the area may have prospects of porphyry copper mineralisation. This question was considered by Lacy (1974), who concluded that the southern part of the area was more favourable than the north. He pointed out that the younger the deposit, the more chance of its preservation, so Cretaceous intrusives should be more favourable targets than Permian ones, which in turn should be more favourable than Devonian ones. He also stressed the destructive effect of erosion, which he considered reached a substantial depth in relation to the potential deposits.

Lacy's conclusions have so far been supported by the results of mineral exploration in the area. Although a number of prospects of 'porphyry copper' affinities have been discovered, in no case has the grade been economic, and some features—e.g. the wide quartz veining at Keans Prospect and Titov—suggest that the deeper parts of the prospects have been exposed. Possibly any hope of economic deposits lies in those prospects not yet exposed by erosion.

Prospects so far investigated include *The Pinnacle,* between Mount Aberdeen and Moss Vale homestead, in Hecate Granite (Cretaceous); Beaks Mountain, southeast of Gumlu, in Late Carboniferous to Early Permian porphyritic granite; *Mount Leslie,* in a minor Cretaceous intrusion into Clematis Sandstone, south of Collinsville; and *The Bank,* southwest of Ravenswood in quartz-porphyry of the Ravenswood Granodiorite Complex.

Gold

Last century gold-mining was the most important industry in the area, and played a considerable part in regional development.

Gold deposits were formed in all metallogenic epochs and in many areas, but all others are overshadowed by those of the Ravenswood Epoch, of which Charters Towers is easily the most important.

Most of the important deposits of the Charters Towers area are in, or immediately adjacent to, the town. This small, highly-productive area lies close to the contact of the Charters Towers Metamorphics with the Ravenswood Granodiorite Complex. Virtually all the deposits are in the granodiorite.

The metamorphics comprise schist, hornfels, quartzite, and recrystallised limestone, strongly folded and metamorphosed. The most important structural feature is on the northwest side of the town, where a southeast indentation in the granodiorite contact represents a northwest plunging syncline.

The sequence of emplacement in the mining area is as follows:

11. Porphyritic hornblende andesite dykes. Isotopic age 330 m.y. (Webb, 1969).
10. The auriferous lodes.
9. Granodiorite. Isotopic age 399 m.y. (Whitaker, 1972).
8. Basalt dykes (younger series).
7. Basalt dykes (older series). Isotopic age 432 m.y. (Heidecker, 1974; Green & Webb, 1974).
2–6. Five series of dykes, ranging in composition from aplitic granite to gabbro.
1. Granodiorite. Isotopic age 454 m.y. (Webb, 1969).

Of the isotopic ages, that of 432 m.y. for the basalt dykes is suspect. There is no known intrusive episode of this age, and these dykes appear to be late-stage differentiates of the earlier granodiorites. The rocks could have been affected by argon loss during the 399 m.y. episode.

The other three ages are accepted as representing the respective ages of intrusion. None of the 399 m.y. intrusives has yet been mapped, but a body in the centre of the mining area is free of dykes, and is likely to represent a stock of this age.

The lodes occupy fissures disposed in cognate sets, one striking east and dipping north, the other striking north and dipping east. These two sets lie symmetrically around the projection of the synclinal axis in the metamorphics, suggesting that the fissuring was produced by the same stress field that produced the folding. In general the overall movement on the fissures appears to have been tensional, with displacements ranging from a metre or so to possibly 12 m, the smaller ones being the rule.

The major fissures often split into separate branches far enough apart to require mining as separate bodies. Of these composite systems, the two largest—the Brilliant and Day Dawn—have been the most extensively explored, but unfortunately they are each to some extent atypical. The Brilliant is a wide arcuate zone of irregular tensional fracturing, suggesting possibly drag-folding or shear-link structures. The Day Dawn, which dips much more steeply than normal, is strongly controlled by a pre-existing basalt dyke, which apparently acted as a plane of weakness. The main structure appears to be a series of cymoid loops, pitching obliquely to the strike.

The ore-veins comprise quartz and sulphides, accompanied by more or less crushed and altered granite. The greatest width recorded was 12 m (in the Day Dawn), but in general a vein over 1.5 m wide would be exceptionally large, and one under 30 cm small. In mineral composition they represent a simple, typically mesothermal assemblage—quartz, pyrite, galena, and spalerite are common, calcite less so, and chalcopyrite, gypsum, barite, arsenopyrite, and native arsenic are rare. Tellurides were identified only in two small patches. Galena is regarded as the most reliable indicator of gold values.

TABLE 15. PRINCIPAL GOLD MINING AREAS

Area	*Metallogenic epoch*	*Estimated production,* kg	*Principal deposits*
Allandale	Ravenswood II	40	Agnes Howson
Argentine	Herberton II	60	Argentine Extended
Black Knob	Ravenswood II	60	Black Knob
Bluff	Ravenswood I	100	Lady Alice, Lighthouse, Livingstone
Brookville	Ravenswood II	1 100	Donnybrook, Brasswire, Erin's Hope
Broughton	Ravenswood II	800	Esperanza, Struggle, Victory
Cape River	Ravenswood II	1 200	Mostly alluvial
Carrington	Herberton II	400	Carrington (see under 'copper')
Charters Towers	Ravenswood II	180 000	See Table 16
Dittmer	Herberton II	1 730	Duffer
Dreghorn	Ravenswood II	280	Currency Lass, Heilanman, Ellen Boss
Fanning	Ravenswood II	180	Welcome, Rose of Allandale, Christian Kruck
Far Fanning	Herberton II	50	Lancashire Lass
Four-mile Creek	Ravenswood II	50	Old Man
Golden Valley	Herberton II	240	Golden Valley
Grass Hut	Ravenswood II	40	City of Melbourne
Hillsborough	Ravenswood I	230	Premier
Kirk	Ravenswood I	830	Sisters, Morning Star, Himalaya, Crescent
Lolworth	Gympie I (?)	260	Midas, Mons Meg
Longford Creek	Mackay	?	Golden Gusher
Mount Charles	Ravenswood II	40	Mount Charles
Mount Clearview	Ravenswood II	50	Mount Clearview
Mount Emu	Ravenswood III	80	Granite Castle
Mount Hector	Mackay	60 (?)	Cedar Ridge
Mount Leyshon	Herberton II (?)	1 200	Mount Leyshon
Mount Stewart	Gympie I	50	Brilliant Brumby
Mount Wright	Herberton II (?)	60	Mount Wright
Normanby	Mackay	250	Grace Darling, some alluvial
Piccadilly	Herberton II	320	Piccadilly
Puzzler	Ravenswood II	70	Puzzler, Beaconsfield
Ravenswood	Ravenswood II	22 000	Sunset, General Grant, London
Rishton	Ravenswood II	510	Disraeli, Englishman, Scotsman
Rochford	Ravenswood II	740	Hadleigh Castle, Captain, Robinson Crusoe
Sandy Creek	Ravenswood II	600	John Bull, Politician, Yellow Jack
Seventy-mile	Ravenswood I	70	Seventy-mile (?)
Southern Cross	Ravenswood II	30	Southern Cross (?)
Trieste	Ravenswood II	90	Trieste
Windsor	Ravenswood II	50	Windsor

The ore shoots are irregular, generally with a greater vertical extent than horizontal. The principal control of deposition appears to be the form of the fissures, but no detailed structural analysis has ever been attempted. Comparison of gold values in different parts of individual shoots, as well as those in different shoots, shows a marked progressive decrease with depth. Average values fell from 55 g/t near the surface to about 14 g/t at the greatest depth of stoping (900 m).

Future prospects of the field are problematical. The deposits are narrow and wall conditions often bad, so mining, even with modern methods, would be expensive. As shown in Table 16, the Brilliant and Day Dawn lodes completely overshadowed all others in production, and these would naturally be the first in which a prospecting group would be interested. However, these two lodes are those most extensively explored in the past, and the workings on them now form part of a connected group over 4 km in length, extending in many places to over 500 m in depth. Prospecting would thus virtually be restricted to the extreme ends of the lodes, and at these points, the results of work have been very discouraging.

The smaller lodes are less extensively explored and the workings on many of them have not been connected to the main group, so some of them may have potential. Their limitation is their size—on past results few of them could sustain an operation greater than 200–300 t month.

A possible lead for future prospecting is the northwestward continuation of the fold axis which is the main structural feature of the area. This plunges northwest, and within a short distance disappears beneath a thin cover of Tertiary ferricrete and Quaternary alluvia. The appropriate conditions for deposition could possibly be repeated beneath this cover, which effectively frustrated early prospectors.

Extending from Charters Towers to Ravenswood, a zone 15 km wide and 80 km long includes practically all the more important gold-mining areas that can be assigned to the Ravenswood II Epoch—Charters Towers, Broughton, Rishton, Rochford, Ravenswood, Brookville, and Sandy Creek. This zone conforms with the main axis of doming of the batholith, and was obviously an important locus of tension during the epi-Silurian intrusive episode.

The deposits of these areas are similar, on a small scale, to those of Charters Towers—mesothermal quartz sulphide veins, generally narrow, occupying fissures in granodiorite or related rocks. The ores are generally simple mixtures offering few treatment problems, with the important exception of those of Ravenswood. There pyrite, galena, chalcopyrite, sphalerite, arsenopyrite, and stibnite accompany the quartz, and in many lodes

TABLE 16. PRINCIPAL GOLD DEPOSITS, CHARTERS TOWERS

Name	*Length, m*	*Max. depth, m*	*Normal width, cm*	*Estimated ore, t*	*Production gold, kg*
Brilliant	1 700	930	30–90	2 270 000	65 000
Day Dawn	2 400	820	90–120	1 850 000	43 500[2]
Queen	1 550	320	?–180	185 000	5 760[2]
Victory	600	370	?–75	127 000	5 130[2]
St. Patrick	300	210	180?	65 000	2 640[1, 2]
Rainbow	600	310	?–90	65 000	2 500[1, 2]
Stockholm (Cross)	140	380	?–90	73 000	1 800
Lady Maria	440	330	15	26 000	1 750
Identity	?	300	?	33 000	1 340[2]
North Australian	300	270	?	25 000	1 300[1, 2]
Old Queen Cross	450	220	?	37 000	1 280[2]
John Bull	450	240	60–120	44 000	1 280
Wellington	360	140	?	36 000	1 120[2]
St. George	250	320	?	20 000	1 000[2]
Columbia	?	?	?	?	1 000[2]
Golden Alexandra	330	160	?	25 000	870[2]
Just-In-Time	?	210	?	24 000	840[1, 2]
Ruby	Possibly two separate lodes			21 000	720
Stockholm (Comstock)	140	290	30–60	26 000	720[2]
Black Jack	220	150	?–90	19 000	590
Moonstone (Cross)	200	160	20	8 000	440
Clarks Moonstone	370	100	?	?	440
Moonstone	900	80	25–90	?	400
Imperial	1 000	120	?	26 000	400[2]
Cumberland	?	120	90?	8 000	380
Swedenborg	400	160	15–25	7 000	290

1. Returns known to be incomplete.
2. An important part of the production was before the introduction of the cyanide process.

the gold is finely divided in the sulphides, rendering extraction uneconomic. Future prospects in these areas are impossible to assess, owing to the lack of detailed information on most of the mines, but on past results it is unlikely that any large producers can be expected.

Among the deposits of the other epochs, few have been major producers, but some are worthy of note because of exceptional features, viz: Duffer, Piccadilly, Mount Leyshon, the deposits of Lolworth, and Mount Wright. The Duffer vein, at Dittmer west of Proserpine, in volcanics (Carmila beds), averaged only 13 cm in width, but was worked over a length of 275 m to a depth of over 150 m. Production was 1730 kg of gold from ore averaging almost 100 g/t. Similarly small and rich was the Piccadilly vein, northwest of Dotswood. The vein, comformable with the enclosing red-beds of the Dotswood Formation, was only 8-10 cm wide, but was followed to a vertical depth of over 150 m and over a length of at least 190 m. Full output is not recorded, but the ore probably averaged 75 g/t. Mount Leyshon is formed by volcanic rocks (Cur?) filling an old vent. Erratic gold values are associated with widespread pyritic mineralisation, and three patches have been rich enough to be worked by open-cutting. About 200 000 t of ore was produced, averaging 6 g/t. Lolworth area was characterised by high-temperature deposits—greisen pipes and pegmatitic quartz veins, carrying in addition to the usual sulphides, tungsten, molybdenum, and bismuth minerals. At Mount Wright the Ravenswood Granodiorite Complex has been intruded by rhyolite dykes and agglomerate. Mineralisation occurs over an ill-defined, roughly circular area 20–30 m in diameter. The ore (altered granite with some sulphide) has been followed by an open cut 30 x 15 m, and 30 m deep, which produced about 6000 t averaging 8 g/t.

Most of the gold-producing areas have produced small amounts of alluvial gold, usually from recent deposits of little further geological or economic importance. However, two of the occurrences are of unusual interest—the Cape River Deep Lead near Pentland, and Rutherfords Table at Ukalunda.

The Cape River Deep Lead consisted of 30–50 cm of auriferous conglomerate—the basal conglomerate of the Campaspe Beds—resting on schist and overlain by virtually barren finer sediment. At the northern end of the Lead, just south of Capeville homestead, it was shallow, narrow, and rich. To the south it became progressively deeper, wider, and poorer. About 4 km south of Capeville a large aplite dyke forms a high bar in the bedrock, south of which the grade fell off abruptly. Although some rich patches probably remain, the cost of exploration beneath 30 m and more of overburden is prohibitive. The total production from the Deep Lead is not known, but it could be as much as 1000 kg.

Rutherford's Table is a mesa of the Suttor Formation, overlying granite. Auriferous conglomerate up to 75 cm thick occurs at the base of the Suttor Formation, and has been followed by adits for a distance of over 300 m. A production of some 50 kg of fine gold is recorded, but this is believed to be far from complete. Unusual features of the occurrence are the cementing of the wash by pyrite; the occurrence of low-grade oil shale some distance above the wash; and the apparent volcanic derivation of the finer sediments immediately overlying the wash. The association is suggestive of deposition in a stagnant lake.

Iron

Pyrometasomatic segregations between late Palaeozoic granites and Devonian limestone occur near Ewan and west of Woodstock. At Ewan a skarn zone 5 km long carries erratic magnetite patches, the largest of which (Willet's Knob) is 60 m long and up to 35 m wide, of grade exceeding 60% Fe. It has not been exploited. To the west of Woodstock the skarn zone is 360 m long and individual magnetite-hematite lenses are up to 10 m wide. Small amounts are mined from time to time for use in cement manufacture.

Molybdenum

In the northern part of the area there are many small deposits in which molybdenum occurs in association with wolfram and bismuth. These are dealt with under 'Tungsten-molybdenum-bismuth'.

A considerable amount of company prospecting has been done on two areas near Ravenswood—Kean's prospect and Titov prospect. At Kean's prospect an area of 70 hectares of granodiorite is cut by a rectangular pattern of quartz veins from a few centimetres to 15 m in width, with irregular patches to 35 m. The quartz carries a number of molybdenum and copper minerals as well as gold in places. Exploration indicated that values are confined to the quartz veins, which are discontinuous and generally uneconomic.

The Titov is rather similar, but smaller overall—the area involved is 270 x 120 m—and even less encouraging.

Silver, lead, zinc

Most of the workings were made last century, and silver was the metal particularly sought. Unfortunately, records of many of the deposits are almost non-existent.

At Argentine (Jack, 1886), the deposits occur in schist, slate, and gneiss of the Argentine Metamorphics, sandstone of the overlying Game Hill Beds, and late Palaeozoic granodiorite intrusive into them. The mineralised area is at the centre of an eroded domal structure in the Game Hill beds, about 13 km in diameter. By association, the deposits are probably derived from the granodiorite, and belong to the Herberton II epoch.

The lodes, most of which trend parallel to major faults to the north and west, range from brecciated country injected with sulphides, through more siliceous types, to quartz veins. The limited exploration done on primary ore has yielded galena, pyrite, arsenopyrite, chalcopyrite, sphalerite, and stibnite. Widths of 3.3 m (Struck Oil), 1.8 m (P. F. Hanran, Prince of Wales, and Union), and 1.5 m (Hero) have been recorded but otherwise the lodes were less than 1 m wide, and many less than 30 cm.

Only four mines were worked to any extent—the Hero, Ard Righ, Colorado and Northbrook—of which the Hero was the most important. Total production from the area was probably only a few thousand kilograms of silver.

In assessing future prospects, factors to be considered are:

1. The known patches of non-complex silver-lead ore have probably been worked out. (An examination of part of the Hero workings in 1965 showed no ore remaining).

2. Much of the remaining ore material would present treatment problems.

3. Most of the lodes are narrow.

4. Most of the area is covered by thirty-two Mineral Freeholds.

It therefore appears unlikely that there is any great incentive for future prospecting—certainly not on any extensive scale.

The country at Liontown is metamorphics of the Mount Windsor Volcanics. Of two known silver-lead lodes, one has been worked over a distance of 170 m to 30 m depth. The worked section averaged 1.2 m in width, including 20 to 60 cm of richer material. Total production was: ore 9432 t, gold 93 kg, silver 1668 kg, lead 528 t.

The structure near the surface appears simple, the principal controls being two fracture systems—one vertical parallel to the schistosity of the country, the other with similar strike but dipping at 60°. However, drillhole intersections cannot be correlated on the basis of this pattern and the picture is obviously more complicated.

The primary ore is a fine-grained mixture of galena, pyrite, and sphalerite, and future prospects depend not only on the quantity of ore available, but also on achieving successful treatment.

At Totley, near Ravenswood, are three silver-bearing lodes. Of these only the middle one (King's) has been worked to any extent. Workings extend over a length of 250 m to a depth of 84 m, with a little exploration at 209 m. Total production cannot be estimated with any accuracy, but recorded values suggest over 1500 kg of silver and 2000 t of lead.

The results of exploration beyond the workings at King's give little hope of further production in their vicinity. However, the main shear is over 600 m long, and except at King's, does not appear to have been explored to any great depth, so the possibility of further shoots cannot be ruled out. The other two lodes have hardly been explored at all, so their potential is unknown.

Ukalunda, near the Sellheim River, was worked mainly last century, and Malone & others (1966) estimated its total silver output at over 21 000 kg. Of this about two-thirds was produced from the Sunbeam mine, of which nothing else is recorded. Another important producer was the Pyramid, of which the only description is by Jack (1889). Over the exposed length of 750 m, there are many trenches, potholes, and shafts, including five shafts over 20 m in depth: lode widths averaged about 1 m with a maximum of 2.3 m. The lack of detailed information on this area prevents any assessment of its potential.

Minor producers in the area were the Kangaroo Hills area (Ingham and Townsville 1:250 000 Sheet area), Flagstone Creek, the Mixer, and Birralee (Bowen), and Mount Emu Plains (Hughenden).

Tin

Tin deposits form a well defined province extending practically across the northern corner of the map area between the latitude of Ingham and a line from Tinvale to Rollingstone. Mineralisation is related to Carboniferous-Permian acid intrusives. It appears to be mainly of the Herberton I epoch, though there may

TABLE 17. PRINCIPAL TIN DEPOSITS

Name	*Max. depth, m*	*Production Ore, t*	*Production Conc., t*	*Form of deposit*	*Remarks*
Achilles	?	?	33+?	?	
Canary	62	424	124	Flattened pipe	
Cleopatra	40	?	?	?	Probably an important producer
Daintree	49	7 826	274	Tabular shoot	
Florist	56	197	69	Circular pipe	
Gladstone	27	?	?	?	Possibly an important producer
Groper	27	?	?	?	Possibly an important producer
Guy Mannering	61	4 360	148?	Tabular shoot	
Last Chance	30	?	50+?	No. of pipes	
Little Wonder	?	?	20	?	
Metropolitan	41	?	100+?	Tabular	
Mount Kidston	44	5 680	116	Several pipes	
Mystery	30+	618	26	Irregular shoot in defined fissure	
Northumberland	?	?	32+	Flattened pipes	
New Years Gift	24	?	?	?	Possibly an important producer
Perseverence	9+	1 333	41	Irregular shoots, in defined fissure	
Sardine	135	10 596	2 077	Flattened pipes	
Sardine Peak	64	1 942	90	Flattened pipes	
Shrimp	26	3 046	126	Number of pipes	
Surprise	15	400	24	Irregular bodies in defined lode	
Uncle Ned	?	?	274?	?	No other information recorded

have been some assimilation and redeposition in the Herberton II epoch.

The intrusives, mainly granite and grandiorite, intrude the Running River Metamorphics in the Kangaroo Hills area, and their probably equivalents, the Argentine Metamorphics, at Tinvale; and the Ewan beds at Ewan. Tin deposits are found in all these formations, with a particular concentration around the intrusive contacts. The main productive area near Ewan is transected by frequent faults and porphyry intrusions.

The major faults are the principal controls of deposition; the minor shears and fractures associated with the faults determine the actual shoots. The resulting deposits range from roughly circular pipes to tabular bodies, with flattened pipes predominating. Most are small and irregular. The usual tin mineral is cassiterite, but in the Sardine some shoots also carry stannite.

The Sardine, which was by far the largest producer, is in an area of heavily fractured low-grade metamorphics (Ewan beds), which dip steeply to the east-southeast. Important structural features are:

(i) A fracture zone, paralleling the metamorphics in strike but slightly steeper in dip; the orebodies lie just beyond its eastern margin, and it is apparently a major control.

(ii) Smaller fissures: steeply dipping fissures may be transgressive and of even course, but most are influenced by bedding and are arcuate and branching, with *en echelon* and linked structures. These are often loci of deposition. Gently dipping fissures control deposition as either loci or barriers.

(iii) Frequent dykes, both acid and basic. In the southern part of the mine porphyry dykes are closely associated spatially with ore-shoots. One basalt dyke appears to have acted as a barrier to porphyry intrusion and to a smaller extent to tin deposition.

The lode matter is crushed country rock with occasional vein quartz. The primary ore concentrate includes cassiterite and stannite, probably about one-third of each, a variety of copper and bismuth minerals, rutile, and arsenopyrite.

The principal shoot yielded about half the total output of the mine. From the surface to 134 m depth the normal stope length was 18 m, the maximum 60 m. The ore was lenticular but the stopes were continuous, suggesting a cymoid or chatter link structure. The other shoots, at least four in number, are irregular bodies controlled by erratic fractures. Some of these extend below water level, and the recorded production includes 423 t of 'stannite' concentrate.

The Daintree lode is a well-defined fissure in granite. The main shoot contracted from 58 m in length at the surface to 24 m at a depth of 49 m. Drilling to the south showed that the barren lode channel continues for at least 100 m. Other tabular bodies were the Guy Mannering, 20 m long between 15 and 30 m depth, and the Metropolitan, in which short shoots developed on cymoid loops to form a continuous body 37 m long to 37 m depth. More pipelike was the Canary shoot, which averaged 4.25 m by 45 cm from the surface to 45 m. Pipes, usually in groups, were found in the Shrimp, Mount Kidston, Sardine Peak, and Florist. The Florist is a particularly well-known example: the single pipe ranged in section from 15 x 15 cm to 25 x 115 cm. Its tortuous course— likened to that of a crankshaft—telescoped some 450 m of pipe into an overall length ot 120 m. The ore averaged 40% cassiterite.

Compared with the main tin area in North Queensland—the Herberton field—the Kangaroo Hills field shows many similarities in mineralogy, types of deposit, and geological context. However, the scale of the deposits and output are completely different. In general terms, the importance of Kangaroo Hills can be regarded as one-tenth that of Herberton. As Herberton has only in recent years attracted major capital, it would appear that the future prospects for Kangaroo Hills are not bright. The only area offering any encouragement is the highly fractured and intruded area lying within 10 km of Ewan. Here conditions have been most favourable for deposition and there are many opportunities for future exploration, particularly in depth.

Tinvale is not as promising, but the Daintree lode, in particular, could still hold prospects.

Alluvial deposits accounted for some 40 percent of the production of the area. Two types occur: Recent alluvium, and Tertiary 'deep leads' and high-level gravels.

Deposits of recent alluvium on many creeks were discovered early and are now largely worked out. In places both creek terraces and bed were workable, in others only the reconcentrated deposits in the bed. Most of the tin is derived from veins, though some may be derived from the redistribution of Tertiary alluvial deposits.

The largest of the Recent alluvial deposits was worked for 19 km along Dingo and Garrawalt Creeks. It forms terraces and flats up to 600 m wide along the meandering creeks. The alluvium is 10 m or more in thickness, the 'wash' 2 m, increasing to 4–6 m near the main channel. Workings were mainly small-scale, as problems of water supply and tailings disposal prevent continuous sluicing.

Some major flats in the area appear suitably placed for tin accumulation, but so far exploration has failed to find anything payable.

High-level gravels are found on many ridges, particularly around the headwaters of Oaky Creek. They are overlain by remnants of horizontal Tertiary sandstone, up to 30 m thick, some of which are capped by basalt. The gravels are stanniferous over a considerable area, but only in a few places have they been payable. One such was at Ruxton, where wash up to 3 m thick was overlain by coarse sand (up to 12 m) and basalt (up to 18 m). In 1969-72 165 000 m^3 of wash yielded 280 t of concentrate. Work was begun again in 1977.

In other places the stanniferous gravels are confined to deep leads. At Fifteen Mile Creek are four of these leads, which have been worked over a length of 2 km, mainly by underground methods. To the end of 1972 they had yielded some 176 t of concentrate. In the main lead the overlying sandstone averages 12–15 m in thickness, the wash 70 cm to 1 m. The maximum width of the wash channel is 30 m, with the best values in a deeper section 13 m wide. The wash material ranges from coarse gravel to fine sand, the finer material being sufficiently cemented in places to require blasting. Average cassiterite content was probably 6–9 kg/m^3. An attempt in 1924-27 to sluice the wash and overburden failed, mainly because of inadequate water supplies and poor values.

Similar but less productive leads occur at Red Hill, Mount Fox, and Black Cow Creek.

Future prospects of alluvial production are difficult to assess. Probably most of the deposits have been discovered, and their future depends on improvements in machinery and access. The possibility of dredging is remote, although sluicing may be possible in some areas. Working of some of the deposits would involve problems, such as lack of water and the presence of a thick basalt cover, which appear to be insurmountable.

Titanium and zirconium

Conditions within the area are not conducive to the formation of beach deposits. Many of the beaches have been tested, but nothing has been found even approaching commercial requirements. The greatest content of rutile recorded is 4% (near Flagstaff Hill, north of Bowen), and of zircon 6% (Dingo Beach, west of Abbot Point).

Tungsten, molybdenum, bismuth

These metals are roughly co-extensive with the tin deposits of Tinvale-Kangaroo Hills, with the important exception of Ollera, a small compact metallogenic province east of the stanniferous area. The host-rock at Ollera is coarse red granite (late Palaeozoic) intruded by quartz porphyry. The deposits are quartz bodies, normally pipes, accompanied by silicified granite, greisen, and kaolin. Tungsten is usually the dominant metal, but the relative proportions of the three vary from pipe to pipe. The remainder of the area has produced lesser amounts from a number of generally small deposits. The relation of these to the tin deposits is reflected in the wide range of associated gangue minerals, including chlorite, tourmaline, and topaz.

The Bell Vue, the most important mine at Ollera, has probably produced over 100 t of wolfram, with a little molybdenite and bismuth. The most important pipe, characterised by large bunches of clean wolfram, has been worked over a length of 90 m. It is reported to be 4.5 m x 3 m in section at the bottom, and carrying little wolfram. The other three, carrying greater proportions of molybdenum and bismuth, have been worked only a short distance below the surface.

Second only to the Bell Vue among Ollera mines was the Sailor Boy, on which quartz pipes have been followed to 60 m and 34 m. Unfortunately nothing else is known of it.

The Isabel was the largest producer outside of Ollera (about 70 t ?). A quartz segregation, 15 m wide and at least 120 m long, is cut by a strong, steeply dipping joint. The shoot, at the intersection of the two, is a pipe less than 5 m in diameter which has been worked to 24 m. The limited workings below that depth were unproductive, and the continuation of the shoot has possibly been lost. Associated with the wolfram are fluorspar and a little bismuthinite.

None of the known deposits is likely to be of interest on anything other than a prospector's scale, and the area can be regarded as offering only minor potential for production of these metals.

TABLE 18. COAL RESERVES, COLLINSVILLE AREA (millions of t)
(Department of Mines, Qld, March 1977)

Type	*Measured*	*Indicated*	*Total*	*Suitable open-cut mining*	*Suitable underground mining*
Coking	131	–	131	15	116
Non-coking	102	5	107	25	82
Totals	233	5	238	40	198

TABLE 19. PETROLEUM PROSPECTING HOLES

Name	*Latitude S. and Longitude E.*	*When drilled*	*Depth, m*	*Formation tops, remarks*
MOPS No. 4	20° 55′ 10″ 149° 05′ 45″	1956	92	Freshwater shales, some Tertiary sandstone
MOPS No. 5	Approximately same as MOPS 4.	1956–7	733	O Tertiary. 221 m. L. Carboniferous?
Proserpine No. 1	20° 29′ 18″ 148° 39′ 56″	1965	1295	3 m Tertiary. 1282 m L. Permian or Devonian-L. Carboniferous
Rosella Creek No. 1	20° 52′ 00″ 147° 51′ 30″	197?	600	4 m Blenheim 151 m Big Strophalosia 369 m Collinsville

FUELS

Coal

The Bowen Basin is by far the most important coal province in Queensland. The map area includes only the Bowen River Coalfield, the extreme northern tip of the basin. In this area the Collinsville Coal Measures include eleven named seams. Those presently worked are:

(i) The Bowen Seam, about 6 m thick, whose coal yields high-grade metallurgical coke. It is worked in the underground mines of Bowen Consolidated Coal Mines, Scottville, and Dacon Collieries, Collinsville.

(ii) The Blake Seam, about 6 m thick, is non-coking steaming coal being open-cut mined by Bowen Consolidated Coal Mines, Scottville.

The Collinsville Fault, a high-angle easterly-dipping reverse fault with a throw of more than 200 m, bounds the coal measures on the east: beyond it they have been removed by erosion. Reserves have been further greatly reduced by extensive feldspar porphyry intrusions, in the form of dykes following fault planes spreading as sills (up to 35 m thick) in the coal seams. Coal near the intrusions is non-coking and low in volatile matter.

Reserve estimates in the area (Department of Mines, Queensland, 1977), are shown in Table 18. Present annual output is some 870 000 t.

Coal also occurs near the top of the Calen Coal Measures; 6.5 km west of Calen two separate attempts at mining yielded 9500 t (1927-1939). The coal is extensively faulted and much of it has been destroyed by dykes. This area can not be regarded as holding any potential.

Potentially economic seams have been explored in the Betts Creek beds in the Oxley Creek area (Galilee Basin).

Petroleum

The abundance of igneous rocks, and of terrestrial sediments among the younger formations, severely restricts the possibilities of petroleum occurrence. Two areas may hold prospects: the Bowen Basin and the Hillsborough Basin.

The Back Creek Group in the Bowen Basin includes possible source beds, while sandstones of the Collinsville Coal Measures, Gebbie Formation, and Blenheim Formation are potential reservoirs. Discouraging factors are the high carbon ratios of the coals, suggesting that hydrocarbons have not been preserved, and the extent of igneous intrusions. Target Exploration's Rosella Creek No. 1 hole, the only exploration well in this part of the basin, yielded no showings.

Onshore and offshore seismic surveys have indicated a deep graben between the mainland and the Cumberland Islands, with up to 3000 m of sediments at the deepest part, northeast of Cape Hillsborough. The basin appears to have been enclosed on all sides, with no well established connections to the sea. The holes drilled, MOPS Nos. 4 and 5 (Mackay Oil Prospecting Syndicate) and Proserpine No. 1 (Ampol Exploration), revealed no evidence of oil or gas, and Proserpine No. 1 encountered poorly sorted sediments with no effective porosity or permeability.

An aeromagnetic survey over the continental shelf east of the Cumberland and Whitsunday Islands indicated that the depth to crystalline basement is generally less than 900 m, with one 1500-m depression 65 km east-northeast of Hook Island. However, it is conceivable that in some areas volcanics were interpreted as basement.

NON-METALLIC MINERALS

Clay

At present clay is mined from Pindi Pindi near Calen (6500 t in 1975), Kurukan north of Townsville (5200 t in 1975), and Stuart (Townsville, 52 000 t in 1975). The Stuart production is used in the manufacture of cement, the remainder for brickmaking.

It seems likely that ample supplies will be available, particularly in the coastal belt of alluvium, for any future population expansion in the area.

Graphite

The Jacks Creek deposit is in steeply-dipping Blackwater Group sediments close to the Collinsville Fault. Graphite, formed by metamorphism of coal, occurs in two bands of sediments 4.5 m and 3 m thick, separated by 4 m of non-graphite sediments. Some 1860 t was produced after 1935, but little recently. There are no reserves, and future prospects are uncertain, but it is unlikely that any large output would ever be possible.

A graphite seam, 1 to 2.5 m wide, occurs in hornfels near Cape Upstart. There was some production early this century but the remaining material is of low grade and the potential can only be regarded as very doubtful.

Limestone

Deposits occur in the Fanning River Group, the Campwyn beds, and the Edgecumbe beds. Limestones of the Fanning River Group are being exploited by North Australian Cement at Calcium, current annual output being some 300 000 t. The presence of dykes and sills, and difficulties of access to some of the deposits, have led to the company's considering other sources, and extensive exploration is proceeding at

Fanning River. Other areas, at present unexplored, are Burdekin Downs and Laroona. The potential of the Fanning River Group is very large, although transport costs restrict interest to deposits nearest to the coast.

Limestones have been recorded in the Campwyn beds at Cape Hillsborough, Seaforth, old St Helens homestead, and East Repulse Island. That on East Repulse Island, the most important, is estimated to contain 88 000 t. The deposits may be convenient for satisfying a small local demand, but could not support any major operation.

Limestone occurs in the Edgecumbe beds at Ben Lomond (a small roof pendant), in Ten Mile Creek, and as scattered outcrops between the two. There is a possibility of fairly substantial reserves in this area, but so far no exploration has been done.

In several parts of the sheet area are deposits of fine-grained powdery calcite known as 'earth-lime'. These are flat-flying, covered only by soil, and are often only a few metres thick. In all cases they appear to have been formed by weathering *in situ* of intermediate-to-basic igneous rocks: at Reid River, from andesitic agglomerates (Ellenvale beds); south of Inkerman homestead, probably diorite; and Mookarra, diorite and gabbro. This type of material is easy to quarry and has proved convenient for agricultural purposes, but it is unlikely that large quantities would be available.

Silica sand

Clean pure quartz forms beaches fringing Whitehaven Bay and Hill Inlet (Whitsunday Island), and dunes up to 60 m above sea level covering about 10 km^2 inland from Whitehaven Bay. No detailed work has been done, but large quantities of high-grade material are available.

Minor occurrences

Non-metallic minerals recorded, but in deposits of little or no potential, are *asbestiform tremolite, garnet* and low-grade *vermiculite,* near Ayr; varicoloured boulder-type *ochre* near Greta Creek; *phosphatic* coralline beach conglomerate on Holbourne Island; *amethyst* near Binbee; *chalcedony* and *agate* northeast of Collinsville; and *opal* and *banded agate* at Cape Hillsborough.

TABLE 20. SUMMARY OF ISOTOPIC AGE DETERMINATIONS

(Determinations by A. W. Webb except where otherwise stated. Analytical error in individual K–Ar determinations is ±3% unless otherwise stated).

Unit	*Specimen No.* *BMR*	*ANU Prefix GA*	*Map Grid Ref.* *E.*	*N.*	*Rock Type*	*Mineral*	*Method*	*Age m.y.*	*Remarks*
Toomba Basalt	E55/14/84	5769	407300	7803900	Olivine basalt	Whole rock	K–Ar	$\ngtr$0.10	
	E55/14/85	5770	409800	7803900	Olivine basalt	Whole rock	K–Ar	$\ngtr$0.10	
	E55/14/90	5775	410200	7803800	Olivine basalt	Whole rock	K–Ar	$\ngtr$0.10	
Nulla Basalt	E55/14/10	5563	418300	7799900	Olivine basalt	Whole rock	K–Ar	1.14	Same flow (with E55/14/11)
	E55/14/11	5564	417800	7800300	Olivine basalt	Whole rock	K–Ar	1.10	Same flow (with E55/14/10)
	F55/ 2/12	5570	351400	7780500	Olivine basalt	Whole rock	K–Ar	1.24±10%	
	E55/14/91	5776	408400	7803800	Olivine basalt	Whole rock	K–Ar	1.25	
	E55/14/81	5764	348400	7822100	Olivine basalt	Whole rock	K–Ar	1.25, 1.27	
	E55/14/75	5758	355600	7823600	Olivine basalt	Whole rock	K–Ar	1.26	
	E55/14/74	5757	355600	7823600	Olivine basalt	Whole rock	K–Ar	1.28	
	E55/14/53	5569	397900	7808200	Olivine basalt	Whole rock	K–Ar	1.28	
	E55/14/56	5576	404400	7798200	Olivine basalt	Whole rock	K–Ar	1.29	
	E55/14/14	5567	395800	7812000	Olivine basalt	Whole rock	K–Ar	1.29	Probably same flow as E55/14/53, 73, 74, 75, 91.
	F55/ 2/2	1154	353900	7778900	Olivine basalt	Whole rock	K–Ar	1.30±0.1	
	E55/14/13	5566	396000	7812000	Olivine basalt	Whole rock	K–Ar	1.32	Underlies E55/14/14
	E55/14/73	5756	355600	7823600	Olivine basalt	Whole rock	K–Ar	1.34	
	E55/14/77	5760	357300	7823600	Olivine basalt	Whole rock	K–Ar	1.43	
	E55/14/52	5568	405900	7802900	Olivine basalt	Whole rock	K–Ar	2.27, 2.37	Same flow as E55/14/12.
	E55/14/12	5565	410900	7802400	Olivine basalt	Whole rock	K–Ar	2.40	
	E55/14/78	5761	352400	7828800	Olivine basalt	Whole rock	K–Ar	3.95	
	F55/ 2/1	1145	371000	7785800	Olivine basalt	Whole rock	K–Ar	4.0±2.0	
	E55/14/79	5762	352600	7831600	Olivine basalt	Whole rock	K–Ar	4.11	
	E55/14/80	5763	353500	7830400	Olivine basalt	Whole rock	K–Ar	4.34	
	E55/14/83	5766	346800	7824000	Olivine basalt	Whole rock	K–Ar	4.45	
Whitsunday Volcanics	F55/ 4/9	5394	711900	7743300	Quartz-feldspar porphyry	Whole rock	K–Ar	96, 106	
	F55/ 4/25	5553	736500	7607900	Dacite	Hornblende	K–Ar	112	
Proserpine Volcanics	F55/ 4/23	5507	679400	7744700	Acid volcanic	Whole rock	Rb–Sr	111±5*	
	F55/ 4/20	5508	683300	7744700	Acid volcanic	Whole rock	Rb–Sr	111±5*	
	F55/ 4/22	5511	678800	7742300	Acid volcanic	Whole rock	Rb–Sr	111±5*	
	F55/ 4/21	5512	677800	7742400	Acid volcanic	Whole rock	Rb–Sr	111±5*	
	F55/ 4/33	5539	676700	7741400	Acid volcanic	Whole rock	Rb–Sr	111±5*	
	F55/ 4/26	5546	677400	7742700	Acid volcanic	Whole rock	Rb–Sr	111±5*	
	F55/ 4/27	5547	679100	7742400	Acid volcanic	Whole rock	Rb–Sr	111±5*	
	F55/ 4/32	5552	676400	7739700	Acid volcanic	Whole rock	Rb–Sr	111±5*	
Kg	F55/ 4/2	1142	706400	7685700	Granite	Hornblende	K–Ar	110	
	F55/ 4/3	1154	706400	7686900	Granite	Hornblende	K–Ar	115	

* Isochron

TABLE 20. SUMMARY OF ISOTOPIC AGE DETERMINATIONS (continued)

Unit	Specimen No. BMR	ANU Prefix GA	Map Grid Ref. E.	N.	Rock Types	Mineral	Method	Age m.y.	Remarks
Mount Abbot Igneous Complex	F55/ 3/119	5531	578800	7774400	Quartz syenite	Hornblende	K–Ar	116	Rolled block, not in situ.
Hecate Granite	F55/ 3/97	5529	597700	7762700	Adamellite	Biotite	K–Ar	120	
	F55/ 3/61	5331	638000	7733000	Adamellite	Biotite	K–Ar	123	
	F55/ 3/100	5399	604900	7762000	Adamellite	Biotite	K–Ar	123	
	F55/ 3/117	5355	618900	7754800	Adamellite	Biotite	K–Ar	124	
	F55/ 3/118	5356	622300	7743000	Adamellite	Hornblende	K–Ar	126	
						Biotite	K–Ar	124	
	F55/ 3/62	5330	642200	7739000	Granodiorite	Biotite	K–Ar	125	
						Hornblende	K–Ar	127	
	F55/ 3/91	5398	616100	7741800	Adamellite	Biotite	K–Ar	128	
Ki	F55/ 3/127	5358	600600	7712000	Adamellite	Biotite	K–Ar	123	
	F55/ 3/33	5272	612400	7677500	Gabbro	Plagioclase	K–Ar	133	
PKg	F55/ 3/35		650300	7786500	Adamellite	Biotite	K–Ar	216	
Urannah Igneous Complex	F55/ 4/5	1170	662100	7699200	Granodiorite	Biotite	K–Ar	117, 117	
	F55/ 4/4	1135	660200	7699200	Granodiorite	Biotite	K–Ar	235	
						Hornblende	K–Ar	235	
	F55/ 3/110	5734	651500	7719500	Adamellite	Biotite	K–Ar	250	Altered—min. age only.
	F55/ 3/135	5354	655800	7709400	Adamellite	Biotite	K–Ar	282	
						Biotite	Rb–Sr	290	
						Whole rock	Rb–Sr	288±31*	
	F55/ 3/113	5346	654600	7699100	Diorite	Biotite	K–Ar	283	
	F55/ 3/114	5396	651600	7703100	Adamellite	Biotite	K–Ar	289	
						Biotite	Rb–Sr	309	
						Whole rock	Rb–Sr	288±31*	
	F55/ 3/115	5392	652800	7700700	Granodiorite	Whole rock	Rb–Sr	288±31*	
						Biotite	Rb–Sr	314	
						Biotite	K–Ar	289	
						Hornblende	K–Ar	294	
Mount Wickham Rhyolite	F55/ 3/69	5520	543600	7770100	Acid volcanic	Whole rock	Rb–Sr	230±15*	
	F55/ 3/74	5521	546500	7745400	Acid volcanic	Whole rock	Rb–Sr	230±15*	
	F55/ 3/75	5522	546500	7745400	Acid volcanic	Whole rock	Rb–Sr	230±15*	
	F55/ 3/76	5523	546300	7745300	Acid volcanic	Whole rock	Rb–Sr	230±15*	
	F55/ 3/72	5524	553400	7751800	Acid volcanic	Whole rock	Rb–Sr	230±15*	
	F55/ 3/78	5525	557600	7740900	Acid volcanic	Whole rock	Rb–Sr	230±15*	
	F55/ 3/143		550400	7734000	Acid volcanic	Whole rock	Rb–Sr	230±15*	
Dyke	F55/ 3/107	5329	627900	7722600	Microdiorite	Hornblende	K–Ar	255	
Thunderbolt Granite	F55/ 3/38	5338	605200	7735500	Adamellite	Hornblende	K–Ar	259	
	F55/ 3/27	5253	591500	7744000	Adamellite	Hornblende	K–Ar	261	

* Isochron

TABLE 20. SUMMARY OF ISOTOPIC AGE DETERMINATION (continued)

Unit	Specimen No. BMR	ANU Prefix GA	Map Grid Ref. E.	N.	Rock Type	Mineral	Method	Age m.y.	Remarks
	F55/ 3/26	5252	596400	7753300	Adamellite	Hornblende	K–Ar	264	
						Hornblende	Rb–Sr	260	
	F55/ 3/86	5332	592700	7754300	Adamellite	Hornblende	K–Ar	264	
						Hornblende	Rb–Sr	271	
	F55/ 3/109	5380	606200	7731300	Adamellite	Hornblende	K–Ar	265	
	F55/ 3/14	473	597300	7744800	Adamellite	Hornblende	K–Ar	270	
Plg	F55/ 3/125	5365	635900	7700300	Granite	Biotite	K–Ar	268	
	F55/ 3/25	5251	517000	7766500	Adamellite	Biotite	K–Ar	272	
Lizzie Creek Volcanics	F55/ 3/56	5374	549900	7748900	Basalt	Plagioclase	K–Ar	229	Ar loss, or related to Mt Wickham Rhyolite?
	F55/ 3/68	5375	547800	7770400	Basalt	Plagioclase	K–Ar	264	Minimum age.
	F55/ 3/55	5373	547100	7751700	Basalt	Plagioclase	K–Ar	274	Minimum age.
CPg	F55/ 3/136	5560	629600	7726900	Adamellite	Biotite	K–Ar	132	Possible Ar loss caused by Hecate Granite.
	F55/ 3/106	5347	629800	7724000	Adamellite	Biotite	K–Ar	186	
								187	
	F55/ 3/95	5513	586400	7784100	Granodiorite	Biotite	K–Ar	269, 272	
	E55/10/1	5159	384400	7917800	Adamellite	Biotite	K–Ar	272	Minimum age.
	F55/ 3/67	5530	564100	7780800	Adamellite	Biotite	K–Ar	272	
	F55/ 3/8	831	520600	7715000	Granodiorite	Biotite	K–Ar	276, 288	
						Biotite	K–Ar	293, 283	
						Whole rock	Rb–Sr	286±3*	
	E55/10/11	5176	403800	7914500	Granodiorite	Biotite	K–Ar	274	Minimum age.
	E55/14/23	5725	445600	7855600	Adamellite	Biotite	K–Ar	277	
	E55/14/26	5730	435900	7851400	Granodiorite	Biotite	K–Ar	277	
						Hornblende	K–Ar	282	
	E55/14/5	5535	421700	7857400	Granodiorite	Biotite	K–Ar	277	
	F55/ 3/1	832	535200	7739100	Adamellite	Biotite	K–Ar	278	
						Whole rock	Rb–Sr	286±3*	
	F55/ 3/23	5198	555600	7722500	Adamellite	Biotite	K–Ar	278, 283, 289	
						Hornblende	K–Ar	282, 291	
	E55/14/19	5731	444600	7860000	Granodiorite	Hornblende	K–Ar	279	
						Biotite	K–Ar	284	
	E55/14/28	5729	434100	7850400	Granodiorite	Biotite	K–Ar	280	
	E55/14/60	5732	482700	7879100	Adamellite	Biotite	K–Ar	280	
	F55/ 3/20	1243	517000	7700800	Granodiorite	Biotite	K–Ar	280	
						Hornblende	K–Ar	280	
						Whole rock	Rb–Sr	286±3*	
	F55/ 3/9	5292	513700	7703500	Granodiorite	Hornblende	K–Ar	281, 283	

* Isochron

TABLE 20. SUMMARY OF ISOTOPIC AGE DETERMINATIONS (continued)

Unit	*Specimen No.* BMR	*ANU Prefix* GA	*Map Grid Ref.* E.	N.	*Rock Types*	*Mineral*	*Method*	*Age* m.y.	*Remarks*
	F55/ 3/42	5391	529900	7737800	Adamellite	Biotite	K–Ar	282	
						Biotite	Rb–Sr	286±3*	
						Whole rock	Rb–Sr	286±3*	
	E55/14/29	5728	441000	7859300	Granodiorite	Biotite	K–Ar	282	
						Biotite	K–Ar	290	
	E55/14/18	5533	412300	7844200	Adamellite	Biotite	K–Ar	283	
	E55/14/30	5727	443700	7857000	Granodiorite	Biotite	K–Ar	284	
			551000	7711400		Biotite	K–Ar	286	
	F55/ 3/3	729			Adamellite	Biotite	K–Ar	283, 286	
						Biotite	Rb–Sr	286±3*	
						Whole rock	Rb–Sr	286±3*	
	F55/ 3/16	5532	556100	7716900	Adamellite	Whole rock	Rb–Sr	286±3*	
	F55/ 3/22	5528	548700	7711500	Adamellite	Whole rock	Rb–Sr	286±3*	
	E55/14/24	5726	441200	7855200	Granodiorite	Biotite	K–Ar	290	
	F55/ 3/94	5534	629500	7770100	Adamellite	Biotite	K–Ar	297, 298	
	E55/10/4	5161	368000	7934100	Biotite granite	Biotite	K–Ar	311	
	E55/14/39	5588	423900	7898100	Granite	Whole rock	Rb–Sr	330±7*	
Tuckers Igneous Complex	F55/ 2/30	5794	456500	7783900	Granodiorite	Biotite	K–Ar	277	Age of intrusions about 280 m.y.
	F55/ 2/33	5796	450900	7781500	Gabbro	Biotite	K–Ar	277	
	F55/ 2/32	5795	450500	7780300	Granodiorite	Biotite	K–Ar	282	
Boori Igneous Complex	F55/ 2/34	5797	470400	7781100	Diorite	Biotite	K–Ar	278	
Bulgonunna Volcanics	F55/ 3/40	5514	530000	7736400	Welded tuff	Whole rock	Rb–Sr	287±12*	
	F55/ 3/41	5515	530000	7736300	Rhyolite	Whole rock	Rb–Sr	287±12*	
	F55/ 3/81	5517	545800	7708400	Acid volcanic	Whole rock	Rb–Sr	287±12*	
	F55/ 3/84	5518	543700	7707800	Acid volcanic	Whole rock	Rb–Sr	287±12*	
	F55/ 3/131	5556	522700	7695600	Rhyolite	Whole rock	Rb–Sr	287±12*	
	F55/ 3/132	5557	538500	7691500	Andesite	Whole rock	Rb–Sr	287±12*	
	F55/ 3/134	5559	554200	7728100	Toscanite	Whole rock	Rb–Sr	287±12*	
Cud	F55/ 3/15	474	604300	7752400	Granodiorite	Hornblende	K–Ar	258, 258	
						Biotite	K–Ar	271, 272	
	F55/ 3/105	5327	606900	7741300	Diorite	Biotite	K–Ar	263	
						Hornblende	K–Ar	279	
	F55/ 3/104	5328	602900	7743600	Quartz diorite	Biotite	K–Ar	265	
						Hornblende	K–Ar	266	
	F55/ 3/87	5336	590000	7754500	Diorite	Biotite	K–Ar	266	
						Hornblende	K–Ar	273	
	F55/ 3/36	5378	606300	7722900	Tonalite	Biotite	K–Ar	268	
	F55/ 3/24	1162	601400	7723100	Diorite	Biotite	K–Ar	268	
						Hornblende	K–Ar	273	

* Isochron

TABLE 20. SUMMARY OF ISOTOPIC AGE DETERMINATIONS (continued)

Unit	*Specimen No.* BMR	*ANU Prefix* GA	*Map Grid Ref.* E.	N.	*Rock Type*	*Mineral*	*Method*	*Age m.y.*	*Remarks*
	F55/ 3/11	1072	636000	7695400	Granite	Muscovite	K–Ar	268, 271, 281	
						Whole rock	Rb–Sr	288±31*	
	F55/ 3/13	812	622000	7709900	Adamellite	Biotite	K–Ar	270	
						Whole rock	Rb–Sr	288±31*	
	F55/ 3/37	5335	617900	7711300	Granodiorite	Biotite	K–Ar	270	
						Hornblende	K–Ar	273	
	F55/ 3/101	5333	599300	7758100	Diorite	Hornblende	K–Ar	270	
	F55/ 3/108	5379	622300	7713900	Granite	Hornblende	K–Ar	270	
	F55/ 3/12	472	634400	7695400	Tonalite	Hornblende	K–Ar	271, 266	
						Biotite	K–Ar	271, 277	
						Biotite	Rb–Sr	284	
Clg	F55/ 3/18	1161	517400	7689000	Adamellite	Biotite	K–Ar	290	
	F55/ 3/17	1160	521100	7688900	Granodiorite	Biotite	K–Ar	294	
						Hornblende	K–Ar	294	
	F55/ 3/7	5288	524600	7687600	Granodiorite	Hornblende	K–Ar	327, 330	
Dyke	F55/ 2/13	5561	426500	7778200	Hornblende porphyrite	Hornblende	K–Ar	328	Age of intrusions about 300 m.y.
	F55/ 2/39	5721	427200	7781100	Hornblende porphyrite	Hornblende	K–Ar	332	
	F55/ 2/38	5720	426500	7778200	Hornblende porphyrite	Hornblende	K–Ar	332	
Cli	E55/10/3	5160	368000	7934100	Adamellite	Biotite	K–Ar	277	Minimum age.
	E55/14/17	5284	380900	7868100	Granite	Biotite	K–Ar	300	Ar loss—cf. Rb–Sr age.
						Whole rock	Rb–Sr	330±7*	
	E55/14/7	5584	412200	7884800	Granite	Whole rock	Rb–Sr	330±7*	
	E55/14/15	5585	350900	7864300	Granite	Whole rock	Rb–Sr	330±7*	
	E55/14/16	5586	352000	7862800	Granite	Whole rock	Rb–Sr	330±7*	
	E55/14/38	5587	403800	7898200	Granite	Whole rock	Rb–Sr	330±7*	
	E55/10/5	5162	357900	7847600	Adamellite	Whole rock	Rb–Sr	330±7*	
	E55/10/6	5163	373100	7926300	Granite	Whole rock	Rb–Sr	330±7*	
	E55/10/13	5191	425600	7900200	Adamellite	Whole rock	Rb–Sr	330±7*	
Barrabas Adamellite	F55/ 2/22	5709	485200	7770600	Adamellite	Whole rock	Rb–Sr	394±30*	K–Ar and Rb–Sr ages concordant.
	F55/ 2/23	5710	482200	7771500	Adamellite	Whole rock	Rb–Sr	394±30*	
						Biotite	K–Ar	397	
Lolworth Igneous Complex	F55/ 1/31	5596	340600	7779700	Granite	Muscovite	K–Ar	390	
						Whole rock	Rb–Sr	401±7*	
	F55/ 1/6	5590	300800	7750900	Granite	Biotite	K–Ar	392	
						Muscovite	K–AR	396	
						Whole rock	Rb–Sr	401±7*	
	F55/ 2/10	5285	354900	7766500	Granite	Muscovite	K–Ar	401	
						Whole rock	Rb–Sr	401±7*	
	F55/ 1/13	5592	291200	7755200	Granite	Whole rock	Rb–Sr	401±7*	
	F55/ 1/27	5595	329500	7753700	Granite	Whole rock	Rb–Sr	401±7*	
	F55/ 2/9	5598	355500	7764500	Granite	Whole rock	Rb–Sr	401±7*	

* Isochron

TABLE 20. SUMMARY OF ISOTOPIC AGE DETERMINATION (continued)

Unit	*Specimen No.* *BMR*	*ANU Prefix GA*	*Map Grid Ref.* *E.*	*N.*	*Rock Type*	*Mineral*	*Method*	*Age m.y.*	*Remarks*
Ravenswood Granodiorite Complex	F55/ 2/4	5704	357200	7746000	Granite	Whole rock	Rb–Sr	394±30*	Dependent on assumption initial 87Sr/86Sr = 0.7053
	F55/ 2/6	5705	347300	7719500	Granite	Whole rock	Rb–Sr	394±30*	
	F55/ 2/16	5706	492100	7775900	Granodiorite	Whole rock	Rb–Sr	394±30*	
	F55/ 2/27	5799	488200	7777200	Quartz diorite	Whole rock	Rb–Sr	394±30*	
	E55/14/47	5798	465200	7796900	Diorite	Whole rock	Rb–Sr	394±30*	
	F55/ 2/37	5735	418400	7768700	Granodiorite	Whole rock	Rb–Sr	394±30*	K–Ar, Rb–Sr ages concordant.
						Biotite	K–Ar	396	
						Hornblende	K–Ar	404	
			423800	7780700	Granodiorite	Hornblende	K–Ar	399	G.S.Q. sample, Univ. Qld. No. QA 66
	F55/ 2/3	5703	380900	7759800	Granite	Whole rock	Rb–Sr		Fits no isochron.
	F55/14/1	5283	446900	7813800	Granodiorite	Biotite	K–Ar	420	K–Ar ages are minimum of Rb–Sr age.
	F55/14/44	5274	462200	7802200	Granodiorite	Hornblende	K–Ar	420	
						Biotite	K–Ar	440	
						Whole rock	Rb–Sr	454±30*	
	F55/ 2/28	5713	465900	7781700	Granite	Biotite	K–Ar	397	Ar leakage during 394 m.y. intrusion.
						Whole rock	Rb–Sr	454±30*	
	F55/ 2/26	5712	473600	7786000	Granodiorite	Hornblende	K–Ar	426	
						Whole rock	Rb–Sr	454±30*	
	F55/ 2/19	5707	483300	7782500	Leucogranite	Whole rock	Rb–Sr	454±30*	
	F55/ 2/20	5708	483700	7780500	Granodiorite	Whole rock	Rb–Sr	454±30*	
	F55/ 2/24	5711	479900	7776400	Granodiorite	Whole rock	Rb–Sr	454±30*	
	E55/14/46	5599	464100	7798700	Granite	Whole rock	Rb–Sr	454±30*	
	E55/14/48	5600	473700	7795300	Adamellite	Whole rock	Rb–Sr	454±30*	
	E55/14/49	5701	476200	7795700	Adamellite	Whole rock	Rb–Sr	454±30*	
	E55/14/59	5702	423400	7791400	Adamellite	Whole rock	Rb–Sr	454±30*	
Cape River Beds	F55/ 1/2	5783	309700	7742600	Biotite gneiss	Whole rock	Rb–Sr	483±25*	
	F55/ 1/4	5784	312400	7743500	Biotite gneiss	Whole rock	Rb–Sr	483±25*	
	F55/ 1/8	5786	288500	7752600	Biotite muscovite schist	Whole rock	Rb–Sr	483±25*	
	F55/ 1/23	5787	305200	7742600	Biotite schist	Whole rock	Rb–Sr	483±25*	
	F55/ 1/7	5785	290300	7747300	Biotite schist	Whole rock	Rb–Sr	483±25*	
	F55/ 1/25	5788	335500	7745800	Granitic biotite gneiss	Whole rock	Rb–Sr		Do not lie on an isochron.
	F55/ 1/30	5789	336500	7738100	Biotite muscovite schist	Whole rock	Rb–Sr		
Mount Windsor Volcanics	F55/ 3/137	5714	519400	7740100	Acid volcanic	Whole rock	Rb–Sr	510±100*	
	F55/ 3/138	5715	519300	7739900	Acid volcanic	Whole rock	Rb–Sr	510±100*	
	F55/ 3/139	5716	519200	7740000	Acid volcanic	Whole rock	Rb–Sr	510±100*	
	F55/ 3/140	5717	519100	7740000	Acid volcanic	Whole rock	Rb–Sr	510±100*	
	F55/ 3/141	5718	518800	7740100	Acid volcanic	Whole rock	Rb–Sr	510±100*	
	F55/ 3/142	5719	518400	7740100	Acid volcanic	Whole rock	Rb–Sr	510±100*	

* Isochron

REFERENCES

BRANCH, C. D., 1966—Volcanic cauldrons, ring complexes and associated granites of the Georgetown Inlier, Queensland. *Bureau of Mineral Resources, Australia, Bulletin* 76.

BROWN, G. A., 1963—Progress report on the geology of the Proserpine area, Qld Authority to Prospect 94 P (surface geology). *Geological Survey of Queensland, Authority Report* 1295 (unpublished).

BRYAN, W. H., 1925—Earth movements in Queensland. (Presidential Address). *Proceedings of the Royal Society of Queensland*, 37, 1-82.

CAMERON, W. E., 1903—Additions to the geology of the Mackay and Bowen districts. *Geological Survey of Queensland, Publication* 181.

CASEY, D. J., 1970—Northern Eromanga Basin. *Geological Survey of Queensland, Report* 41.

CLARKE, D. E., 1971—Geology of the Ravenswood 1-mile Sheet area, Queensland. *Geological Survey of Queensland, Report* 53.

CLARKE, D. E., & PAINE, A. G. L., 1970—Charters Towers, Queensland—1:250 000 Geological Series. *Bureau of Mineral Resources, Australia, Explanatory Notes* SF/ 55-2.

CLARKE, D. E., PAINE, A. G. L., & JENSEN, A. R., 1971—Geology of the Proserpine 1:250 000 Sheet area, Queensland. *Bureau of Mineral Resources, Australia, Report* 144.

CONNAH, T. H., & HUBBLE, G. D., 1960—Laterites. *In* The Geology of Queensland. *Journal of the Geological Society of Queensland*, 7, 373-86.

DAINTREE, R., 1868—Report on Cape River diggings. *Queensland Parliamentary Papers.*

DAINTREE, R., 1870a—On the Ravenswood, Mount Wyatt, Cape River goldfields, etc. *Notes, Proceedings of the Legislative Assembly, Queensland.*

DAINTREE, R., 1870b—General report upon the Northern District. *Journal of the Legislative Council*, 16, 61-72.

DAINTREE, R., 1872—Notes on the geology of the Colony of Queensland. *Quarterly Journal, Geological Society of London*, 28, 271-317.

DAVID, T. W. E., (Ed. W. R. BROWNE), 1950—THE GEOLOGY OF THE COMMONWEALTH OF AUSTRALIA, *London, Arnold.*

DE KEYSER, F., FARDON, R. S. H., & CUTLER, L. G., 1964—Geology of the Ingham 1:250 000 Sheet area, SE55-10, Queensland. *Bureau of Mineral Resources, Australia, Record* 1964/78 (unpublished).

DE KEYSER, F., FARDON, R. S. H., & CUTTLER, L. G., 1965—Ingham, Queensland—1:250 000 Geological Series. *Bureau of Mineral Resources Australia, Explanatory Notes*, SE/55-10.

DE KEYSER, F., & LUCAS, K. G., 1968—Geology of the Hodgkinson and Laura Basins, North Queensland. *Bureau of Mineral Resources, Australia, Bulletin* 84.

DEAR, J. F., 1974—Lower Ordovician graptolites, northern part of the Tasman Geosyncline; *in* THE TASMAN GEOSYNCLINE DENMEAD, A. K., TWEEDALE, G. W., & WILSON, A. F. (editors). *Geological Society of Australia, Queensland Division.*

DICKINS, J. M., & MALONE, E. J. 1973—Geology of the Bowen Basin, Queensland, *Bureau of Mineral Resources, Australia, Bulletin* 130.

ETHERIDGE, R. (Sen.), 1872—Description of the Palaeozoic and Mesozoic fossils of Queensland. *Quarterly Journal, Geological Society of London*, 28, 317-50.

FAIRBRIDGE, R. W. 1950—Recent and Pleistocene coral reefs of Australia. *Journal of Geology*, 58, 330-401.

GREEN, D. C., & WEBB, A. W., 1974—Geochronology of the northern part of the Tasman Orogenic Zone; *in* THE TASMAN GEOSYNCLINE, DENMEAD, A. K., TWEEDALE, G. W., & WILSON, A. F. (editors) *Geological Society of Australia, Queensland Division.*

GREGORY, C. M., 1969—Ayr, Queensland—1:250 000 Geological Series. *Bureau of Mineral Resources, Australia, Explanatory Notes* SE/55-15.

HARLAND, W. B., SMITH, A. G., & WILCOCK, D., 1964—The Phanerozoic Time Scale. *Quarterly Journal, Geological Society of London* (Supplement), 120S.

HEIDECKER, E., 1974—A review of major Palaeozoic tectonometallogenic events, northern part of the Tasman Orogenic Zone; *in* THE TASMAN GEOSYNCLINE, DENMEAD, A. K., TWEEDALE, G. W., & WILSON, A. F. (editors) *Geological Society of Australia, Queensland Division.*

HILL, D., 1942—The Middle Devonian rugose corals of Queensland (3): Burdekin Downs, Fanning River and Reid Gap, north Queensland. *Proceedings of the Royal Society of Queensland*, 53, 229-68.

HILL, D., 1951—Geology; *in* HANDBOOK OF QUEENSLAND. *Australian Association for the Advancement of Science, Brisbane*, 13-24.

HILL, D., (Ed.), 1953—Geological map of Queensland (at a scale of 40 miles to 1 inch). *Queensland Department of Mines.*

HILL, D., 1960—Geological structure; *in* THE GEOLOGY OF QUEENSLAND. *Journal, Geological Society of Australia*, 7, 1-19.

HILL, D., & DENMEAD, A. K., 1960—The geology of Queensland. *Journal, Geological Society of Australia*, 7.

JACK, R. L., 1879a—Report on the geology and mineral resources of the district between the Charters Towers Goldfield and the coast. *Geological Survey of Queensland, Publication* 1.

JACK, R. L., 1879b—On the Bowen River Coalfield. *Geological Survey of Queensland, Publication* 4.

JACK, R. L., 1879c—On the Normanby and Marengo Goldfields. *Geological Survey of Queensland, Publication* 5.

JACK, R. L., 1887a—Geological observations in the north of Queensland. *Geological Survey of Queensland, Publication* 35.

JACK, R. L., 1887b—The geological features of the Mackay district. *Geological Survey of Queensland, Publication* 39.

JACK, R. L., 1889—On the Sellheim silver mines and surrounding district. *Geological Survey of Queensland, Publication* 57.

JACK, R. L., & ETHERIDGE, R., Jr, 1892—The geology and palaeontology of Queensland and New Guinea. *Geological Survey of Queensland, Publication* 92.

JONES, O. A., 1947—Ore genesis in Queensland. *Proceedings of the Royal Society of Queensland*, 59.

JONES, O. A., & CARRUTHERS, D. S., 1965—Geology and mineralization in eastern Queensland; *in* GEOLOGY OF AUSTRALIAN ORE DEPOSITS (*Eighth Commonwealth Mining and Metallurgical Congress, Melbourne*), 352-60.

JUKES, J. G., 1847—NARRATIVE OF THE SURVEYING VOYAGE OF THE H.M.S. FLY. *London, T. and W. Boone.*

LACY, W. C., 1974—Review of Upper Palaeozoic metallogenesis in the northern part of the Tasman Orogenic Zone; *in* THE TASMAN GEOSYNCLINE, DENMEAD, A. K., TWEEDALE, G. W., & WILSON (editors). *Geological Society of Australia, Queensland Division.*

LAWRENCE, J. L., 1956—Geological report on the Mackay Oil Prospecting Syndicate's holdings. *Geological Survey of Queensland, Authority Report* 174 (unpublished).

LEICHHARDT, L., 1847—JOURNAL OF AN OVERLAND EXPEDITION IN AUSTRALIA FROM MORETON BAY TO PORT ESSINGTON DURING THE YEARS 1844-5. *London, Boone.*

LEVINGSTON, K. R., 1971—Mineral deposits and mines of the Townville 1:250 000 Sheet area, North Queensland. *Geological Survey of Queensland, Report* 61.

LEVINGSTON, K. R., 1972—Ore deposits and mines of the Charters Towers 1:250 000 Sheet area, North Queensland. *Geological Survey of Queensland, Report* 57.

MCCLUNG, G., 1976—Early Ordovician (late Arenigian) graptolites from the Cape River Beds in the Rollston Range, Charters Towers district. *Queensland Government Mining Journal*, 77, 605.

MAITLAND, A. G., 1889—Geological observations at the heads of the Isaacs, the Suttor, and the Bowen Rivers. *Geological Survey of Queensland, Publication* 54, 5.

MAITLAND, A. G., 1891—On the geology and mineral resources of the upper Burdekin. *Geological Survey of Queensland, Publication* 71.

MALONE, E. J., JENSEN, A. R., GREGORY, C. M,. & FORBES, V. R., 1966—The geology of the southern half of the Bowen 1:250 000 Sheet area, Queensland. *Bureau of Mineral Resources, Australia, Report* 100.

MCDOUGALL, I., & SLESSAR, G. C., 1972—Tertiary volcanism in the Cape Hillsborough area, North Queensland. *Journal, Geological Society of Australia*, 18 (4), 401-8.

MORTON, C. C., 1920—The Normanby Goldfield. *Queensland Government Mining Journal*, 21, 268.

MORTON, C. C., 1921—Recent notes on the Normanby Goldfield. *Queensland Government Mining Journal*, 22, 271-4, 316-20.

OLGERS, F., 1972—Geology of the Drummond Basin, Queensland. *Bureau of Mineral Resources, Australia, Bulletin* 132.

ÖPIK, A. A., 1960—Cambrian and Ordovician geology; *in* THE GEOLOGY OF QUEENSLAND. *Journal, Geological Society of Australia*, 7, 89-109.

PAINE, A. G. L., 1972a—Proserpine, Queensland—1:250 000 Geological series. *Bureau of Mineral Resources, Australia, Explanatory Notes*, SF/55-4.

PAINE, A. G. L., 1972b—Geology; *in* Burdekin-Townsville Region Resources Series—Geology and Minerals. *Geographic Branch, Department of National Development, Canberra*.

PAINE, A. G. L., & CAMERON, R. L., 1972—Bowen, Queensland—1:250 000 Geological Series. *Bureau of Mineral Resources, Australia, Explanatory Notes*, SF/55-3.

PAINE, A. G. L., CLARKE, D. E., & GREGORY, C. M., 1974—Geology of the northern half of the Bowen 1:250 000 Sheet area, Queensland (with additions to the geology of the southern half). *Bureau of Mineral Resources, Australia, Report* 145.

PAINE, A. G. L., GREGORY, C. M., & CLARKE, D. E., 1969—Geology of the Ayr 1:250 000 Sheet area, Queensland. *Bureau of Mineral Resources, Australia, Report* 128.

PAINE, A. G. L., HARDING, R. R., & CLARKE, D. E., 1971—Geology of the northeastern part of the Hughenden 1:250 000 Sheet area, Queensland. *Bureau of Mineral Resources, Australia, Report* 126.

POOLE, W., 1909—Notes on the physiography of North Queensland. *Australasian Association for the Advancement of Science*. 12th Meeting, 316-17.

RANDS, W. H., 1891—Cape River goldfield. *Geological Survey of Queensland, Publication* 73.

REID, J. H., 1917—The Charters Towers Goldfield. *Geological Survey of Queensland, Publication* 256.

REID, J. H., 1928—The Isaacs River Permo-Carboniferous coal basin. *Queensland Government Mining Journal*, 29, 239-410.

REID, J. H., 1929a—Coal prospects, Mackay district. *Queensland Government Mining Journal*, 30, 156-8.

REID, J. H., 1929b—Geology of the Bowen River Coalfield. *Geological Survey of Queensland, Publication* 276.

REID, J. H., 1930—The Queensland Upper Palaeozoic succession. *Geological Survey of Queensland, Publication* 278.

RICHARDS, J. R., WHITE, D. A., WEBB, A. W., & BRANCH, C. D., 1966—Isotopic ages of acid igneous rocks in the Cairns hinterland, North Queensland. *Bureau of Mineral Resources, Australia, Bulletin* 88.

SMITH, J., 1972—Minerals; in Burdekin-Townsville Region Resources Series—Geology and Minerals. *Geographic Branch, Department of National Development, Canberra*.

STANLEY, G. A. V., 1927—The physiography of the Bowen district, and of the northern islands of the Cumberland Group (Whitsunday Passage). *Report, Great Barrier Reef Committee*, 2(1).

TRAVES, D. M., 1953—A brief outline of the geology of the Townsville-Bowen region. *CSIRO Land Resources Series*, 2, pt 3.

VINE, R. R., & PAINE, A. G. L., 1974—Hughenden, Queensland, 1:250 000 Geological Series. *Bureau of Mineral Resources, Australia, Explanatory Notes*, SF/55-1.

WEBB, A. W., 1969—Metallogenic epochs in eastern Queensland. *Proceedings, Australasian Institute of Mining & Metallurgy*, 230, 29-38.

WEBB, A. W., & MCDOUGALL, I., 1968—The geochronology of the igneous rocks of eastern Queensland. *Journal, Geological Society of Australia*, 15(2), 313-46.

WEBB, E. A., & CRAPP, C. E., 1960—The geology of the Collinsville Coal Measures. *Proceedings, Australasian Institute of Mining & Metallurgy*, 193.

WHITE, D. A., 1961—Geological history of the Cairns-Townsville hinterland, north Queensland. *Bureau of Mineral Resources, Australia, Report* 59.

WHITE, D. A., 1965—The geology of the Georgetown/Clarke River area, Queensland. *Bureau of Mineral Resources, Australia, Bulletin* 71.

WHITE, W. C., & BROWN, G. A., 1963—Preliminary report on the geology of the Mackay region, area 93P and the southern part of 94P. *Report, Ampol Exploration (Qld) Ltd* (unpublished).

WHITEHOUSE, F. W., 1955—The geology of the Queensland portion of the Great Australian Artesian Basin, Appendix G; *in* ARTESIAN WATER SUPPLIES IN QUEENSLAND. *Queensland Parliamentary Papers*, A56-1955.

WHITAKER, W. G., 1972—K/Ar determination of N.S. 17 granodiorite. Memo to Chief Government Geologist, Qld, 22.2.72 (unpublished).

WYATT, D. H., 1968—Townsville, Queensland—1:250 000 Geological Series. *Bureau of Mineral Resources, Australia, Explanatory Notes* SE/55-14.

WYATT, D. H., PAINE, A. G. L., CLARKE, D. E., & HARDING, R. R., 1970—Geology of the Townsville 1:250 000 Sheet area, Queensland. *Bureau of Mineral Resources, Australia, Report* 127.

WYATT, D. H., PAINE, A. G. L., CLARKE, D. E., & GREGORY, C. M., 1971—The geology of the Charters Towers 1:250 000 Sheet area, Queensland. *Bureau of Mineral Resources, Australia, Report* 137.

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GEOLOGY OF BURDEKIN RIVER REGION

QUEENSLAND

1980

Scale 1:500 000

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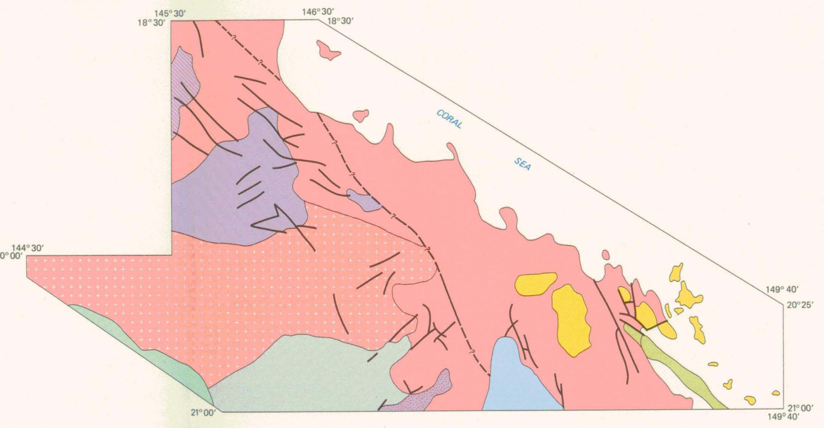
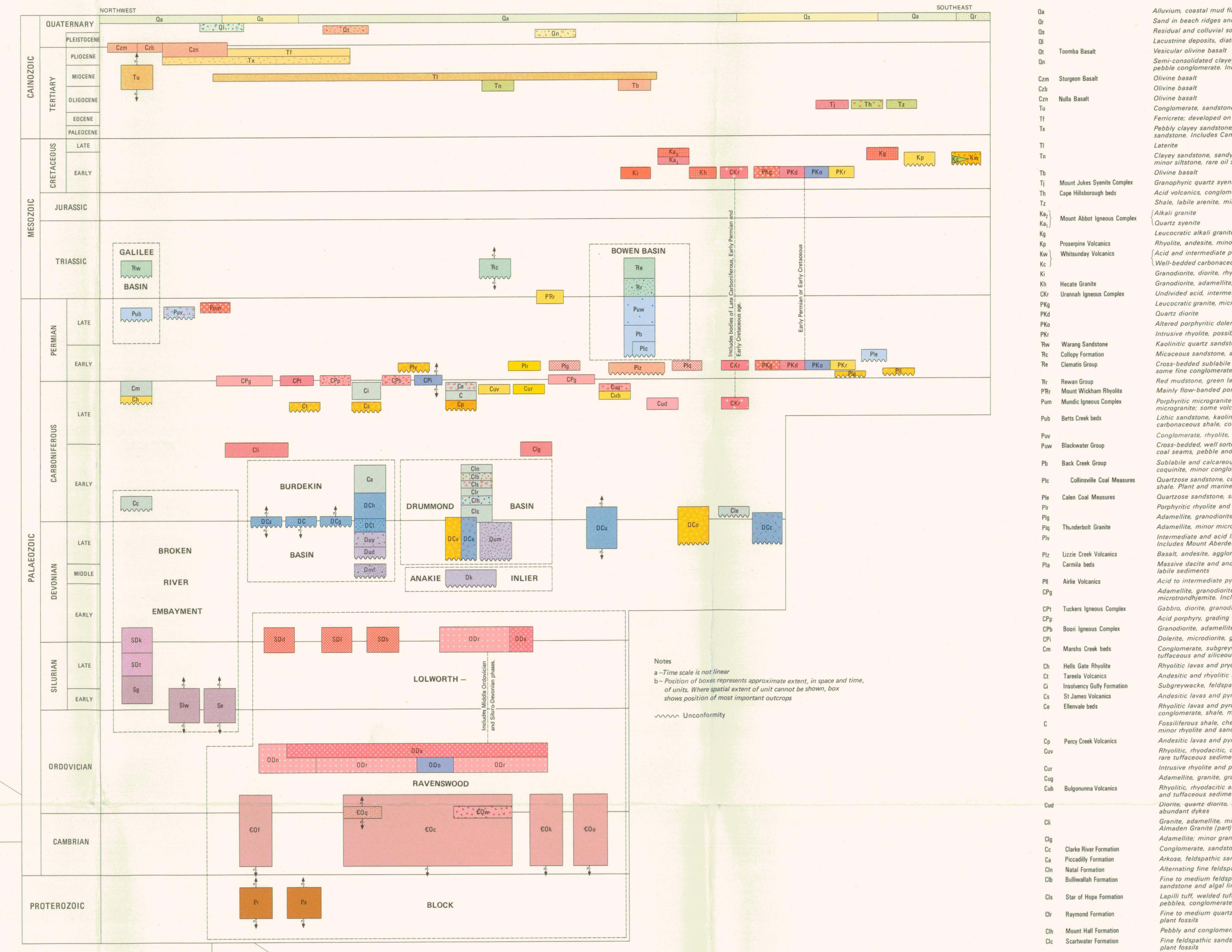
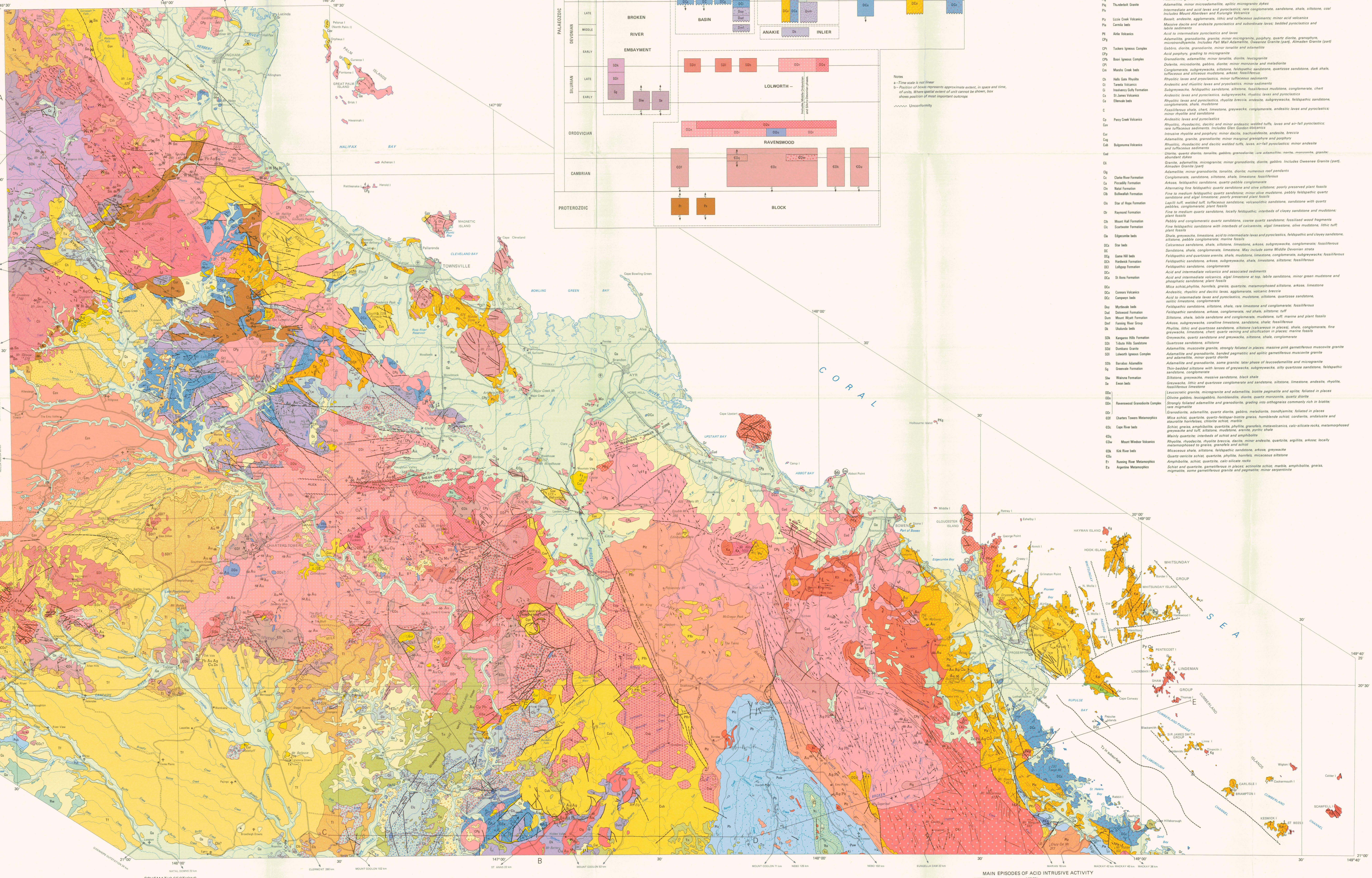
MAJOR STRUCTURAL UNITS

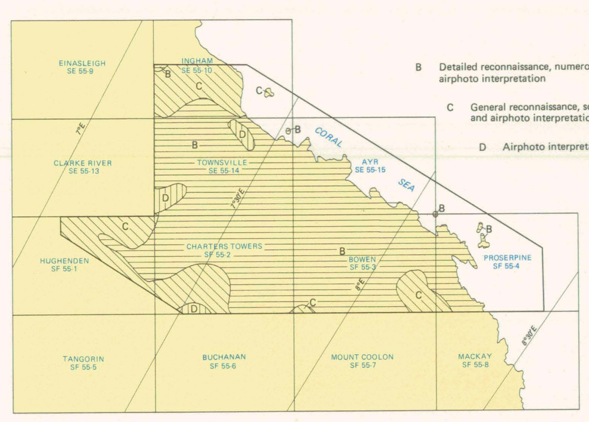
TERTIARY – Oligocene	Hillsborough Basin
EARLY CRETACEOUS	Volcanics and intrusives
EARLY PERMIAN TO TRIASSIC	Galilee and Bowen Basins
LATE PALAEOZOIC	Mainly intrusives and volcanics
MIDDLE DEVONIAN TO EARLY CARBONIFEROUS	Burdekin and Drummond Basins
MIDDLE DEVONIAN	Anakie Inlier
LATE ORDOVICIAN TO EARLY CARBONIFEROUS	Broken River Embayment
PROTEROZOIC TO EARLY DEVONIAN	Lolworth – Ravenswood Block



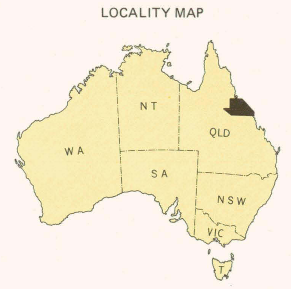




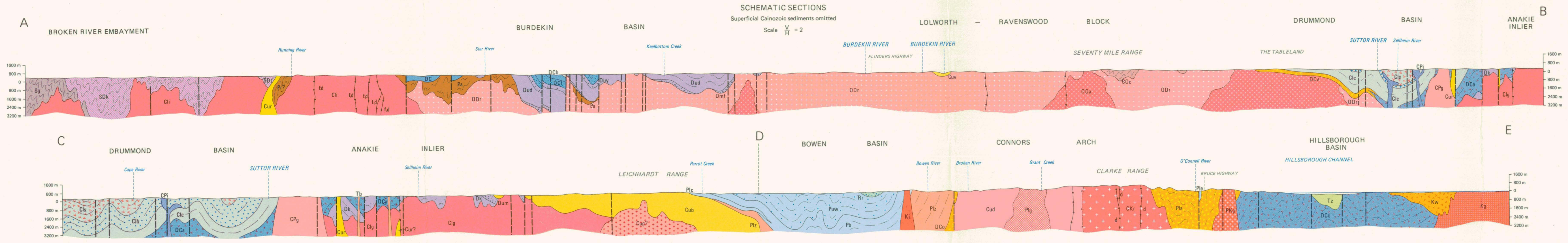
RELIABILITY DIAGRAM AND INDEX TO 1:250 000 SHEETS



LOCALITY MAP

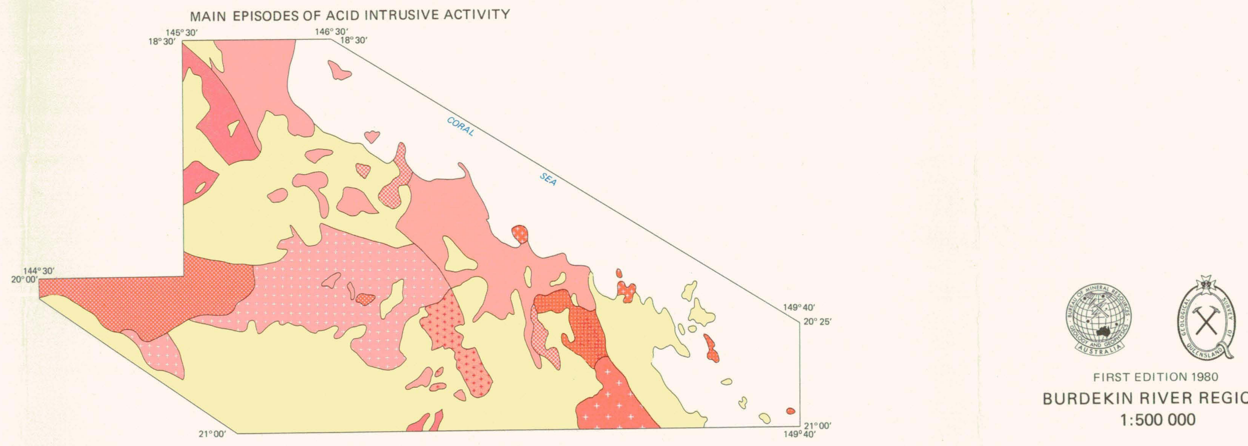


SCHEMATIC SECTIONS



MAIN EPISODES OF ACID INTRUSIVE ACTIVITY

EARLY CRETACEOUS
EARLY PERMIAN OR EARLY CRETACEOUS
LATE CARBONIFEROUS, EARLY PERMIAN AND EARLY CRETACEOUS
EARLY PERMIAN
LATE CARBONIFEROUS OR EARLY PERMIAN
LATE CARBONIFEROUS
EARLY CARBONIFEROUS
LATE SILURIAN TO EARLY DEVONIAN
MIDDLE ORDOVICIAN AND LATE SILURIAN OR EARLY DEVONIAN



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