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1961/68

GEOLOGICAL HISTORY OF THE CAIRNS-TOWNSVILLE HINTERLAND, NORTH QUEENSLAND

by

D.A. White

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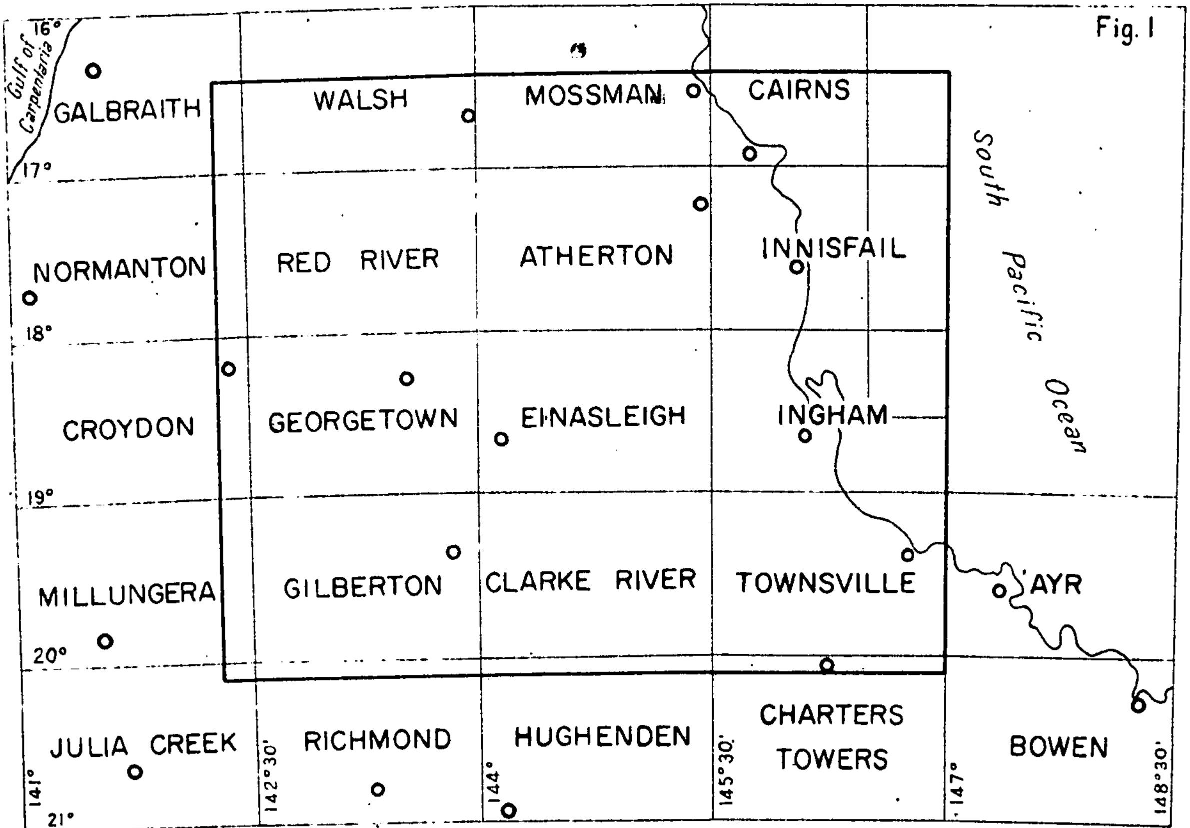

Bureau of Mineral Resources Geology and Geophysics July 1961

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SUMMARY

A history of geological events has emerged from the regional geological mapping of 35,000 square miles of the Cairns-Townsville Hinterland of North Queensland from 1956 to 1959. The hinterland consists of a broad Precambrian shield - the Georgetown Shield - which is 200 miles long and 150 miles wide, and flanked to the east by a Palaeozoic geosynclinal zone 50 to 150 miles wide, containing 40,000 feet of sediments. The geosynclinal zone is the northern part of the Tasman Geosynclinal Zone, which occupies most of the eastern coast of Australia. The shield and geosynclinal zones are intruded by igneous rocks: 20,000 square miles of acid and 5,000 square miles of basic and ultrabasic crop out.

The decipherable history of the Georgetown Shield began early in the Precambrian (Archaean?) when its central region was depressed into deep crustal levels. Sediments deposited in the depression were regionally metamorphosed to granulite, amphibolite, and migmatite, and during the Middle Precambrian (Lower Proterozoic?) uplifted to form a geanticline. At the same time the western flank of the central geanticline was down-warped to form the Etheridge Geosyncline, in which a total thickness of 30,000 feet of sediments most pelagic, with lesser amounts of terrigenous and organic sediments, were deposited. Also during this uplift 15,000 feet of fine-grained quartz and calcareous detritus were deposited on its eastern flank in the Paddys Creek area. The Precambrian history of the Shield terminated with the intrusion of the Forsayth Batholith into the core of the geanticline, and of ultrabasic rocks along its eastern fractured edge. Steep-angled thrusting of the

Archaean metamorphics over the Lower Proterozoic sediments may have accompanied both these intrusions. After the Precambrian, the shield was uplifted and fractured extensively during the deformation of the Tasman Geosyncline.

The Tasman Geosyncline in North Queensland contains a maximum thickness of 40,000 feet of sediments ranging from Upper Ordovician? to Permian, which were deposited in a belt 270 miles long and averaging 100 miles wide. The deformation of the geosyncline began in the late Silurian with the uplift of a mass of early Palaeozoic sediments in its central region, which divided the original depositional area into two parts. During this uplift serpentine and gabbro were intruded along the south-western fractured edge of the central tectonic land. The uplift of the tectonic land continued in the Devonian and Carboniferous, and was one of the major events that controlled sedimentation in the geosyncline; it forced the depositional areas to contract and migrate, resulting in the replacement of the early widespread marine sedimentation by restricted freshwater sedimentation. The geosyncline was further deformed by fracturing along the south-eastern edge of the Shield, which gave rise to a rift - the Broken River Rift.

The last sediments in the hinterland were deposited during the late Carboniferous and Permian; immediately after this period the whole of the Tasman Geosyncline and the Georgetown Shield was land, and the shield continued to arch upwards. This arching resulted in extensive fracturing of the central region of the shield and its north-eastern edges. The fractures formed rift valleys and cauldron subsidence areas, which were occupied by rhyolite and ignimbrite, coeval and comagmatic with two ages of granite.

The extrusion of continental olivine basalt in the Cainozoic near the eastern fractured shield edges was the final igneous episode of the history of the Cairns-Townsville Hinterland.

INTRODUCTION

Between 1955 and 1959 the Bureau of Mineral Resources and the Geological Survey of Queensland jointly mapped an area of 35,000 square miles comprising the five 1:250,000 Sheets Atherton, Georgetown, Einasleigh, Clarke River, and Gilberton, in North Queensland. This area lies inland from Cairns and Townsville and for the purpose of this report will be referred to as the "Cairns-Townsville Hinterland". It covers the Etheridge, Oaks, Gilberton, and Woolgar Goldfields, the Herberton - Mount Garnet Tinfield, and the Chillagoe Copperfield. Since this Report was written the combined regional survey completed the Mossman Sheet area north of the Atherton Sheet in 1960, and in 1961 began mapping the Cooktown Sheet.

It is the aim of this Report to synthesize the sedimentary, igneous, and tectonic history of the Cairns-Townsville Hinterland. The stratigraphic nomenclature of the area has been defined by White (1959 a, b), and these details will not be repeated here; the stratigraphy will be described in broad time-rock units. Also the Precambrian, Palaeozoic, and Cainozoic geology was recently described by White, Best, Branch, and others of the combined survey in the 'Geology of Queensland' (Hill & Denmead, eds., 1960). Detailed results will be published in full by White, Best, De Keyser, and Branch, in forthcoming Bulletins of the Bureau of Mineral Resources.

Terminology

The terms 'trough', 'shelf', and 'basin' are used for reasonably well known sedimentary environments and depositional areas of the North Queensland part of the Tasman Geosynclinal Zone, which is shown on the Tectonic Map of Australia (1960) as a narrow zone occupying the eastern coast of Australia.

Tectonic terms used in the text are:

Geosyncline - defined by Kay (p.4, 1951) as 'a surface of regional extent subsiding through a long time while contained sedimentary and volcanic rocks are accumulating; great thickness of the rocks is almost invariably the evidence of subsidence, but not a necessary requisite. Geosynclines are prevalently linear, but non-linear depressions can have properties that are essentially geosynclinal'.

Tasman Line - defined by Hill (p.1, 1951) as 'the boundary between the Precambrian craton and the Tasman geosyncline in early Palaeozoic times'.

Tectonic Land - defined by Kay (p. 5, 1951) as 'lands raised by tectonic movements, which contrast to volcanic lands and deltal plains that rise by accumulation'.

DEVELOPMENT OF THE TASMAN GEOSYNCLINAL ZONE

Hill (1951) was the first to attempt to divide the Tasman Geosynclinal Zone of Queensland into structural elements: narrow belts of older rocks projecting through younger rocks, referred to by Hill as 'structural highs', and narrow belts of younger rocks bounded by older, referred to as 'structural lows'; all trended north-north-west. Later (1960) Hill suggested that most of the structural lows were younger separate basins of deposition. In the North Queensland part of the geosyncline, Hill (1951) outlined the 'Hodgkinson Basin' occupying the central area, which separated a narrow shelf - the 'Chillagoe Shelf' - to the west, from a structural high - the 'North Coastal High' - to the east. These elements were bounded to the west by the Precambrian 'Georgetown Massif'. Hill suggested that the Hodgkinson Basin was part of a larger basin extending farther south and including the 'Star' and

'Drummond' Basins. She referred to the Basin as the 'Jack Basin', and concluded that it was probably an intermontane basin, or possibly a marginal geosyncline, and that the North Coastal High was a highland during the sedimentation in the Jack Basin. Later Hill (1960) stated that the Jack Basin may have been a false simplification; the Star and Drummond Basins were probably separated by a granitic complex near Charters Towers, which supplied detritus to both basins.

Hill (1960) referred to the major embayment extending south-west into the Precambrian Shield in the Broken River area as the 'Broken River Embayment'. (The structure is shown in this Report to be a rift.)

The history of development of the Tasman Geosyncline in North Queensland supports Hill's general concept of high and low structural elements, but differs from it in detail of some of the elements. Briefly the history of the geosyncline began in the Upper Ordovician, when north-east and north-west faults determined the eastern edge of the Precambrian Georgetown Shield, and about 40,000 feet of sediments were deposited along the eastern margin of the shield in a depositional area elongated north-north-west. Rejuvenation of these faults in the Upper Silurian was accompanied by a major uplift of the sea-floor, and tectonic land arose in the centre of the area, dividing the original depositional area into northern and southern basins. Serpentine was intruded along the north-east faulted edge of the tectonic land. During the Devonian the central land continued to rise gently, causing the depositional areas to contract and migrate, the northerly basin moving north and east, and the southerly one south-west. During the Upper Devonian-Carboniferous renewed faulting along the edges of the rising tectonic land and the Precambrian Shield split the southern basin into three freshwater basins, of which the most westerly - the Bundock Basin - was contained in a major rift - the Broken River Rift - in the Precambrian Shield. The geosyncline was consolidated in the Permian to (?) Lower Triassic time by the intrusion of a granite batholith, which was contemporaneous with outpouring of acid volcanics; the acid igneous activity was concentrated along the north-west faulted edge of the Precambrian Shield, and the shelf regions of the northern basin.

The history of the development of the geosyncline strongly suggests that fracturing of, and parallel to the edge of, the Precambrian Shield was a major process during the growth of the geosyncline. It supports statements made by Hills (1956a, p.343) that 'it is true that eastern Australia is mobile, but the évidence indicates that there is an underlying basement throughout', and (1956b, p.14-45) that 'the primitive continental mass has fractured both marginally and internally'. Recently, Voisey (1959) in a synthesis of Australian Geosynclines maintained that the Tasman Geosyncline (for the whole of Eastern Australia) advanced to the east by the development and deformation of secondary geosynclines. The advance of the Tasman Geosyncline in North Queensland is not wholly to the east, but rather to the north, and south-west. Its development does support Voisey's concept of secondary geosynclines.

GEOLOGICAL HISTORY

The stratigraphic nomenclature of the area has been outlined by White (1959a, b, c; 1960a, b, c). Rock unit names will not be used in this paper; they have been grouped into broad time and time-rock units ranging from Precambrian to Cainozoic (Tables 1, 2 and 3). These tables also show igneous activity, environment, and tectonics. The time-rock units have not been formally named, since their correlation with similar units in other parts of Queensland is not yet sufficiently known.

TABLE 1

PRECAMBRIAN STRATIGRAPHY OF THE CAIRNS-TOWNSVILLE HINTERLAND

NORTH QUEENSLAND

AGE	LITHOLOGY	DIMENSIONS	PALAEONTOLOGY	IGNEOUS ACTIVITY	ENVIRONMENT	TECTONIC ELEMENT		ECONOMICS
Late Precambrian		10,000 square miles area		Acid Granite batholith. (grey; biotite and hornblende). Platy flow.	Mesozone intrusion into core of geanticline of Georgetown Shield.	Forsayth Batholith		Gold
	INTRUSIVE CONTACT							
		90 miles long, ¼ mile wide (25 square miles)		Ultrabasic & Basic Antigorite serpentine, gabbro, linear masses.	High greenschist to low albite-epidote amphibolite metamorphic facies. Intrusion along eastern thrust edge of Precambrian Shield.		GEORGETOWN	Gold Copper Nickel Manganere
		Relationship unknown						
		100 square miles area		Dolerite, gabbro, stocks, sills and dykes.	Greenschist and low epidote amphibolite metamorphic facies. Grouped around Forsayth Batholith.			Gold Copper Silver Lead.
INTRUSIVE CONTACT								
Late Precambrian (Lower Proterozoic)	Black-grey shale, carbonaceous shale, chert, quartz siltstone, quartzite, calc-silicate hornfels, marble, calcareous quartz sandstone and siltstone, schists (mica, andalusite, staurolite-garnet).	30,000 feet thick.			Trough and shelf. Contact and regional metamorphism increases towards centre of Shield.	Etheridge Geosyncline	SHIELD	
	METAMORPHIC UNCONFORMITY -- PARTLY (?) THRUST							
Early Precambrian (? Archaean)	Migmatite, banded granulite amphibolite, gneiss.	5,000 square miles area.		?Palingenetic "granite".	Central part of Shield. Amphibolite metamorphic facies.	Primordial Crust.		?Gold

<u>Precambrian</u> (Fig. 2)

The Precambrian of the Georgetown-Einasleigh area has been named by Hill (1951) 'Georgetown Massif'. It is also the eastern portion of the 'Northern Massif' (Bryan, 1932), and a part of the 'Carpentaria Block' (Andrew, 1937). The name <u>Georgetown Shield</u> is used here for the Precambrian rocks of the Georgetown-Einasleigh area.

The Georgetown Shield consists of an older metamorphic complex, and a younger unfossiliferous sedimentary and metasedimentary unit, both of which have been deformed and intruded, initially by ultrabasic and basic rocks, and finally by a granite batholith - the <u>Forsayth Batholith</u>.

Bryan (1925), and Bryan & Jones (1946) suggested that the Precambrian metamorphics in the Einasleigh-Etheridge area are of two ages: the older metamorphics are tentatively assigned to the Archaean, and the younger to the Proterozoic. Some guide to the ages of these units will shortly be obtained from radioactive age dating of granite samples collected in 1958 from many parts of the Forsayth Batholith, which is undoubtedly the youngest unit of the Georgetown Shield.

The Archaean metamorphics occupy two areas: one, the main area of exposure, occupies the central region of the Georgetown Shield and crops out as roof pendants in the Forsayth Batholith; the other, of smaller area, occupies a narrow belt on the eastern margin of the Shield, and crops out intermittently over a length of 200 miles from Dargalong, just west of Chillagoe, south-east to near Mount Garnet, then south-west to Minnamoolka Homestead and the Valley of Lagoons Homestead. The metamorphics are also exposed as a smaller outlier on the western part of the massif in the Woolgar Goldfield. The Archaean metamorphics are regionally metamorphosed to the amphibolite metamorphic facies (Turner & Verhoogen, 1951, p.446). A few of the granulites contain pyroxene and may be relics of original higher grade rocks of the granulite facies (op.cit., p.473).

Some granulites are banded and resemble the 'charnockitic' rocks described by Wilson (1958) in the Precambrian of the south-west of Western Australia.

The largest exposure of Proterozoic sediments and metamorphics occupies the western part of the Georgetown Shield and is 120 miles long and 90 miles wide. The sediments are 30,000 feet thick and are mainly pelagic, with lesser amounts of terrigenous material. The fold axes are arcuate and trend from north-north-west to east. Their distribution and relationships of the sediments are sufficiently established to call the depositional area a geosyncline, named the Etheridge Geosyncline. The other younger sediments and metasediments are exposed at two localities: one in the north at Tate River, and the other in the south at Paddy's Creek. The relationship between these two depositional areas, and of both to the Etheridge Geosyncline, is not known, since they are separated by Precambrian and Upper Palaeozoic granites and Cainozoic basalt. The Tate River and Paddy's Creek areas are tentatively shown as once forming a continuous arcuate belt. Some of the Paddy's Creek sediments may have been deposited later, in the beginning of the Palaeozoic, in epicontinental seas on the eastern margin of the Georgetown Shield, and contemporaneous with the early Palaeozoic sedimentation in the adjoining Tasman Geosyncline to the east (Fig. 9, section 2). If this is so, part of the Tate River/Paddys Creek area of deposition is probably the northern part of the 'North-east Passage' (Bryan, 1932), which links the Tasman Geosyncline to the Central Geosyncline on the Australian continent.

Metamorphism of the Proterozoic sediments is mainly contact or low-grade regional. The regional metamorphic grade increases in the Etheridge Geosyncline from west to east towards the centre of the Georgetown Shield and ranges from the muscovite-chlorite subfacies of the greenschist facies

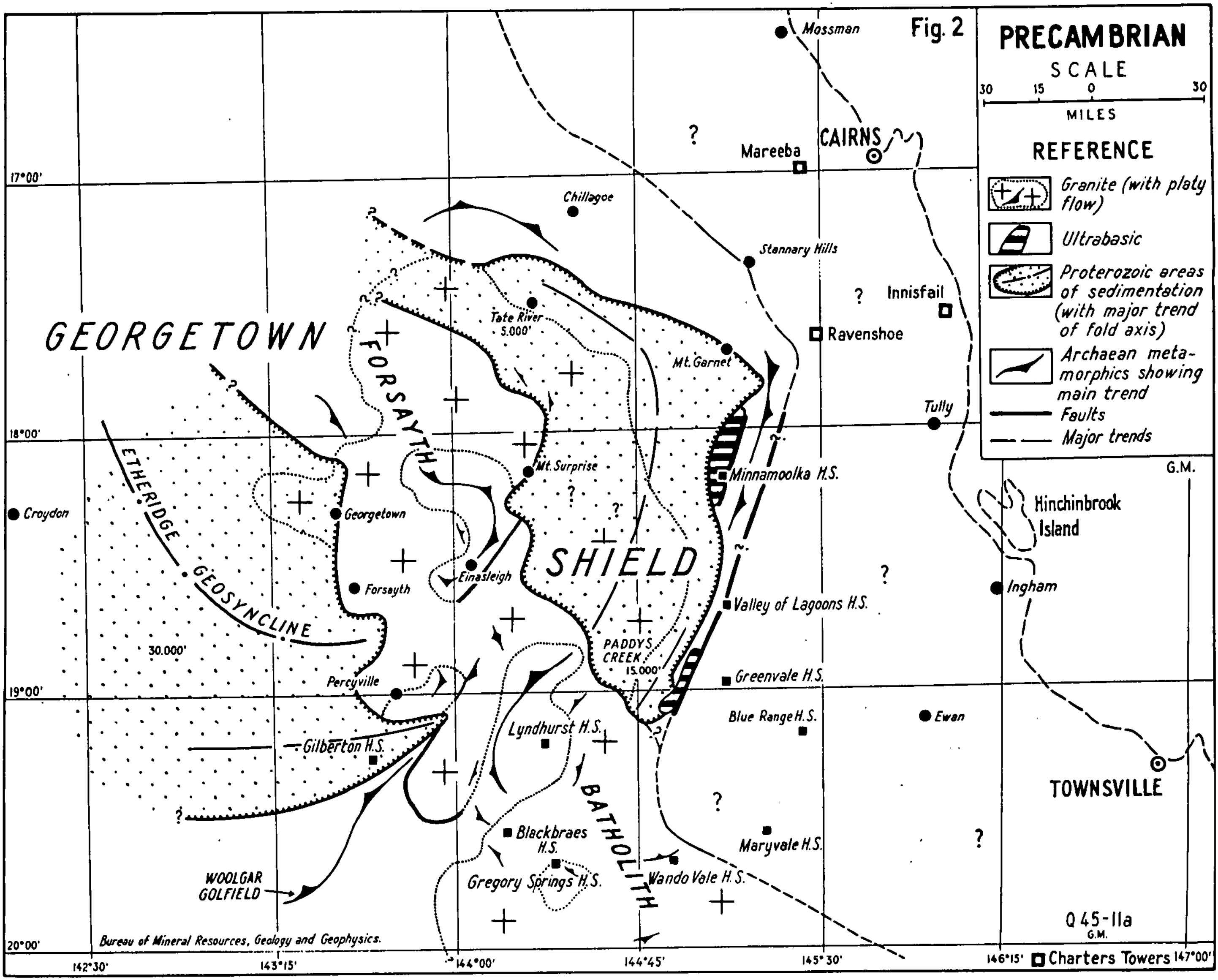


Fig. 2
PRECAMBRIAN
SCALE
30 15 0 30
MILES
REFERENCE
Granite (with platy flow)
Ultrabasic
Proterozoic areas of sedimentation (with major trend of fold axis)
Archaean metamorphics showing main trend
Faults
Major trends
GEORGETOWN
FORSAYTH
SHIELD
BATHOLITH
ETHERIDGE
GEOSYNCLINE
Mossman
CAIRNS
Mareeba
Chillagoe
Stannary Hills
Innisfail
Ravenshoe
Tate River
5.000'
Mt. Garnet
Tully
Mt. Surprise
Minnamoolka H.S.
Hinchinbrook Island
Croydon
Georgetown
Einasleigh
Forsayth
Valley of Lagoons H.S.
Ingham
30.000'
PADDYS CREEK
15.000'
Greenvale H.S.
Percyville
Blue Range H.S.
Ewan
Lyndhurst H.S.
Gilberton H.S.
TOWNSVILLE
Blackbraes H.S.
Maryvale H.S.
Wando Vale H.S.
Gregory Springs H.S.
WOOLGAR GOLFIELD
Q 45-11a
G.M.
Bureau of Mineral Resources, Geology and Geophysics.
17°00'
18°00'
19°00'
20°00'
142°30'
143°15'
144°00'
144°45'
145°30'
146°15'
147°00'
Charters Towers

(Turner & Verhoogen, 1951, p.466), through the albite-epidote facies (p.460), to the staurolite-kyanite subfacies of the amphibolite facies (p.452). The staurolite schists are generally flat-lying and overlie the lower-grade metamorphics. Although the study of the lineations is not yet complete, the general field relations suggest that the metamorphic contact is a thrust, which may have accompanied the intrusion of the Forsayth Batholith.

Towards the end of the Precambrian the Shield was consolidated by the intrusion of ultrabasic and basic rocks along its eastern edge, and finally, by the intrusion of the Forsayth Batholith in its central region. The ultrabasic and basic rocks were intruded along the north-east trending faulted edge of the Burdekin River Fault Zone (Fig. 2); some dykes and sills of dolerite were intruded in the central region of the field. The Forsayth Batholith trends north-north-west across the central region of the shield. The batholith has contact-metamorphosed the Proterozoic sediments, and retrograde-metamorphosed the Archaean metamorphics.

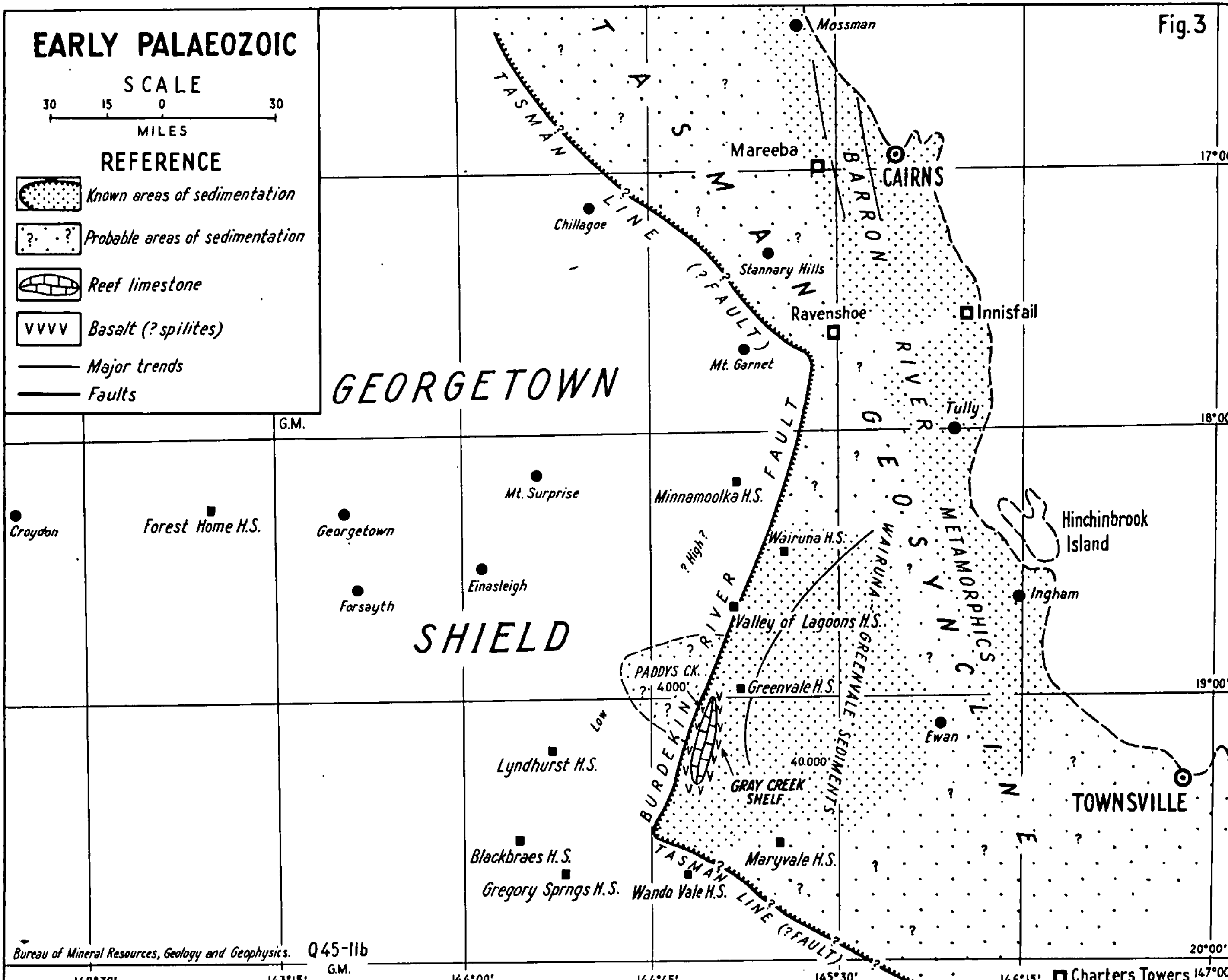
The Georgetown Shield is about 210 miles long and 210 miles wide, and occupies more than half of the Cairns-Townsville hinterland. Its limits as a land mass in late Precambrian time are not precisely known, although, for reasons advanced later, it may have extended beyond the present-day boundaries. The Georgetown Shield probably extended to the south-west along the 'Euroka Ridge' (Hill, 1951) and joined the 'Cloncurry Massif' (Hill, 1951). Also its outcrop may have extended south in the Precambrian and joined the Cape River Series (Daintree, 1870). The most easterly exposure known of the Georgetown Shield is near longitude 145°30'E., some 50 miles from the present coastline, between Innisfail and Tully. The eastern limit of the Shield is not known, but from the synthesis of the history of the Tasman Geosyncline in North Queensland, the structure of the Georgetown Shield appears to have influenced the subsequent formation and deformation of the Tasman Geosyncline, and the Shield may have once extended at least to the present eastern coastline.

Early Palaeozoic (Fig. 3)

The early Palaeozoic sequence contain the oldest fossiliferous sediments of the Tasman Geosyncline of North Queensland. The sediments are about 40,000 feet thick and consist of fine-grained quartz clastics, graptolitic shale, and greywacke, with lesser amounts of coral reef interbedded with basalt (spilite). The low grade regional metamorphics of the 'Barron River Series' (Whitehouse, 1930) and the 'Barron River Metamorphics' (Geological Map, 1953) probably belong to the early Palaeozoic. The sequence is intensely folded, and intruded by ultrabasic, basic, and acid igneous rocks.

The early Palaeozoic sequence is exposed in two separate areas: one of definite early Silurian age in the south-west - the Wairuna-Greenvale area; the other of uncertain age in the north-east, occupying the coastal region near Cairns - the Barron River area.

The Wairuna-Greenvale area contains all the fossils of the early Palaeozoic sediments. The fossils are graptolites of Lower Silurian age (Thomas, 1960); trilobites of Lower Silurian age (Öpik, in White, Best, et al., 1959); and corals of Lower Silurian and ?Upper Ordovician age (Hill, in White, Stewart, et al., 1959). The sediments are exposed in the Gray Creek area adjacent to the eastern boundary of the Georgetown Shield; they occupy a belt 20 miles wide extending south-west for 90 miles from Wairuna Homestead. Coral reef and spilitic basalt are exposed in the Gray Creek Shelf in part of the western edge of the Wairuna-Greenvale depositional area.



EARLY PALAEOZOIC
SCALE
30 15 0 30
MILES
REFERENCE
Known areas of sedimentation
Probable areas of sedimentation
Reef limestone
Basalt (? spilites)
Major trends
Faults
Fig. 3
TASMAN GEOSYNCLINE
TASMAN LINE (? FAULT)
GEORGETOWN SHIELD
BURDEKIN RIVER FAULT
BARRON RIVER METAMORPHICS
WAIRUNA - GREENVALE SEDIMENTS
GRAY CREEK SHELF
PADDYS CK.
Mossman
Mareeba
CAIRNS
Chillagoe
Stannary Hills
Ravenshoe
Innisfail
Mt. Garnet
Tully
Mt. Surprise
Minnamoolka H.S.
Croydon
Forest Home H.S.
Georgetown
Wairuna H.S.
Hinchinbrook Island
Einasleigh
Forsayth
Ingham
Valley of Lagoons H.S.
Greenvale H.S.
Ewan
Lyndhurst H.S.
TOWNSVILLE
Maryvale H.S.
Blackbraes H.S.
Gregory Sprngs H.S.
Wando Vale H.S.
Charters Towers
? High ?
Low
4,000'
40,000'
G.M.
17°00'
18°00'
19°00'
20°00'
142°30'
143°15'
144°00'
144°45'
145°30'
146°15'
147°00'
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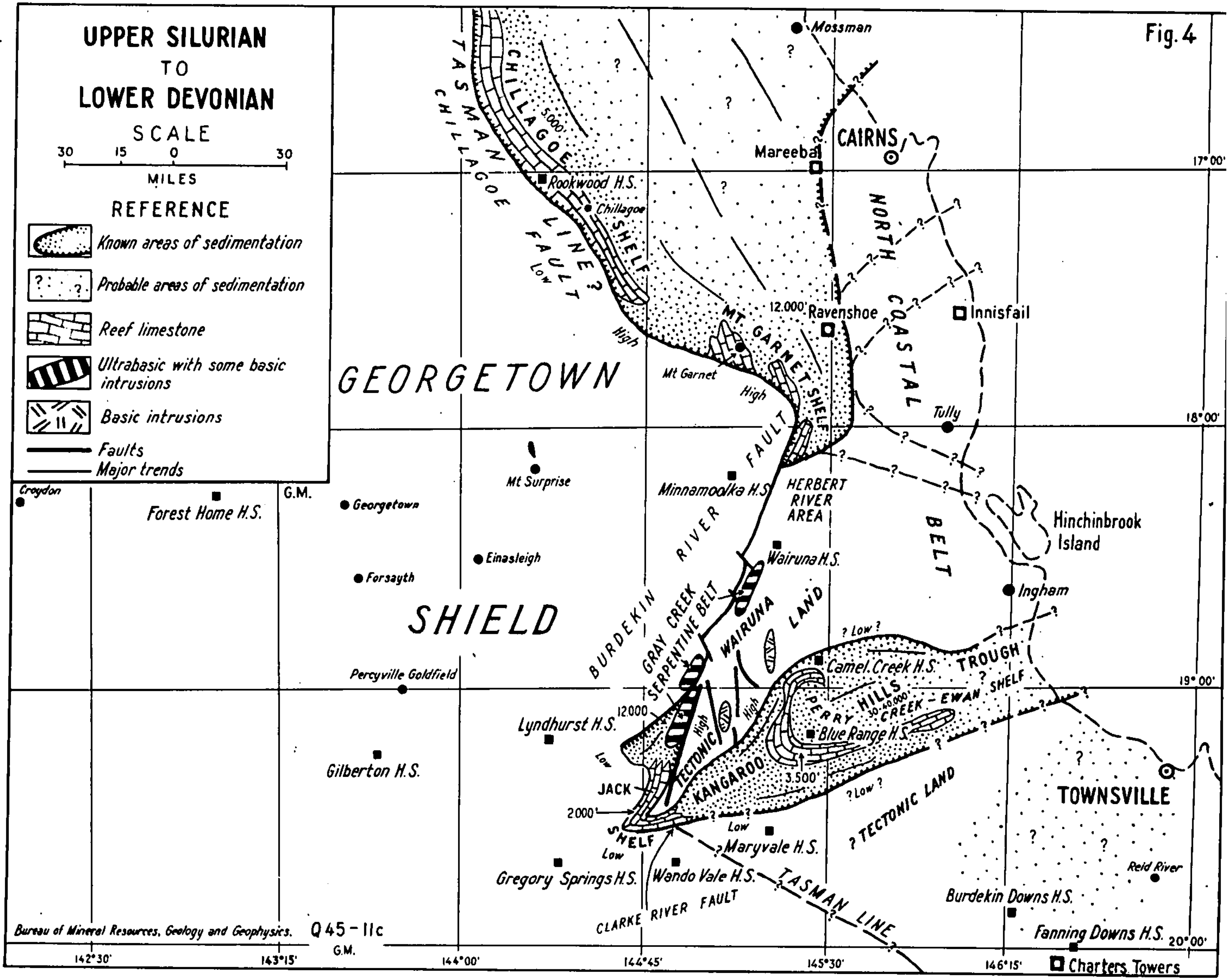
Little is known of the age and distribution of the Barron River Metamorphics, partly because only a small portion of the Coastal area has been mapped. The metamorphics are shown on the 1953 Geological Map of Queensland as extending from latitude 14°30'S. to Ingham. The sedimentary and tectonic history of North Queensland suggests that some of the sedimentation in the Barron River area was probably contemporaneous with the ?Upper Ordovician/Lower Silurian sedimentation in the Wairuna-Greenvale area. Also the Barron River Metamorphics, as previously defined by Whitehouse (1930) and shown on the 1953 map, may contain, not only some Wairuna-Greenvale sediments, but also the Upper Silurian/Carboniferous sediments of the Hodgkinson Trough, Mount Garnet Shelf, and Kangaroo Hills Trough. Already de Keyser and party (pers. comm. 1960) have shown that the Barron River Metamorphics north of Cairns are conformable with the sediments of the Hodgkinson Trough; whether these beds continue south beyond Cairns to include all the Barron River Metamorphics is not yet known.

The precise age limits of the early Palaeozoic sediments are not known. Nowhere is the bottom of the beds seen, and as yet fossils have not been found in the top 30,000 feet of the Wairuna-Greenvale area, or in the Barron River belt. The sediments in the southern part must be older than Upper Silurian, since they are separated by a regional unconformity from Upper Silurian/Lower Devonian sediments, and younger than Precambrian.

<u>Upper Silurian to Lower Devonian</u> (Fig. 4).

The Upper Silurian to Lower Devonian sediments consist of 35,000 to 40,000 feet of terrigenous material, coral reefs and their detritus. They are folded, and intruded by minor ultrabasic, basic, and acid igneous rocks. The age of these sediments is determined by corals described by Hill (in White, Stewart, et al., 1959; White, Best, et al., 1959).



UPPER SILURIAN
TO
LOWER DEVONIAN
SCALE
30 15 0 30
MILES
REFERENCE
Known areas of sedimentation
Probable areas of sedimentation
Reef limestone
Ultrabasic with some basic intrusions
Basic intrusions
Faults
Major trends
Fig. 4
GEORGETOWN
SHIELD
TASMAN CHILLAGOE LINE
CHILLAGOE FAULT ?
CHILLAGOE SHELF
MT GARNET SHELF
NORTH COASTAL BELT
BURDEKIN RIVER FAULT
HERBERT RIVER AREA
GRAY CREEK SERPENTINE BELT
WAIRUNA LAND
TROUGH
PERRY HILLS
CREEK - EWAN SHELF
TECTONIC HIGH
KANGAROO
JACK SHELF
? TECTONIC LAND
CLARKE RIVER FAULT
TASMAN LINE
Mossman
CAIRNS
Mareeba
Rookwood H.S.
Chillagoe
Ravenshoe
Innisfail
Mt Garnet
Tully
Mt Surprise
Minnamoolka H.S.
Hinchinbrook Island
Croydon
Forest Home H.S.
Georgetown
Einasleigh
Forsayth
Wairuna H.S.
Ingham
Camel Creek H.S.
Percyville Goldfield
Lyndhurst H.S.
Blue Range H.S.
Gilberton H.S.
TOWNSVILLE
Maryvale H.S.
Gregory Springs H.S.
Wando Vale H.S.
Reid River
Burdekin Downs H.S.
Fanning Downs H.S.
Charters Towers
5,000'
12,000'
12000
30-40,000'
3,500'
2000'
High
Low
? Low ?
17°00'
18°00'
19°00'
20°00'
142°30'
143°15'
144°00'
144°45'
145°30'
146°15'
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The Upper Silurian and Lower Devonian age limits are also determined by parts of the depositional area where the sediments unconformably overlie the Silurian Wairuna-Greenvale sediments, and are unconformably overlain by Middle Devonian coral reef limestone.

Two areas of Upper Silurian/Lower Devonian sedimentation are known: one in the north between Chillagoe and Mount Garnet; and the other in the south between Gray Creek and Ewan. These areas are separated by the early Palaeozoic sediments of the Wairuna, Greenvale, and Barron River areas, which by uplift in the late Silurian emerged as a land barrier in the Upper Silurian-Lower Devonian; and by an Upper Palaeozoic granite batholith.

The Chillagoe section consists of 5,000 feet of coralline reef limestone, reef detritus, and lesser amounts of terrigenous material derived from the neighbouring Precambrian Georgetown Shield to the west. Thin basalt flows are exposed among some of the reefs. The sedimentary environment must have been that of a broad continental shelf - the 'Chillagoe Shelf' of Hill (1951) - bordering an old Precambrian continent of low relief, which allowed the shallow Upper Silurian/Lower Devonian sea to transgress some distance to the west of the present exposure of the Chillagoe coral reefs. The eastern limit of the Chillagoe Shelf is not precisely known, but it probably did not extend farther east than the Featherbed Range and Petford. Near Petford cobbles and pebbles of the Georgetown Shield are exposed in a greywacke conglomerate, which resembles other conglomerates of the Mount Garnet area, suggesting that the provenance was the shield situated a few miles to the west. The Chillagoe Shelf sediments continue to the south-east and must have merged with the Mount Garnet Upper Silurian/Lower Devonian sediments before being separated by later Upper Palaeozoic igneous intrusions.

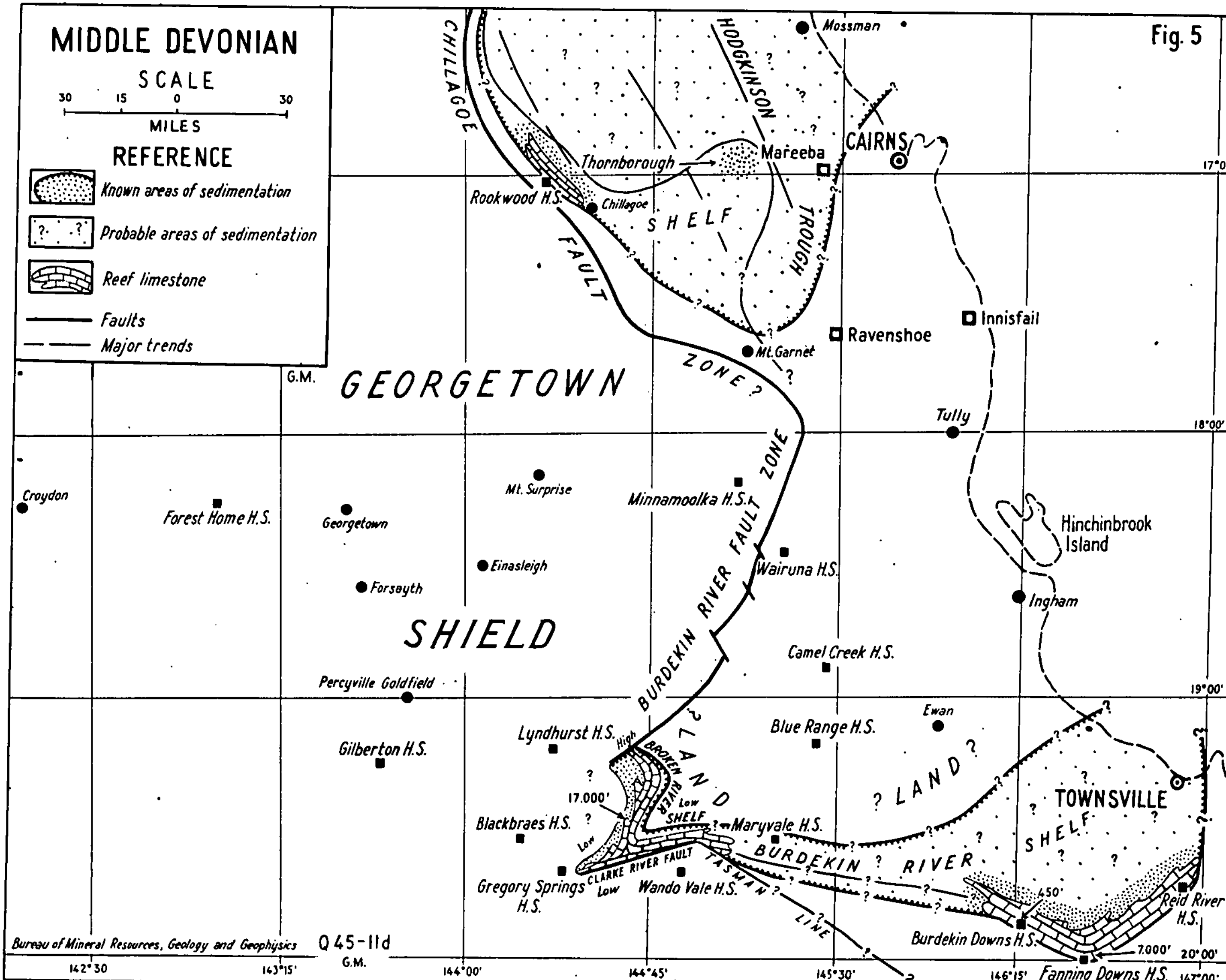
The sediments of the Mount Garnet area contain more massive greywacke and greywacke conglomerate, and less reef limestone and reef detritus, and are thicker (12,000 feet), than the sediments of the Chillagoe Shelf. The Mount Garnet area was probably a shelf; its sea floor must have been more irregular than that of the Chillagoe Shelf, and its shore-line steeper, more abrupt and more irregular, thus restricting the western transgression of the sea to near its present known boundary. The Mount Garnet Shelf was probably similar to the 'Continental Borderland' (Wiseman & Ovey, 1953, p.14) recognised in the present-day sea floors.

The second and thicker Upper Silurian/Lower Devonian depositional area is situated in the south between Gray Creek and Ewan. It contains mainly greywacke, and lesser amounts of reef limestone and its detritus; the thickness is 35,000-40,000 feet. The configuration of the depositional area and the amount of the containing sediments suggest that it was essentially an east-west trough, named here the Kangaroo Hills Trough. The Kangaroo Hills Trough is at least 110 miles long and 30 miles wide; its eastern limit, beyond Ewan, is not known. Its western limit must have been close to the present known eastern edge of the Precambrian Georgetown Shield; its southern and northern limits were probably fixed by Silurian tectonic lands. The northern limit was the Wairuna land mass, whose southern end divided the Kangaroo Hills Trough into two distinct sedimentary areas: one to the west of the Wairuna mass near Graveyard Creek; and the other to the east in the Camel Creek/Blue Range/Ewan area. The western part of the Trough is 15 miles wide and 40 miles long, and bordered to the west and south by the Georgetown Shield. Its position in the Trough suggests that it was a fore-deep (Gignoux, 1955, p.3) in the Upper Silurian/Lower Devonian sea. The topography of the floor of this western fore-deep must have been irregular, since coral limestone reefs are scattered sporadically through greywacke which is its main constituent. The coral reefs are thickest in the southern part of the fore-deep, where continental shelf conditions prevailed; this shelf is named the Jack Shelf.

The sediments of the eastern part of the Kangaroo Hills Trough are similar to those in the western fore-deep in that they contain greywacke and limestone. The main differences are the greater thickness (35,000-40,000 feet) of sediments and the restriction of the greywacke to thick beds in a succession of monotonous rhythmically alternating beds of quartz siltstone and fine-grained quartz sandstone. All these sediments contain most of the turbidity-current structures described by Kuenen (1952) and others. A feature of the eastern part of the Kangaroo Hills Trough is the arcuate shelf area between Camel Creek, Blue Range, and Ewan, which contains coral reefs and reef detritus as well as small amounts of amygdaloidal basalt. The corals are Upper Silurian/Lower Devonian, as are those on the Jack Shelf, western fore-deep, and Mount Garnet and Chillagoe Shelves.

Middle Devonian (Fig. 5).

The sediments of Middle Devonian age consist of coral reef, reef detritus, and lesser amounts of pelagic and terrigenous sediments. The thickness ranges from 450 feet to 17,000 feet. The beds are tightly folded and invaded by small basic, intermediate, and acid igneous intrusions. Their age has been determined by abundant corals, which are listed in preliminary reports by Prof. Hill, University of Queensland, in unpublished reports by White, Stewart, et al. (1959), and White, Best, et al. (1959). Most of the corals are of Givetian age, and a few may extend down to the Lower Devonian, and in one locality, Gregory Springs, up into the Frasnian (Upper Devonian). The age of the corals suggests that sedimentation was almost continuous from the Lower Devonian to the Upper Devonian. Field mapping of formations indicates a break, probably erosional, and certainly a regional unconformity between the dominantly Middle Devonian


MIDDLE DEVONIAN
SCALE
30 15 0 30
MILES
REFERENCE
Known areas of sedimentation
Probable areas of sedimentation
Reef limestone
Faults
Major trends
Fig. 5
Mossman
CHILLAGOE
HODGKINSON
CAIRNS
Mareeba
Thornborough
Rookwood H.S.
Chillagoe
SHELF
TROUGH
FAULT
ZONE ?
Mt. Garnet
Ravenshoe
Innisfail
GEORGETOWN
SHIELD
Tully
Mt. Surprise
Minnamoolka H.S.
Croydon
Forest Home H.S.
Georgetown
Einasleigh
Forsayth
Hinchinbrook Island
Wairuna H.S.
Ingham
BURDEKIN RIVER FAULT ZONE
Camel Creek H.S.
Percyville Goldfield
Ewan
Blue Range H.S.
Lyndhurst H.S.
Gilberton H.S.
? LAND
? LAND ?
High
BROKEN RIVER
Low
SHELF
17,000'
Blackbraes H.S.
Maryvale H.S.
TOWNSVILLE
SHELF
BURDEKIN ? RIVER
CLARKE RIVER FAULT
Gregory Springs H.S.
Wando Vale H.S.
TASMAN ? LINE
450'
Reid River H.S.
Burdekin Downs H.S.
7,000'
Fanning Downs H.S.
Bureau of Mineral Resources, Geology and Geophysics
Q 45-11d
G.M.
17°00'
18°00'
19°00'
20°00'
142°30
143°15'
144°00'
144°45'
145°30'
146°15'
147°00'

and the Upper Silurian/Lower Devonian successions. There is no major interruption of sedimentation between the Middle Devonian and the overlying Upper Devonian/Lower Carboniferous sediments of the Bundock Basin (Fig. 6); but there is strong evidence for overlap of the upper beds of the Bundock Basin in the Tournaisian (Lower Carboniferous).

Middle Devonian sediments are exposed in three localities in the Cairns-Townsville area. One small locality is in the north at Rookwood Homestead near Chillagoe; the two others are in the south, and are more widespread; one is in the Broken River area, the other in the Burdekin Downs/Fanning Downs/Reid River area between Charters Towers and Townsville.

The Middle Devonian age of the Rookwood sediments is based on a doubtful Stringocephalus and other lamellibranchs (Hill, pers. comm., 1958) collected from a limestone. Another probable Middle Devonian bed (Hill, op. cit.) is a reef conglomerate in the Thornborough Goldfield about 20 miles west-north-west of Mareeba. The sedimentational history of the Rookwood/Thornborough Middle Devonian sediments, and their relationship to the Upper Silurian/Lower Devonian sediments of the Chillagoe and Mount Garnet Shelves, and to the later Upper Devonian/Carboniferous sediments of the Hodgkinson Trough (Fig. 6), are not yet known, since mapping is still in progress, and most of the boundary is obscured by granite intrusions. The Rookwood-Thornborough reefs may be remnants of a Middle Devonian shelf marginal to the Chillagoe Shelf, and extending farther east of the shelf.

Time-rock relationships are best known in the southern locality in the Broken River area, where the thickest Middle Devonian succession (17,000 feet) is exposed. Well preserved Givetian corals from limestone reefs have been determined by Prof Hill. The coral reefs are thickest in the basal and middle sections of the succession. The Middle Devonian Broken River sediments overlie the Upper Silurian/Lower Devonian sediments of the western fore-deep of the Kangaroo Hills Trough; they are separated from these underlying sediments by a regional erosional unconformity; and they are overlapped by the Upper Devonian/Lower Carboniferous sediments of the Bundock Basin (Fig. 6).

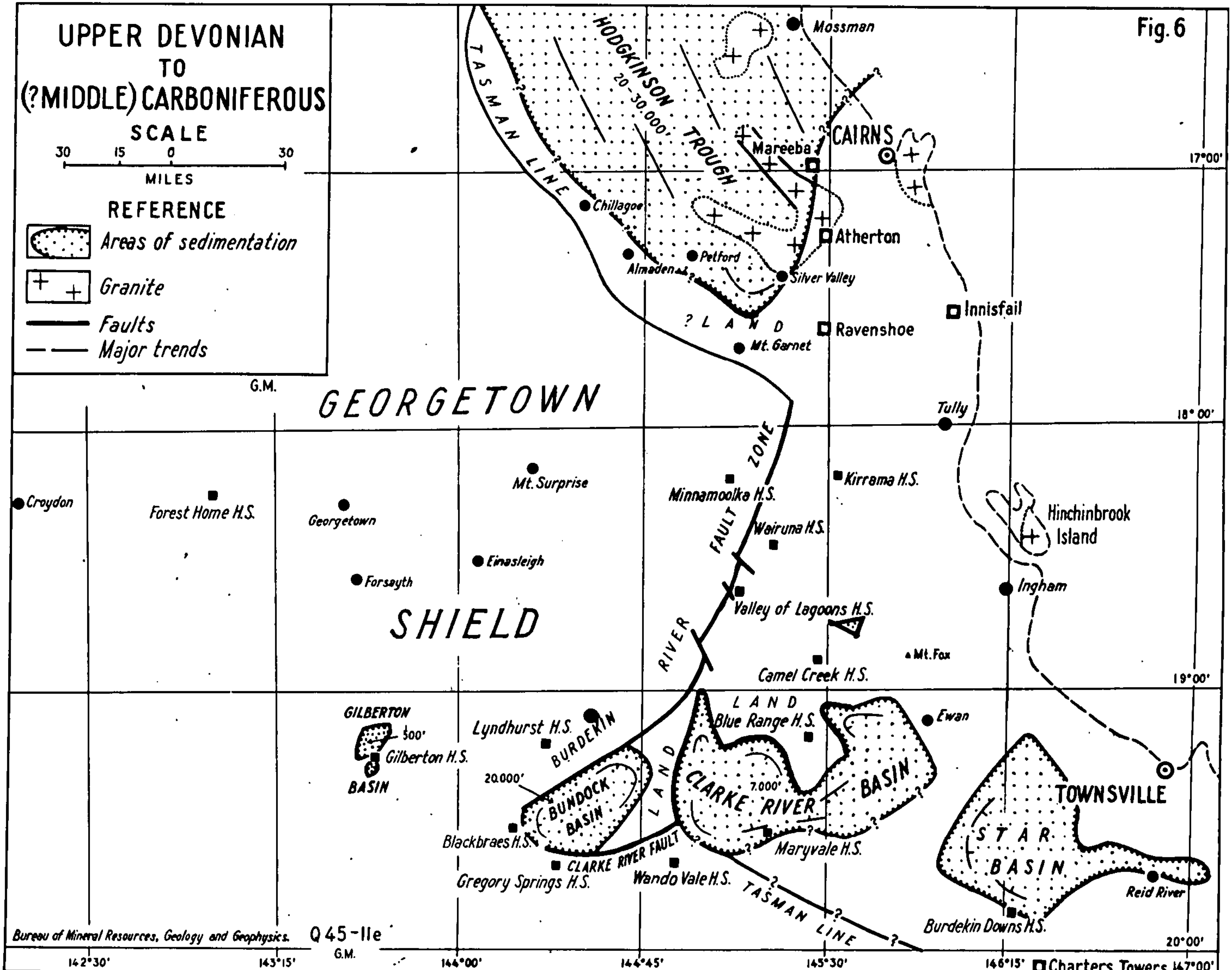
Jack & Etheridge (1892, p.35-36) described the other southern Middle Devonian locality, which is situated in the Burdekin Downs area about 70 miles south-west of Townsville. They estimated 450 feet of coral reef limestone at Burdekin Downs, and 7,000 feet at Fanning Downs. Reid (1930) discussed the problem of the correlation of these reefs with the coral limestone occurrences of the Broken River area. Hill (1942, p. 229) described Givetian corals from these localities and from nearby Reid River; and Heidecker (1959) described three new genera of Middle Devonian molluscs from a coral reef locality 25 miles north-west of Charters Towers. Regional unconformities now recognised in the Silurian-Devonian succession of the Broken River area (frequently referred to as the Upper Burdekin area) mean that only a small part of this succession (the 'Broken River Formation', White, 1959a) can be correlated with the Burdekin Downs area (generally referred to as the Burdekin River area). Also since Middle Devonian fossils have not yet been found in the Kangaroo Hills Trough, nor on the Wairuna land mass, the Broken River and Burdekin River areas were probably connected by a narrow sinuous shelf, named here the <u>Burdekin River Shelf</u>. The northern limit of the Burdekin River Shelf could not have extended north of, and may well have connected with, the southern boundary of the Kangaroo Hills Trough. Its western limit is partly determined by the Georgetown Shield, and its eastern limit is not known, though it probably extended to the present coast near Townsville.

Upper Devonian/(Middle) Carboniferous (Fig. 6)

The Upper Devonian/Carboniferous sediments consist of 20,000 to 30,000 feet of mainly fossiliferous coarse-grained terrigenous material, and lesser amounts of organic limestone. The sediments are dominantly freshwater. Plants collected from these sediments are described by Mary White (1958, 1959, 1960). One fish collected by F.G. de V. Gipps in 1934 was described later by Hills (1936); Tournaisian shelly fossils are listed by Dickins and Hill (White, Stewart, et al. 1959; White, Best, et al. 1959). The sediments are folded, and intruded by granite and acid volcanics. The Upper Devonian/ Carboniferous sediments unconformably overlie the Upper Silurian/Lower Devonian, and disconformably overlie the Middle Devonian sediments. The first unconformity is angular; the second one is a regional overlap.

Two areas of Upper Devonian/Carboniferous sedimentation are known: one widespread area occupying most of the Hodgkinson Goldfield in the north between Chillagoe and Mossman; and the other in the south consisting of four small separate areas between Gilberton and the Star River, separated from the northerly one by pre-Upper Devonian sediments, which emerged in the early Carboniferous to form a broad land mass.

The Hodgkinson area contains the greatest thickness (20,000 to 30,000 feet, Jack & Etheridge, 1892, p.114) of Upper Devonian/Lower Carboniferous sediments. The shape and sedimentation content suggest that the depositional area was a trough about 100 miles long and 60 miles wide; the southern three-quarters of the trough is shown in Figure 6. The sediments consist of rhythmically alternating beds of quartz siltstone, shale, and medium to coarse-grained greywacke, all containing turbidity current structures. The sediments generally contain plant fragments; White (1960) has described Leptophloeum australe (M'Coy) from the sediments of the



UPPER DEVONIAN TO (?MIDDLE) CARBONIFEROUS
SCALE
30 15 0 30
MILES
REFERENCE
Areas of sedimentation
Granite
Faults
Major trends
Fig. 6
HODGKINSON TROUGH
20-30,000'
TASMAN LINE
Mossman
CAIRNS
Mareeba
Chillagoe
Atherton
Almaden
Petford
Silver Valley
Innisfail
? LAND
Ravenshoe
Mt. Garnet
GEORGETOWN
SHIELD
Tully
FAULT ZONE
RIVER
Mt. Surprise
Minnamoolka H.S.
Kirrama H.S.
Croydon
Forest Home H.S.
Georgetown
Wairuna H.S.
Hinchinbrook Island
Einasleigh
Forsayth
Ingham
Valley of Lagoons H.S.
Mt. Fox
Camel Creek H.S.
LAND
Blue Range H.S.
Ewan
GILBERTON
500'
Gilberton H.S.
BASIN
Lyndhurst H.S.
BURDEKIN
20,000'
BUNDOCK BASIN
LAND
CLARKE RIVER BASIN
7,000'
TOWNSVILLE
STAR BASIN
Blackbraes H.S.
CLARKE RIVER FAULT
Maryvale H.S.
Gregory Springs H.S.
Wando Vale H.S.
TASMAN LINE
Reid River
Burdekin Downs H.S.
Bureau of Mineral Resources, Geology and Geophysics.
Q 45-11e
G.M.
17°00'
18°00'
19°00'
20°00'
142°30'
143°15'
144°00'
144°45'
145°30'
146°15'
147°00'
Charters Towers

Hodgkinson Trough at Stannary Hills. Reef and greywacke conglomerates are exposed in the sequence. Cribb (1960) has listed Upper Devonian corals from a limestone lens near Beaconsfield in the trough.

The sediments are almost identical with those in the eastern part of the Upper Silurian/Lower Devonian Kangaroo Hills Trough and a similar environment is envisaged for both troughs, though they are of different ages. More will be shortly known of the history of the Hodgkinson Trough, as the regional mapping by F. de Keyser and party of the main part of this trough is still progressing. Its western boundary is partly obscured by later acid volcanics of the Featherbed Range, and in other parts it is separated from the Precambrian Georgetown Shield by a narrow belt (5 to 10 miles) of sediments of the Chillagoe Shelf. Its southern boundary almost coincides with the edge of a later Upper Palaeozoic granite intrusion and cannot be far removed from an arcuate line joining Petford and Silver Valley (Fig. 6). This line probably coincides with a marked change of sedimentation from greywacke to quartz siltstone and sandstone, indicating an overlap of Upper Devonian/Carboniferous sedimentation from the Hodgkinson Trough in the north on to the Mount Garnet Shelf in the south. The eastern boundary of this trough against the Barron River Metamorphics is not known, since it is obscured by basalt and granite; and it is arbitrarily shown between Silver Valley and Mareeba.

A small inlier of Middle Carboniferous sediments is exposed at Silver Valley near the southern edge of the Hodgkinson Trough, from which Stirling (1904) described *Rhacopteris* and *Aneimites*. Twenty feet of rhyolite breccia is exposed at the base of the section. Morton in Reid (1930) estimated the Silver Valley beds to be less than 300 feet thick. The boundaries of the Silver Valley beds with the underlying sediments of the Hodgkinson Trough are faulted.

The southern area consists of four basins, referred to here as the <u>Gilberton Basin</u>, the <u>Bundock Basin</u>, the <u>Clarke River Basin</u>, and the <u>Star Basin</u>.

The Gilberton Basin, which lies within the Georgetown Shield, consists of two small areas of freshwater sediments separated by the Gilbert River, and covering about 45 square miles. Their boundary with the Shield is generally faulted. The sediments are cross-bedded quartz pebble conglomerate and ferruginous shale, containing <u>Leptophloeum australe</u>, and one Antiarchan fish (Hills, 1936) . The total thickness of sediments is 500 feet.

The other three basins, Bundock, Clarke River, and Star, form a broad east-west belt, 180 miles long and 45 miles wide, which transgresses the earlier Kangaroo Hills Trough and the Burdekin River Shelf. The stratigraphy of these basins suggests that they were probably connected by a Tournaisian (Lower Carboniferous) seaway, which approximately followed the outline of the Burdekin Shelf.

The Bundock Basin contains 20,000 feet of greywacke, arkose, conglomerate, shale, and minor amounts of limestone and calcareous sediments. The thin calcareous sediments are confined to the base of the sequence and contain Tournaisian brachiopods and gastropods determined by J.M. Dickins (<u>in</u> White, Best, et al., 1959). Frasnian corals collected near Gregory Springs and determined by Prof Hill (<u>in</u> White, Best, et al., 1959) may represent the base of the Bundock Basin. The sediments are folded into elongated domes and basins, and are intruded by widespread rhyolite porphyry.

The Clarke River Basin lies about 5 miles east of the Bundock Basin, and is separated from it by Silurian and Devonian sediments, uplifted in the early Carboniferous to form a land ridge between the two basins. The basin is 2,000 square miles in area, and contains a maximum of 7,000 feet of quartz conglomerate, quartz greywacke, quartz sandstone, and thin basal beds of limestone and calcareous sediments. The calcareous basal beds contain Tournaisian shelly fossils, and the upper and middle sections contain the Carboniferous plants Calamites, Rhacopteris, Sigillaria, Stigmaria, and Lepidodendron. The boundaries of the Clarke River Basin are generally faulted. The sediments are folded into tight domes and basins, and are intruded by minor amounts of granite, rhyolite porphyry, and diorite.

The Star Basin is situated some ten miles to the south-east of the Clarke River Basin. The relationship between the two basins is not known, since only a small portion of the Star Basin and the intervening area has been mapped. The two basins may have been connected in the Upper Devonian or early Carboniferous before finally being separated into two freshwater basins. Jack & Etheridge (1892, p.129-133) described the Star Basin sediments, and record a section some 1,500 feet thick. Reid (1930, p.16-20) discusses the possible correlation of the Star Basin sediments with Queensland Upper Devonian-Carboniferous localities at Mount Wyatt and Drummond Range.

IGNEOUS ACTIVITY

Four periods of igneous activity are represented (Tables 1-3): basic and ultrabasic rocks intruded by acid rocks in the Precambrian; basic and ultrabasic rocks in the Middle Palaeozoic; acid rocks in the Upper Palaeozoic; and finally, basic rocks in the Cainozoic.

Precambrian

The Precambrian ultrabasic and basic rocks are dolerite, gabbro, and serpentine. Dolerite and gabbro are exposed in sills, dykes, and stocks, which are generally located around the margins of the later Forsayth Batholith. Serpentine and lesser amounts of gabbro are restricted in outcrop to a narrow north-north-east belt about 90 miles long near the eastern edge

TABLE 3

CAINOZOIC AND MESOZOIC STRATIGRAPHY OF THE CAIRNS-TOWNSVILLE HINTERLAND, NORTH QUEENSLAND

AGE	LITHOLOGY	DIMENSIONS	PALAEONTOLOGY	IGNEOUS ACTIVITY	ENVIRONMENT	TECTONIC ELEMENT	ECONOMICS
Cainozoic	Siltstone shale sandstone	50 ft.-500 ft. (basalt) (volume of basalt 400 cubic miles)	Diatoms (*Melosira*)	*Basic* Olivine basalt flows. Some pyroclasts	Continental flood basalts	Tableland (Atherton, McBride, Chudleigh, Nulla).	Diatomite; pozzolan; water.
REGIONAL UNCONFORMITY							
Mesozoic	Shale sandstone conglomerate	100 ft. thick.	Plants (Linguifolium sp.; *Cladophlebis australis*; *Cladophlebis albertsi*; *Phyllopteris lanceolata*; *Cycadites* sp.?). Marine (Pelecypods-*Maccoyella*; Gastropods-*Natica*; Brachiopods-*Rhynchonella*).		Freshwater and marine. Environment changes over Croydon-Gregory Range 'ridge'.	Carpentaria Basin; Great Artesian Basin.	Water

ANGULAR UNCONFORMITY

UPON PERMIAN (-TRIASSIC?) SEQUENCE

of the Georgetown Shield. The serpentine is metamorphosed to antigorite, chlorite, talc, and tremolite-actinolite rocks (Green, 1958), the gabbro is metamorphosed to the albite-epidote amphibolite facies.

The Precambrian acid igneous rocks consist of the granites of the Forsayth Batholith, intruded in the centre of the Georgetown Shield. The main granite is grey, massive to porphyritic, coarse-grained, with biotite, and shows platy flow structures, particularly around its edges. Another granite of the Forsayth Batholith is a pink to grey medium-grained biotite-hornblende granite.

Middle Palaeozoic

The Middle Palaeozoic ultrabasic and basic intrusive rocks are restricted to 50 square miles in the Gray Creek area, where they intrude Lower Silurian basalt. Green (1958) has described the rocks as dunite, peridotite, diallagite, gabbro, and microdiorite, formed by differentiation of an olivine rich basic magma, he believes them to be co-magmatic with the basalt that they invade.

The Upper Devonian/(?Middle) Carboniferous basins contain the last major recorded sedimentation in the Cairns-Townsville Hinterland - except of course for the widespread Mesozoic sedimentation in the Great Artesian and Carpentaria Basins that overlaps the western part of the area (Fig. 1); the widespread activity in the Upper Palaeozoic was almost entirely igneous.

Upper Palaeozoic

Bryan (1925) stated that the widespread Upper Palaeozoic granites of North Queensland, which were previously regarded as early Carboniferous by Jensen (1920, p.28), late Carboniferous by Jensen (1923, p.29), and Permian by Ball (1923), were associated with the great epeirogenic uplift which closed the Palaeozoic era, rather than intruded during the great post-Devonian orogeny. Bryan & Whitehouse (1929) point out the lack of Devonian rhyolites and other lavas in Queensland as compared with their widespread occurrence in New South Wales and Victoria. The following brief account of the Upper Palaeozoic igneous activity emphasises these points.

Upper Palaeozoic igneous activity shown in Figures 6 and 7 mainly took place in the Permian, and may have extended into the Lower Triassic. The activity consisted of the intrusion of at least two granites, and two periods of acid volcanic extrusion, which were probably comagmatic with the two granite intrusions. The extrusion of acid volcanics generally preceded the granite intrusions, but in some places the boundary between the two rocks is not well defined and appears gradational. The age of the acid volcanics within the Upper Palaeozoic is not known, but the rhyolite at Agate Creek conformably overlies Permian plant-bearing sediments. In other localities the relative ages are known, and the general sequence of events in the Upper Palaeozoic (-Lower Mesozoic?) igneous history is established.

The older granite intrusion is the Herbert River Batholith (Fig. 7). Its age is shown as Permian, but it may include some Carboniferous and possibly Lower Triassic granites. The shape of the batholith is a long rectangle, which trends north-west from Townsville to Chillagoe, and tapers at its northern end. It covers an area of 5,000 square miles. Very little is known of the southern part between Ewan and Townsville, and it may contain some acid volcanics. The contacts of the batholith are generally sharp, straight and curved linear. It intrudes the earlier Palaeozoic Wairuna tectonic land and the Kangaroo Hills Trough, and the northern part of its eastern edge parallels and partly coincides with the eastern edge of the Georgetown Shield near Mount Garnet. It intrudes thin acid volcanics in the Mount Garnet-Ravenshoe-Kirrama area. The Herbert River Batholith consists mainly of

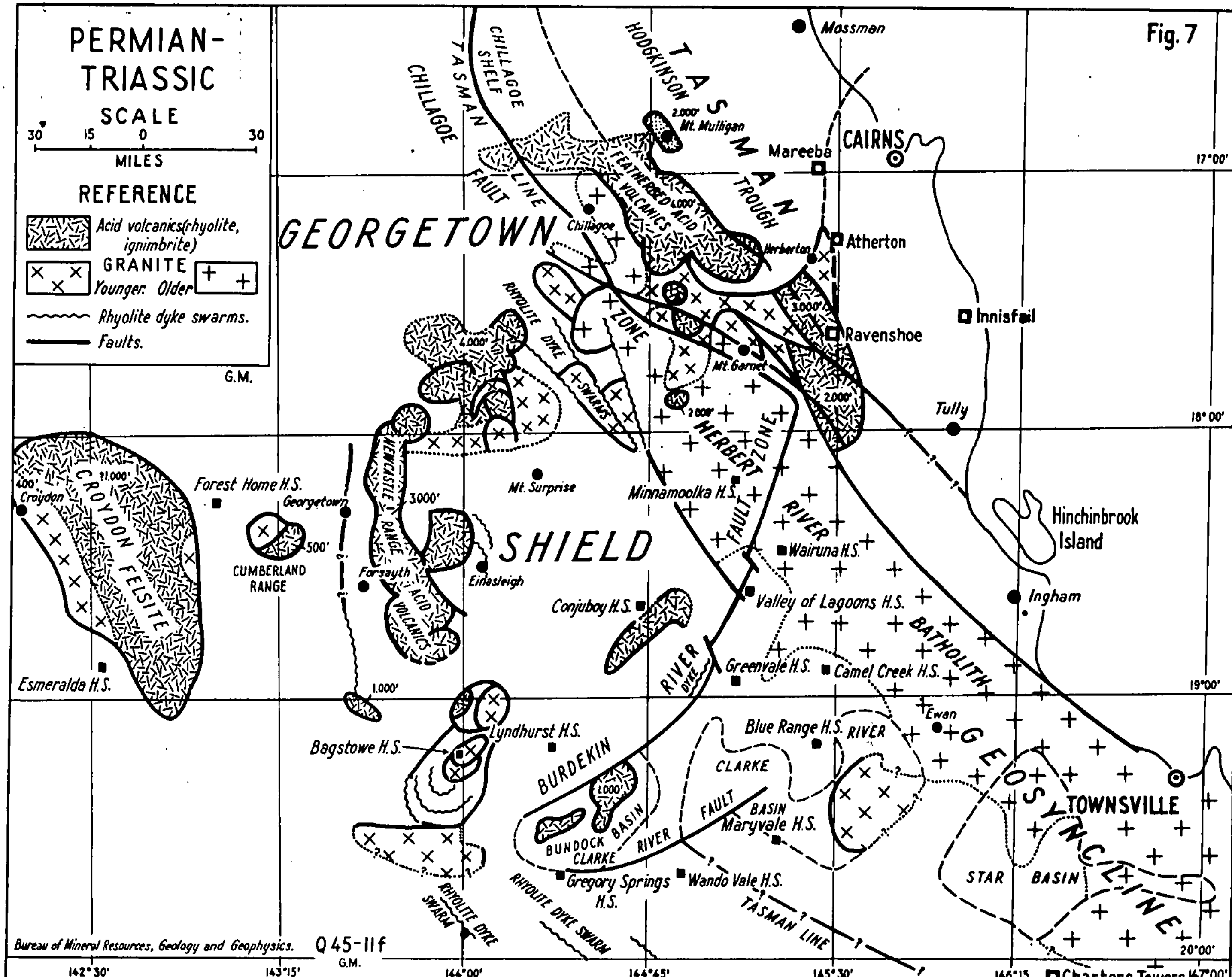


Fig. 7
PERMIAN-TRIASSIC
SCALE
30 15 0 30
MILES
REFERENCE
Acid volcanics (rhyolite, ignimbrite)
GRANITE
Younger Older
Rhyolite dyke swarms.
Faults.
G.M.
GEORGETOWN
SHIELD
TASMAN TROUGH
HODGKINSON
CHILLAGOE SHELF
TASMAN FAULT LINE
CHILLAGOE
FEATHERBED ACID VOLCANICS
Mt. Mulligan
Mossman
CAIRNS
Mareeba
Atherton
Herberton
Chillagoe
Innisfail
Ravenshoe
Mt. Garnet
Tully
RHYOLITE DYKE SWARMS
ZONE
HERBERT ZONE
HERBERT RIVER FAULT ZONE
Minnamoolka H.S.
Mt. Surprise
Forest Home H.S.
Georgetown
Croydon
CROYDON FELSITE
NEWCASTLE RANGE
CUMBERLAND RANGE
Forsayth
Einasleigh
ACID VOLCANICS
Wairuna H.S.
Hinchinbrook Island
Conjuboy H.S.
Valley of Lagoons H.S.
Ingham
BATHOLITH
RIVER DYKE
Greenvale H.S.
Camel Creek H.S.
Esmeralda H.S.
Lyndhurst H.S.
Bagstowe H.S.
Ewan
GEOSYNCLINE
Blue Range H.S.
RIVER
CLARKE
BASIN
FAULT
BURDEKIN
BUNDOCK BASIN
CLARKE RIVER
Maryvale H.S.
TOWNSVILLE
STAR BASIN
RHYOLITE DYKE SWARM
Gregory Springs H.S.
Wando Vale H.S.
TASMAN LINE
Charters Towers
Bureau of Mineral Resources, Geology and Geophysics.
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a grey, massive, medium-grained, biotite granite; it contains large pink feldspar phenocrysts in the Herbert River gorge. The batholith contains granodiorite at the Ruddygore Copper Mine near Chillagoe, which Branch (1960) described as probably formed by the assimilation of limestone by the granite. Syenite in the Herbert River Gorge area was probably also formed by assimilation of limestone. Base metals introduced by the Herbert River Batholith are copper, lead, and silver in the Chillagoe, Mount Garnet, and Ewan Shelf areas; and lesser amounts of wolfram and tin at Perry Creek near Camel Creek Homestead.

The younger, and probably more complex, Upper Palaeozoic igneous activity of granite stocks and acid volcanics is shown in Figure 7, of the Permo-Triassic period. The first event associated with this younger igneous activity occurred immediately after the intrusion of the Herbert River Batholith, and consisted of widespread acid vulcanism. The volcanics are rhyolite and rhyolite porphyry, many of which are now recognised as ignimbrites. The total volume of acid volcanics is about 3,000 cubic miles. Most of the volcanics (and associated intrusives) are confined to areas of large-scale fracturing and cauldron subsidence areas, with the result that they occupy rift valleys, ring dykes, cone sheets, and dyke swarms. The largest of these structures form the Featherbed, Gregory, and Newcastle Ranges; the most complex structure is in the Bagstowe area, described by Branch (1959). The acid volcanics are confined to the Chillagoe and Mount Garnet Shelves - mainly along their junctions with the Hodgkinson Trough - and in the Bundock Basin near its junction with the Georgetown Shield; they are also widely distributed on the Shield in the central region of the Forsayth Batholith.

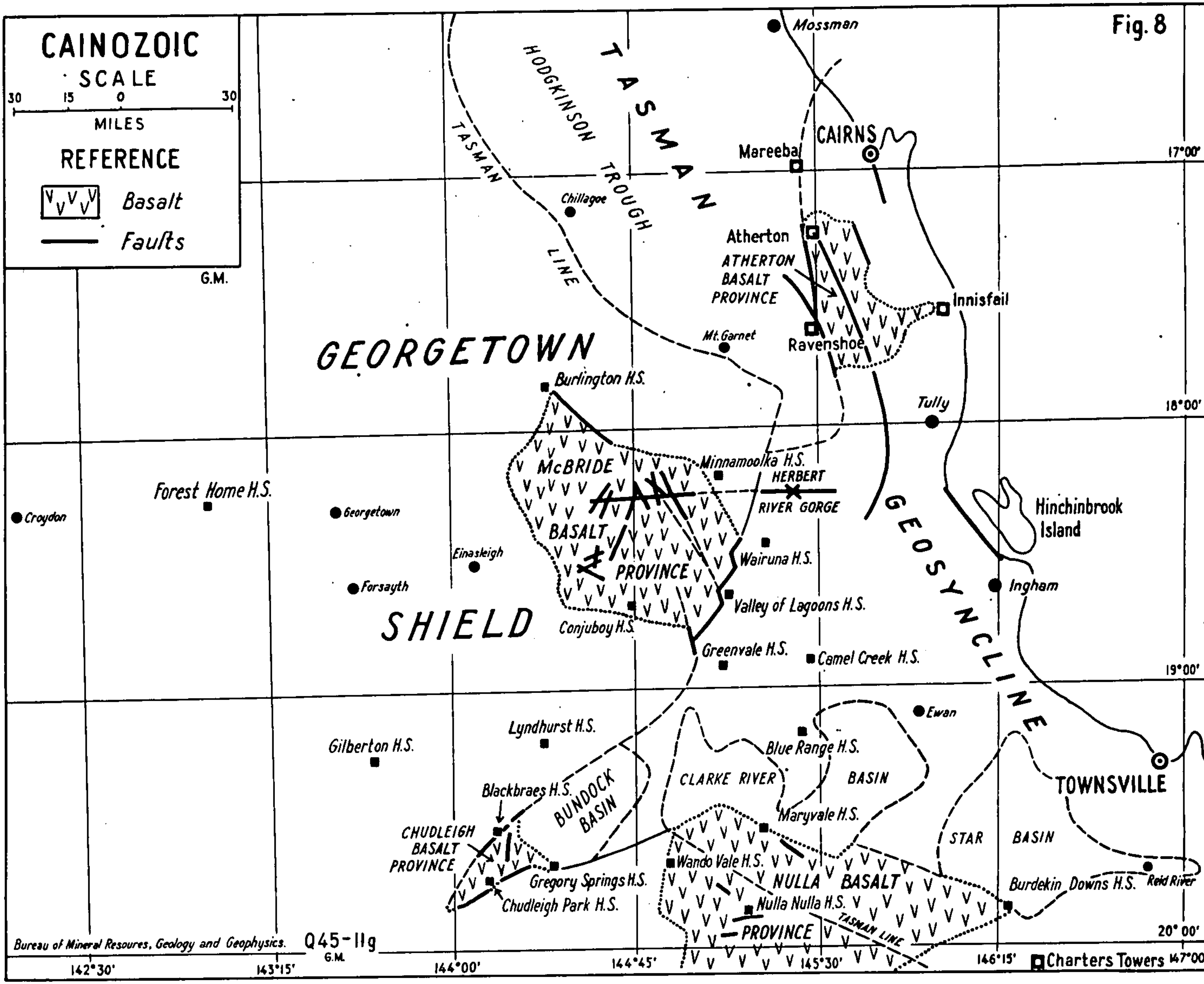
After the younger period of widespread acid vulcanism 3,000 square miles of granite were intruded. The granite (the 'Elizabeth Creek Granite' of White 1959b) is generally massive, medium-grained to coarse-grained, and pink, and contains small amounts of mafic minerals. It is intruded into the Herbert River Batholith and older acid volcanics as stocks, which are oval or are bounded by straight and curved lines. The stocks are confined to the areas of acid volcanics with which they are genetically related, and they are intruded between the intervening areas of the Herbert River Batholith, Forsayth Batholith, and acid volcanics. The Permo-Triassic pink granite has introduced tin (Mount Garnet and Herberton); wolfram, molybdenum, and bismuth (Wolfram Camp and Bamford Hill); and fluorite (between Chillagoe and Mount Surprise) on north-west fractures in the Georgetown Shield.

Grey granite and acid volcanics are genetically associated in the Croydon area (Fig. 7). Many reports on the geology and gold genesis of this area have been written by geologists of the Aerial, Geological and Geophysical Survey of North Australia, the Queensland Geological Survey, and others; and C.D. Branch, a Bureau of Mineral Resources member of the combined regional mapping party, is at present examining the Croydon area. The igneous rocks occupy 2,500 square miles between Croydon and Esmeralda in the western part of the Georgetown Shield. The relative ages of the granite and acid volcanics (Croydon Felsite) have been the subject of much controversy. The Croydon Felsite has been variously reported as intruded and underlain by, and grading into, granite, and these phenomena can be explained by the emplacement of an acid magma into the crust at a high level, and probably a final break-through on to the surface to extrude as acid volcanics. The Croydon felsite and granite are similar to other areas of Upper Palaeozoic igneous activity on the Georgetown Shield and Tasman Geosyncline of North Queensland, but their age within this period is not known. Gold lodes occur in both granite and felsite at Croydon; the richest part of the field is almost completely covered by Mesozoic sediments. The depth limits of payable ore average 480 feet in the granite and 300 feet in the felsite. Graphite occurs in the lodes, in the felsite, and to a lesser amount in the granite. The felsite - granite contact zone contains gold of high silver content and much native silver. The average bullion values produced range from 737 fine gold in the felsite to 536 fine in the granite. The purity of the Croydon bullion (it contains less than 2% base metals after amalgamation) may be partly due to the presence of carbon, which has been obtained by assimilation of carbonaceous sediments, and which is known to precipitate noble metals more readily than base metals. Fisher (1945) adequately explained the impoverishment of gold at depth in the Croydon Goldfield as due to secondary enrichment.

Cainozoic

After the widespread Upper Palaeozoic acid igneous activity large quantities (400 square miles) of basalt were extruded in four main areas during the Cainozoic: the Atherton and McBride areas in the north, and the Chudleigh and Nulla areas in the south (Fig. 8). They have been described by Twidale (1956) and Best (1959, 1960). The volcanics are almost entirely olivine basalts; basaltic pyroclastics form a small part of the total volume. Many volcanic craters are still preserved.

The Atherton Basalt Province is situated on the contact of the Mount Garnet Shelf and the Barron River Metamorphic Belt; its northern edge is near the contact of the Hodgkinson Trough and the metamorphic belt. Best (1960) described the Atherton Province as a confined lava field of 500 square miles, containing four explosion craters; these craters have emitted pyroclastics which mantle the earlier basalt flows. Best explains the present-day topography and the disposition of the volcanoes by differential vertical movement on faults trending north-west and north-east. Some of these movements are of Recent age and have largely determined the present


CAINOZOIC
SCALE
30 15 0 30
MILES
REFERENCE
Basalt
Faults
G.M.
Mossman
HODGKINSON TROUGH
TASMAN
TASMAN LINE
CAIRNS
Mareeba
17°00'
Chillagoe
Atherton
ATHERTON BASALT PROVINCE
Innisfail
Mt. Garnet
Ravenshoe
GEORGETOWN
Burlington H.S.
Tully
18°00'
McBRIDE BASALT PROVINCE
Minnamoolka H.S.
HERBERT RIVER GORGE
Forest Home H.S.
Croydon
Georgetown
GEOSYNCLINE
Hinchinbrook Island
Einasleigh
Wairuna H.S.
Forsayth
Ingham
Valley of Lagoons H.S.
SHIELD
Conjuboy H.S.
Greenvale H.S.
Camel Creek H.S.
19°00'
Ewan
Lyndhurst H.S.
Blue Range H.S.
Gilberton H.S.
TOWNSVILLE
Blackbraes H.S.
BUNDOCK BASIN
CLARKE RIVER BASIN
Maryvale H.S.
CHUDLEIGH BASALT PROVINCE
STAR BASIN
Wando Vale H.S.
Gregory Springs H.S.
NULLA BASALT PROVINCE
Burdekin Downs H.S.
Reid River
Chudleigh Park H.S.
Nulla Nulla H.S.
TASMAN LINE
20°00'
Bureau of Mineral Resources, Geology and Geophysics.
Q45-11g
G.M.
142°30'
143°15'
144°00'
144°45'
145°30'
146°15'
147°00'
Charters Towers
Fig. 8

topography of the coast near Cairns.

The association of faulting and vulcanism has been previously recognised in Queensland by Ball and Richards. Ball (1923) suggested that the Tertiary basalts of the Cooktown district were probably genetically associated with fissures due to the Cook Uplift, during which the Triassic-Jurassic sediments were elevated more than 1,000 feet. Richards (1924) recognised that great lava floods have welled up through fissures, where rifts trending generally north and south have been accompanied by deep crustal faulting and sinking.

The McBride Basalt Province is situated on the Georgetown Shield near its eastern fault contact with the Tasman Geosyncline, and is the largest of the four provinces. Best (1960) described the area as an extensive lava field of 2,000 square miles. The basalt province contains 109 craters, and according to Best conforms to Tyrrell's definition of 'multiple-vent basalts', except that Best considers that most of the basalt was erupted through few large vents, instead of many vents as suggested by Tyrrell, and that many small vents were parasitic scoria cones. These cones contributed little more than the material which built them. The craters are grouped in a wide area in the central region of the province. They form a triangular dispersion pattern controlled by the intersection of many north-east and north-west, and some east-west, fractures. The north-west fractures are near the contact of the Precambrian Forsayth Batholith and the Upper Palaeozoic Herbert River Batholith; the north-east fractures parallel the eastern fault edge (Burdekin River Fault Zone) of the Georgetown Shield (Fig. 1). A recent basalt flow - the Kinrara Basalt (Best 1960), on the eastern side of the McBride Basalt Province - is erupted from a pit crater and is about 30 miles long. It has dammed the Burdekin River at the Valley of Lagoons and formed large lakes.

The Chudleigh Basalt Province is the smallest of the four basalt provinces (150 square miles). It is situated on the eastern edge of the Georgetown Shield and on the south-western extension of the Bundock Basin. Its northern and southern edges are controlled by the divergence of the Burdekin River and Clarke River Fault-zones to the south-west (Fig. 8). However, lavas flow over these zones 40 miles north along the Copperfield and Einasleigh Rivers, and 80 miles south-west down the tributaries of the Saxby and Flinders Rivers. Fifteen craters similar to those of the McBride Province have been located on the Chudleigh Province.

The Nulla Basalt Province is situated in the south-eastern part of the Georgetown Shield near its junction with the Clarke River Basin. The basalt overlaps on to the Burdekin River Shelf and the Bundock Basin, and to the south-east on to the Star Basin. It covers an area of 3,000 square miles, between Maryvale, Wando Vale, and Burdekin Downs. Fifteen craters have been located on the Nulla Province. The craters are in groups of two to four, and evenly distributed throughout the province. Alignments of craters along north-west and east-west trends are noted.

The province contains a Recent flow - the Toomba Basalt (Twidale, 1956) - similar in age to the Kinrara Basalt of the McBride Province. The Toomba Basalt flows east-north-east along the southern margin of the Nulla Basalt and terminates near Burdekin Downs Homestead on the Burdekin River.

CONCLUSIONS

Development of the Tasman Geosyncline

The development of the Tasman Geosyncline is illustrated in Figure 9. It is best understood by first studying the history of the Georgetown Shield. In fact, the theory evolved suggests that the history of the Tasman Geosyncline is strongly influenced by an underlying Precambrian mass, similar to the adjoining shield.

FIGURE 9. GEOLOGICAL HISTORY CAIRNS-TOWNSVILLE HINTERLAND NTH. QUEENSLAND

8 MESOZOIC-CAINOZOIC

Freshwater and marine sedimentation in Artesian Basin. Widespread Cainozoic basalt volcanism controlled by ? Precambrian fractures. Recent vertical movement in Cairns -Innisfail coastal region.

7. PERMIAN (-TRIASSIC ?)

Widespread epizone acid igneous activity. Cauldron and rift subsidence filled with acid volcanics and intruded by granite. Ring dykes and cone sheets. Minor freshwater sedimentation.

6 UPPER DEVONIAN-MIDDLE CARBONIFEROUS

? Restricted marine sedimentation in Upper Devonian to Lower Carboniferous. Freshwater sedimentation in basins. End of major sedimentation in Tasman Geosyncline.

5 MIDDLE DEVONIAN

Continual uplift of Precambrian Georgetown Shield (? land) and Pre-Middle Devonian rocks. Restriction of marine sedimentation to Burdekin River Shelf and Chillagoe Shelf.

4 UPPER SILURIAN TO LOWER DEVONIAN

Uplift of Wairuna-Barron River sediments (? cordillera). Intrusion of ultrabasic along western faulted (? thrust) edge of tectonic land. Greywacke sedimentation in inner (? fore-deep) and outer trough (deep). Coral limestone growth resrtricted to trough shallows and Precambrian continental shelf (Chillagoe).

3 UPPER ORDOVICIAN-SILURIAN

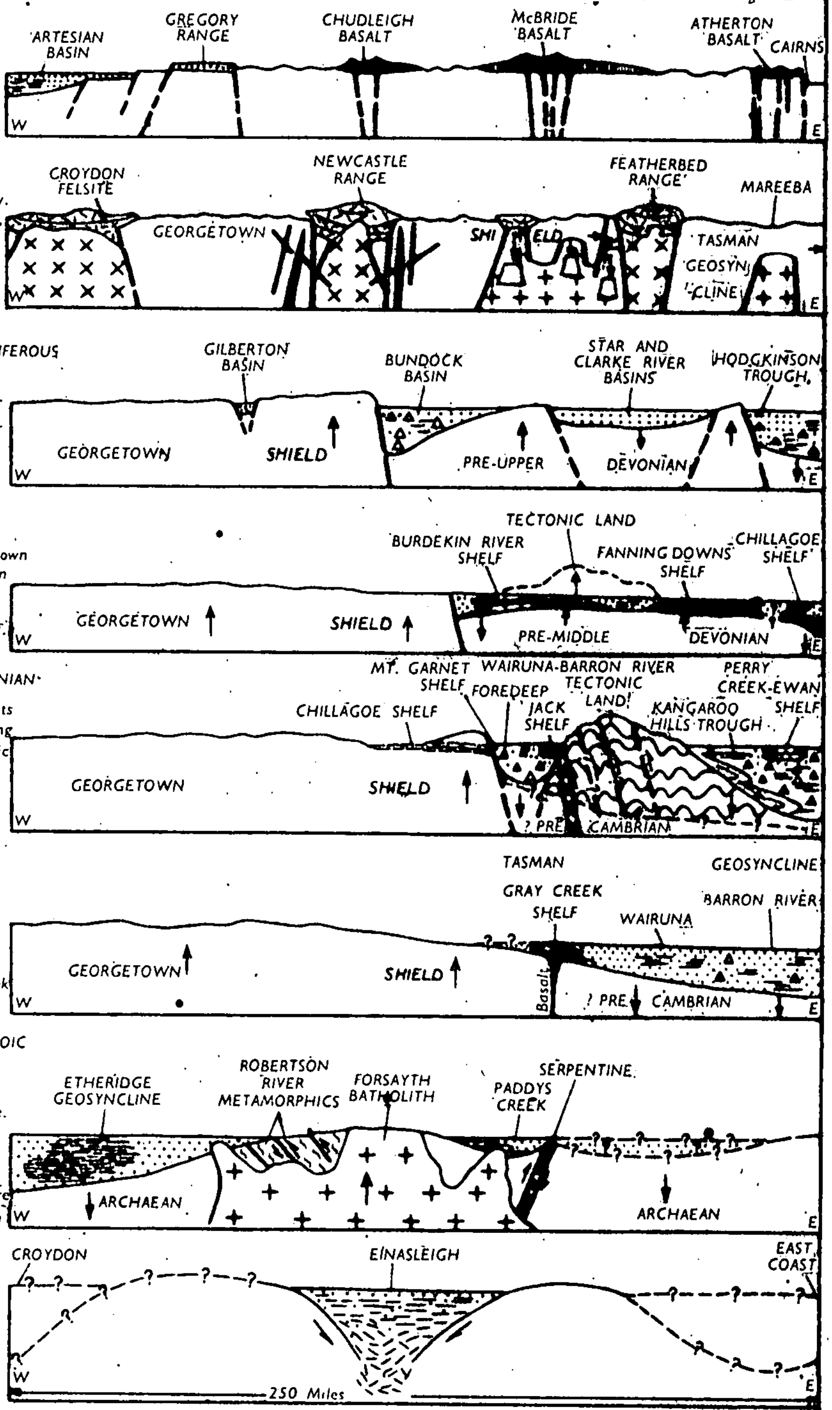
Continuing uplift of Precambrian Shield and major downwarp in Tasman Geosyncline. Organic reef growth and basalt extrusion restricted to Gray Creek Shelf.

2 PROTEROZOIC TO ? EARLY PALAEOZOIC

Uplift of Precambrian geanticline. Major downwarp on western flank and minor downwarp on eastern edge of geanticline. Thick pelagic deposits in west. Thin ? epicontinental facies in east. Intrusion of serpentine along eastern edge of geanticline and granite batholith in centre of geanticline. ? Sedimentation in Tasman Geosyncline.

1 ARCHAEAN

Formation of central depression. Sedimentation Regional metamorphism at base of depression.



Q7-4

Bureau of Mineral Resources, Geology and Geophysics

△ Greywacke
(Quartz) Detritus
Shale
Limestone

Scale
Vert. - 15 miles to an inch.
Hor. - 60 miles to an inch.

The main features to be explained in the formation of the Georgetown Shield are:

(i) the circular and arcuate fold patterns of the Proterozoic sediments, which surround and overlap an inner core of Archaean metamorphics;

(ii) the zigzag outline of the eastern edge formed by the Chillagoe, Burdekin, and Clarke River Fault Zones;

(iii) the possibility of thrusts: one of steep angle partly occupied by serpentine on the eastern margin; and another (perhaps of low angle) between the contact of staurolite-garnet and mica-andalusite metamorphics on the western edge of the Forsayth Batholith;

(iv) the intrusion of the Forsayth Batholith into the central region of the Shield;

(v) the increase of metamorphism of the Proterozoic sediments of the Etheridge Geosyncline from the west to the central part of the Shield.

Most of the features (iii, iv, & v) may be explained by the initial formation of a major downwarp ('tectogene' of Scheidegger, 1958, p.12) in the central portion of the Shield between Forsayth and Einasleigh. Sediments were deposited in the downwarp, perhaps while it was still active. The basal sediments of the downwarp were regionally metamorphosed to the granulite facies; and lower grade metamorphism (staurolite-kyanite subfacies) was restricted to higher levels in it. After this stage, the downwarp began to rise to form a geanticline, and probably contemporaneous with this upward movement, a depression formed the Etheridge Geosyncline on the western margin of the geanticline, and the Paddy's Creek depositional area on its eastern margin. Sedimentation and sinking are assumed to have been contemporaneous in the Etheridge Geosyncline.

The general emergence of the central geanticline was accompanied by thrusting. The eastern thrust must have formed first and reached deep crustal levels, since serpentine lenses occupy the thrust zone between Paddys Creek and Minnamoolka Homestead, and the serpentine was later intruded by the Forsayth Batholith, with which the western thrust was probably associated. Low-grade regional metamorphism accompanied the intrusion of the Forsayth Batholith into the central portion of the geanticline. This widespread granite intrusion consolidated and finalized the Precambrian movements of the Georgetown Shield.

Features (i) and (ii) of the Shield may be partly explained by the pan-tectogenesis process (Hills, 1946, p. 83). This process involves folding about centres of tectonic foci produced mainly by convection currents in the substratum. Hills explained the circular and arcuate old Precambrian trends of the Yilgarn, Pilbara, Nullarbor, Kimberley, Sturtian, and Carpentaria Nuclei on the Australian Shield by this process. The old Precambrian structures on the Georgetown Shield could be added to this list, and may be an easterly continuation of the Carpentaria Nucleus.

The folding that produced feature (i) and the faulting that produced feature (ii) were probably cognate, although the faulting is later than the folding.

Although the Precambrian Shield was consolidated by the intrusion of the Forsayth Batholith, and it was relatively stable compared to the adjoining Tasman Geosyncline, the Shield generally tended to arch upwards during the Palaeozoic history of the Tasman Geosyncline. This arching of the Shield was punctuated by vertical fracturing, particularly in the Upper Devonian, Upper Palaeozoic, Mesozoic, and Cainozoic.

Sedimentation in the Tasman Geosyncline began in the ?Upper Ordovician/Lower Silurian with the growth of coral reefs on the Gray Creek Shelf (Fig. 9, section 3); the reefs are interbedded with the extrusive basalts parallel to the adjoining Burdekin River Fault Zone. This early basalt activity may indicate that the initial depression of the Tasman Geosyncline was formed by faulting along the Burdekin River Fault Zone.

Any theory of the development of the Tasman Geosyncline must explain the following features:

(i) the migration and contraction of the original depositional area **to** both north and south.

(ii) the association of some of this movement with two main periods of contrasting igneous activity: one of ultrabasic and basic igneous rocks in the Middle Palaeozoic; and the other of acid igneous rocks in the Upper Palaeozoic;

(iii) the fault boundaries of most of the depositional and provenance areas;

(iv) the parallelism of later sedimentary trends and folds of depositional areas to the edges of earlier provenance areas;

(v) The recurrence of greywackes in the early Silurian, in the Upper Silurian to Lower Devonian, and the Upper Devonian sediments.

The history of the Tasman Geosyncline is controlled by the uplift of a central part of the original depositional area in the Upper Silurian, and its continual rise to form land in the Devonian and Carboniferous. This vertical movement split the original depositional area into two areas, which as a result of the continued uplift contracted and migrated to finally form land. The faulted and linear boundaries of many of the source and depositional areas, particularly those bounded by the Burdekin and Clarke River Fault Zones, strongly suggest that they were moved vertically by faults. The Burdekin and Clarke River Fault Zones form a major south-westerly rift in the Broken River area. The Burdekin River Fault penetrated deep crustal levels, for it is occupied in places by ultrabasic and basic, igneous rocks. The intrusion of serpentine along the Burdekin River Fault Zone towards the end of the Precambrian, and again in the Middle Palaeozoic, indicates that this fault zone was a major zone of deformation along which the steep upthrusts took place. A steep compressional upthrust of the Georgetown Shield against the Wairuna Tectonic Land has been described by White et al. (1958) in the Burdekin River Fault Zone near the Hall's Reward Copper Mine of the Paddys Creek area. The Burdekin River Fault must have moved vertically hingewise during the Upper Silurian, Middle Devonian, and Upper Devonian sedimentation, as is shown by the rapid change of thickness of sediments from 4,000 feet to 20,000 feet along the strike of the fault. Folding accompanied some of the vertical movements of the parts of the Upper Silurian, Middle Devonian, and Upper Devonian sediments that formed shelving land masses and on which later sediments were deposited and formed disconformities.

The recurrence of greywacke - particularly greywacke conglomerate - three times in the history of the Tasman Geosyncline may indicate a method of determining the more violent movements of the segments. Greywackes are exposed in the Silurian Wairuna area; the Upper Silurian/Lower Devonian Kangaroo Hill Trough, and Chillagoe and Mount Garnet Shelves; and the Upper Devonian/ Lower Carboniferous Hodgkinson Trough and Bundock Basin. Each greywacke occurrence is probably the result of irregular upward movements in the source area.

The movement of segments of the Tasman Geosyncline and the Georgetown Shield by faults is further evidenced by the widespread Upper Palaeozoic igneous activity. The 11,000 square miles of acid magma now exposed have been emplaced in the Shield and the Tasman Geosyncline by stoping of large crustal blocks on arcuate and linear fractures. Some of these fractures are clearly related to the Shield fractures, as may be deduced from:

(i) the repetition of serpentine intrusions along the Burdekin River Fault Zone in the late Precambrian and Middle Palaeozoic;

(ii) the parallelism of the Herbert River and Forsayth Batholiths;

(iii) the emplacement of the Newcastle Range volcanics in a rift in the centre of the Forsayth Batholith;

(iv) the alignment of Cainozoic volcanic craters along north-west and north-east trends, which parallel the main fracture pattern of the shield;

(v) the localization of most of the Cainozoic Basalt Provinces near the fractured edges of the Georgetown Shield.

Palaegeographic Implications

Recently Crook (1959) and Heezen (1959) stressed the importance of turbidity and ocean current scour in forming submarine unconformities; also that these unconformities may be often devoid of conventional tectonic or palaeogeographical implication, and that they certainly do not imply subaerial erosion. Hence the origin of relief of the sea floor of the Tasman Geosyncline is in doubt, particularly for the early and Middle Palaeozoic marine conditions, where 'turbidites' (Kuenen, 1952) were abundant.

However, parts of the Tasman Geosyncline certainly emerged to form land barriers in the Upper Devonian and early Carboniferous period, since from this time freshwater conditions have prevailed to the present day; and it is difficult to believe that this emergence suddenly began in the Upper Devonian. The geological history strongly suggests that the uplift of certain parts of the Tasman Geosyncline began earlier in the Palaeozoic and that the pattern of the final disintegration of the geosyncline was established by the deformation of the Precambrian Shield in the early Palaeozoic.

In some places the boundaries of the Tasman tectonic elements (Fig. 1) cannot be far removed from shorelines. The trace of the Tasman Line (Fig. 3, 4 & 5) around the eastern edge of the Georgetown Shield must approximate to the shoreline for the period shown, particularly opposite the portions of the Shield marked 'high'. In the Tasman Geosyncline Wairuna-Barron River sediments were folded to form a major geanticline and finally emerged as land; this deformation initiated widespread greywacke sedimentation in the Upper Silurian/Lower Devonian in the Kangaroo Hills Trough, and to a lesser extent in the Mount Garnet Shelf. That the Wairuna-Barron River sediments emerged in early Palaeozoic (Silurian) time is also supported by the fringing coral reefs on parts of the Mount Garnet Shelf and the Jack Shelf, and in parts of the Kangaroo Hills Trough (Fig. 4). During this emergence the Chillagoe and Mount Garnet Shelves were probably linked to the Kangaroo Hills Trough by a north-south seaway either around the eastern extension of the Wairuna River land ridge (into the present Coral Sea) or along the long north-west axis of intrusion of the Herbert River Batholith between the Herbert River Gorge and Mount Fox (Fig. 6). The restriction of a 'Wildflysch' type conglomerate to the south-eastern and south-western edges of the Wairuna land-mass suggests that this part of the mass may have been uplifted by a thrust to the south-west. This thrust was later occupied by an intrusion of serpentine.

The Palaeozoic shoreline limits in the Broken River Rift are not precisely known. Greywacke conglomerate and arkose exposed adjacent to the Burdekin River Fault Zone in the Bundock River Basin suggest that the Upper Devonian-Carboniferous shoreline may have been the fault zone. Similar sediments are exposed near Gregory Springs, and the Clarke River Fault Zone may have been the southern shoreline in the Upper Devonian/ Carboniferous. The fixing of the marine Middle Devonian shoreline is more difficult. The conditions in the Broken River area were unique: they supported a rich coral fauna, which according to Prof. Hill (pers. comm.) contains the best range of genera and species of any Devonian locality in Australia. The hooked-shaped constriction of the Burdekin

River Shelf shown in the Broken River area (Fig. 5) appears to be too narrow to allow free flow of sea water for thick coral growth: the Middle Devonian sea may have transgressed farther east on to the Jack Shelf. There are no Middle Devonian outcrops on the Georgetown Shield to suggest a westerly transgression on to the massif; the sea may have extended farther south-west along the Broken River Rift, but its limits are not known since the Devonian-Carboniferous sediments are covered by Cainozoic basalt, and farther south-west the Mesozoic sediments of the Artesian Basin obscure the underlying rocks. The reasons for linking the Broken River shelf deposits to the Burdekin River reefs by a sinuous east-west seaway have already been discussed. The Burdekin River Shelf and the Hodgkinson Trough must both have been open to the sea. Middle Devonian rocks are not exposed on the Wairuna-Barron River land mass, so the sea did not transgress over the mass.

Igneous Activity

The most outstanding feature of the igneous activity is the cyclic repetition of a basic and an acid magma from the Precambrian to the Cainozoic. A basic and ultrabasic magma first appears in the Precambrian, and recurs in the Middle Palaeozoic, and finally in the Cainozoic. Widespread acid magma was emplaced after the basic magma towards the end of the Precambrian, and again in the Upper Palaeozoic. Another feature is that the total area of acid magma is about four times that of the basic (and ultrabasic): 20,000 square miles of acid, and 5,000 square miles of basic and ultrabasic. These relative proportions of acid to basic regions and the cyclic pattern of the igneous activity suggest a two-magma source (acid and basic) for most of the igneous rocks of the Cairns-Townsville Hinterland, and that the magmas were independent of each other. Also the area of outcrop of the Precambrian and Upper Palaeozoic acid magmas are about the same (10,000 square miles), and in places their chemical compositions are similar, which suggests that they could have been both derived from a similar source. The outcrop area of Upper Palaeozoic pink granite is much the same as that of Upper Palaeozoic acid volcanics. This would be expected if the two rocks were derived from the same acid magma, which was emplaced in some places as granite into high levels in the crust, and elsewhere extruded as acid volcanics. In other places granite and acid volcanics are exposed in the one province and they are structurally associated.

The concept of a two-magma origin for most igneous rocks has been put forth by Joplin (1959) and others, intermediate rocks being formed by hybridization of a basaltic and a granodioritic magma. The concept seems to be consistent with the origin of the North Queensland igneous rocks. Also the small amounts of intermediate rocks compared to the huge amounts of acid and basic rocks indicate that differentiation and contamination (hybridization and assimilation) have formed few intermediate igneous rocks in this area. Green (1958) has proved that differentiation formed the ultrabasic, basic, and intermediate rocks in the Gray Creek area; but again the amount of differentiates is insignificant.

The Precambrian Forsayth Batholith and the Upper Palaeozoic granites show the features of granite emplacement into the mesozone and epizone as described by Buddington (1959). If the assumption that the two granites were derived from the same source is correct, then the Upper Palaeozoic granite could be interpreted as the remobilization of the same deep crustal layer which gave rise to the Precambrian granite. The history of igneous activity in North Queensland supports the remarks by Bryan (1925), who noted the absence of granite activity accompanying the Ordovician and Devonian folding in Queensland, and widespread granites during the epeirogenic uplift, which closed the Palaeozoic era.

Economic Implications

Tables 1, 2 and 3 list the main associations of metals (and non-metals) with igneous rock and their positions in the geological history of the area. Jones (1943; 1947; 1953a; 1953b) has described some of the relationships between orogenesis and metallogenesis, and now that more detail is available some of the ages of mineralization listed by Jones (1947) need revision, although the general associations still hold.

The late Precambrian age of the gold and tin mineralization of the Croydon-Stanhills area stated by Jones (p.7, 1947) is not valid. The gold and tin of the Croydon Felsite and the associated granite are best regarded as Upper Palaeozoic (or Lower Mesozoic?) of similar age to the widespread acid vulcanism and granite intrusion in other parts of the Georgetown Shield and the Tasman Geosyncline. Jones described four main periods of mineralization in Queensland: late Precambrian (the Cloncurry Epoch); late Devonian or early Carboniferous (the Herberton Epoch); late Permian-Triassic (the Gympie Epoch); Upper Cretaceous (the Maryborough Epoch). The Cloncurry and Gympie Epochs are most widespread in North Queensland. There is some evidence that the Gympie Epoch may be continuous from the Carboniferous to the ?Lower Triassic. There is no evidence of the Maryborough Epoch.

The late Precambrian period of mineralization is complicated and consists mainly of two distinct ages: an older one of gold, copper, silver, and lead, probably introduced by a basic magma, and represented by the mineralization of the Gilberton, Mosquito Creek, Ortona, and Eveleigh areas (the copper, gold, and nickel of the Hall's Reward Copper Mine area (White et al., 1958) were probably introduced by basics and ultrabasics during this period), and a younger period consisting mainly of gold with minor amounts of base metal, introduced by the Forsayth Batholith.

The Upper Palaeozoic is the other main period of mineralization. It consists of two ages of mineralization: in the older one copper, with lesser amounts of silver, lead, and iron, were introduced by the Herbert River Batholith in the Chillagoe, Mount Garnet, and Ewan areas; in the younger, tin, wolfram, molybdenum, and lesser amounts of bismuth, and fluorite, were introduced by a pink granite in the Herberton, Irvinebank, Bamford, Mount Garnet, and probably Ewan areas. Gold, tin, and copper of the Croydon area may belong to this younger period.

Gold is the most ubiquitous metal, recurring at least four times in the history of the area, and introduced by both acid and basic igneous rocks in the Georgetown Shield and the Tasman Geosyncline. Copper is the next most abundant metal, recurring twice in the history of the area, and introduced by basic and intermediate (monzonite) igneous rocks. Special reference to the copper mineralization of the Herbert River Batholith should be made. Branch (1960) has described the metasomatized granodiorite-copper association at the Ruddygore Mine, Chillagoe, as a possible example of a porphyry-copper type mineralization. The conditions for this type of mineralization are not clearly understood, but the association of granodiorite, limestone, and hooded granitic intrusions, like that exposed in parts of the Chillagoe and Mount Garnet Shelves, and probably at Ewan, seems to be an indicator of one type of porphyry-copper environment. Unfortunately the main part of the Herbert River Batholith is intruded in the Georgetown Shield near its boundary with the Chillagoe and Mount Garnet Shelves, and its western edge does not extend far enough west to intrude the thick limestone deposits of the Perry Creek, Jack, and Broken River Shelves. However the Herbert River Batholith intrudes limestone at Ewan, and it is encouraging for the discovery of porphyry copper that similar mineralization to that of the Chillagoe area is exposed in the Ewan area. Also, if the Mount Garnet Shelf was once linked, in the Upper Silurian/Lower Devonian, to the Kangaroo Hill Trough by a shelf across the Wairuna Tectonic Land, part of the shelf reef deposits may be intruded by the Herbert River Batholith between the Herbert River Gorge region and Mount Fox. This shelf area would be worth prospecting for copper deposits, as some copper has been previously mined in the Herbert River Gorge region.

The main non-metals of the area are diatomite (White & Crespin, 1959) and pozzolan (Best, 1959; Bush, 1960), which are related to the Cainozoic vulcanism.

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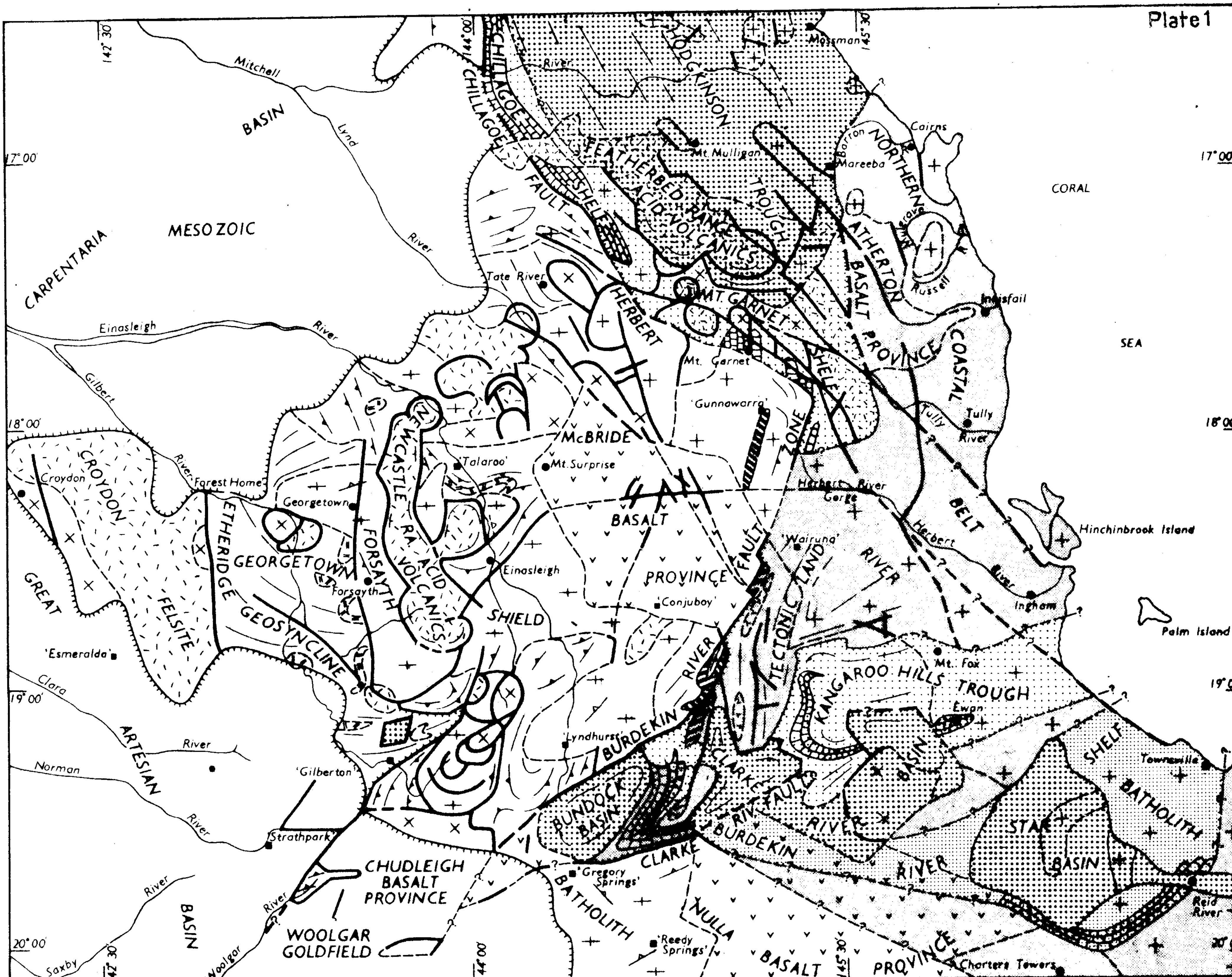
Plate 1



TECTONIC MAP
CAIRNS-TOWNSVILLE HINTERLAND
NORTH QUEENSLAND

Scale

Miles 30 15 0 30 60 Miles

REFERENCE

- Upper Devonian to Middle Carboniferous depositional areas. Permian tectonic land.
- Middle Devonian (to ? Upper Devonian) depositional area. Limestone reefs. Upper Devonian to Middle Carboniferous tectonic land.
- Upper Silurian to Lower Devonian depositional area. Limestone reefs. Middle Devonian to Middle Carboniferous tectonic land?
- ? Upper Ordovician to Silurian depositional area. Upper Silurian to Middle Carboniferous tectonic land?
- Precambrian Shield: Proterozoic sediments. Archaean metamorphics. Palaeozoic tectonic land.

Igneous Rocks

- Cainozoic basalt
- PERMIAN(-TRIASSIC?):
  - Younger granite.
  - Acid Volcanics.
  - Older granite.
- Upper Silurian to ? Lower Devonian basic and ultrabasic intrusions.
- Precambrian granite (trend of platy flow).
- Precambrian basic and ultrabasic intrusions.
- Faults

Bureau of Mineral Resources, Geology and Geophysics.

Q7-3

PAB