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The Geology of the Drummond Basin, Queensland

by

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SUMMARY

The Upper Devonian to Lower Carboniferous Drummond Basin sequence crops out over an area of approximately 10,000 square miles, mainly west but also east of the Anakie High in east central Queensland. The Drummond Basin is a structural remnant of a large intermontane depositional basin that developed in the Tasman Geosynclinal zone after the Tabberabberan Orogeny. It received up to 40,000 feet of predominantly fluviatile sediments which were transported into the basin by a generally north-flowing river system. Marine incursions may have occurred. Basement to the basin consists of early Palaeozoic rocks, mainly slightly metamorphosed sediments and granite. The Drummond Basin sedimentation came to an end in the Kanimblan Orogenic event, when the sequence was folded and uplifted to form a structural high shedding detrital material into the Bowen and Galilee Basins.

INTRODUCTION

The Upper Devonian to Lower Carboniferous Drummond Basin sequence crops out over an area of about 10,000 square miles in east central Queensland including the Central Highlands and surrounding tablelands, plains, and lowlands.

The Drummond Basin was mapped by combined parties of the Bureau of Mineral Resources and Geological Survey of Queensland from 1960 to 1963, when the southern part of the basin was examined as part of the regional mapping of the Bowen Basin, and in 1966 and 1967 when the northern portion of the basin was mapped and the southern region was re-examined.

The largest town in the area is Clermont. It has a population of about 2000. Alpha, Blair Athol, Anakie, Bogantungan, Sapphire, and Rubyvale are the only other small settlements in the area. The central railway, from Rockhampton on the coast to Longreach in central Queensland, passes through the southern part of the area, and there is a branch line from Emerald to Clermont and Blair Athol. Clermont has a regular air service. The area is served by a network of unsealed main and subsidiary roads. The Gregory Developmental Road connects Clermont with Charters Towers, 12 miles north of the area, and with Emerald, 10 miles to the east. The central highway follows the central railway, and other main roads connect Alpha and Clermont and extend eastward from Clermont to Sarina on the coast, and from the Gregory Developmental Road south of Mount Douglas homestead to Collinsville via Mount Coolon. Numerous station tracks provide good access throughout the region. Most of the roads and tracks are impassable after heavy rain.

Complete photographic cover at 1:50,000 and 1:85,000 scales is available. Planimetric maps at 1 inch to 4 miles published by the Army, and at 1:250,000 scale published by the Division of National Mapping, and cadastral maps at scales of 1 inch to 2 miles and 1 inch to 4 miles, published by the Department of Lands, Brisbane, are also available for the entire area.

The area has a subtropical to tropical, subhumid to semi-arid climate with an annual rainfall decreasing from about 27 inches in the east to about 20 inches in the west. The rainfall is highly variable, particularly in the west. About three-quarters of the rain falls between November and April. February is the wettest month with an average of at least 3.5 inches at most stations. The driest months are August and September. Mean maximum temperatures range from approximately 70^{o}F in July to 95^{o}F in January, and the mean minimum temperatures range from about 45^{o}F in July to about 70^{o}F in January. Frosts occur in winter, especially in the southern part of the area. The mean annual evaporation is about 6 feet.

Most of the area is open woodland with Eucalypts the most prominent trees. Dense scrub covers large areas in the east of the Buchanan Sheet area and the northern parts of the Galilee and Clermont Sheet areas, and grassland is widespread east and northeast of Clermont on the Peak Downs. Pedley (in CSIRO, 1967) gives a detailed description of the vegetation of the whole region.

Beef cattle raising is by far the most important industry in the area; sheep are run in only a few areas in small numbers. Large areas of scrub have been cleared in recent years for pasture improvement, and cultivation for grain crops, mainly sorghum, wheat, and oats is becoming increasingly important on the basalt country in the Clermont district. Coal is the only mineral being mined commercially. About 75,000 tons per year are taken from an open cut at Blair Athol, mainly for the railways.

Previous investigations

The earliest published geological work consists of reports covering isolated areas of the Drummond Basin. The first regional work was done by Shell (Queensland) Development Pty Ltd (1952) in the south of the area in the Springsure region, and combined Bureau of Mineral Resources/Geological Survey of Queensland parties have since 1960 regionally mapped the whole of central Queensland (Exon et al., 1966; Malone et al., 1964, 1966; Mollan et al., 1969; Olgers et al., 1967; Olgers, in prep. a, b, c; Veevers et al., 1964 a & b; Vine et al., 1965; Wyatt et al., 1967). A complete evaluation of the basin was made by de Bretizel (1966).

The whole area is covered by BMR helicopter gravity (Gibb, 1966), and an aeromagnetic survey conducted by Adastra Hunting Geophysics Pty Ltd (1962) covers the northern part of the basin (Fig. 1).

Seismic work has not been done in the outcrop area of the Drummond Basin;. it is confined to the region to the west where the Galilee and Eromanga Basin sequences crop out. The areas covered by some of these surveys adjoining the Drummond Basin are shown in Figure 1.

Exploratory oil wells have not been spudded within the Drummond Basin outcrop belt either, but of the many wells drilled to the west and south, Jericho No. 1, Warrang No. 1, Penjobe No. 1, Purbrook No. 1 and possibly Lake Galilee No. 1 penetrated the Drummond Basin sequence at depth (Fig. 5). Shows of gas were encountered in Lake Galilee No. 1 and a drill stem test of the interval 8679'-8752' recovered 10 feet of 43^{o} gravity oil with an associated small flow of petroliferous gas from Upper Carboniferous or Lower Permian rocks.

GEOMORPHOLOGY

The geomorphology of most of the area has been described in detail by Galloway (in CSIRO, 1967, pp 97-100), and the following account is largely taken from his work.

Physical regions

Eight physical regions may be distinguished on the bases of relief and geology (Fig. 2). Each of these regions is a complex of subregions and only the major features are described. It should be emphasized that the names used for these regions refer only to the area covered by this report and are not to be regarded as proper names.

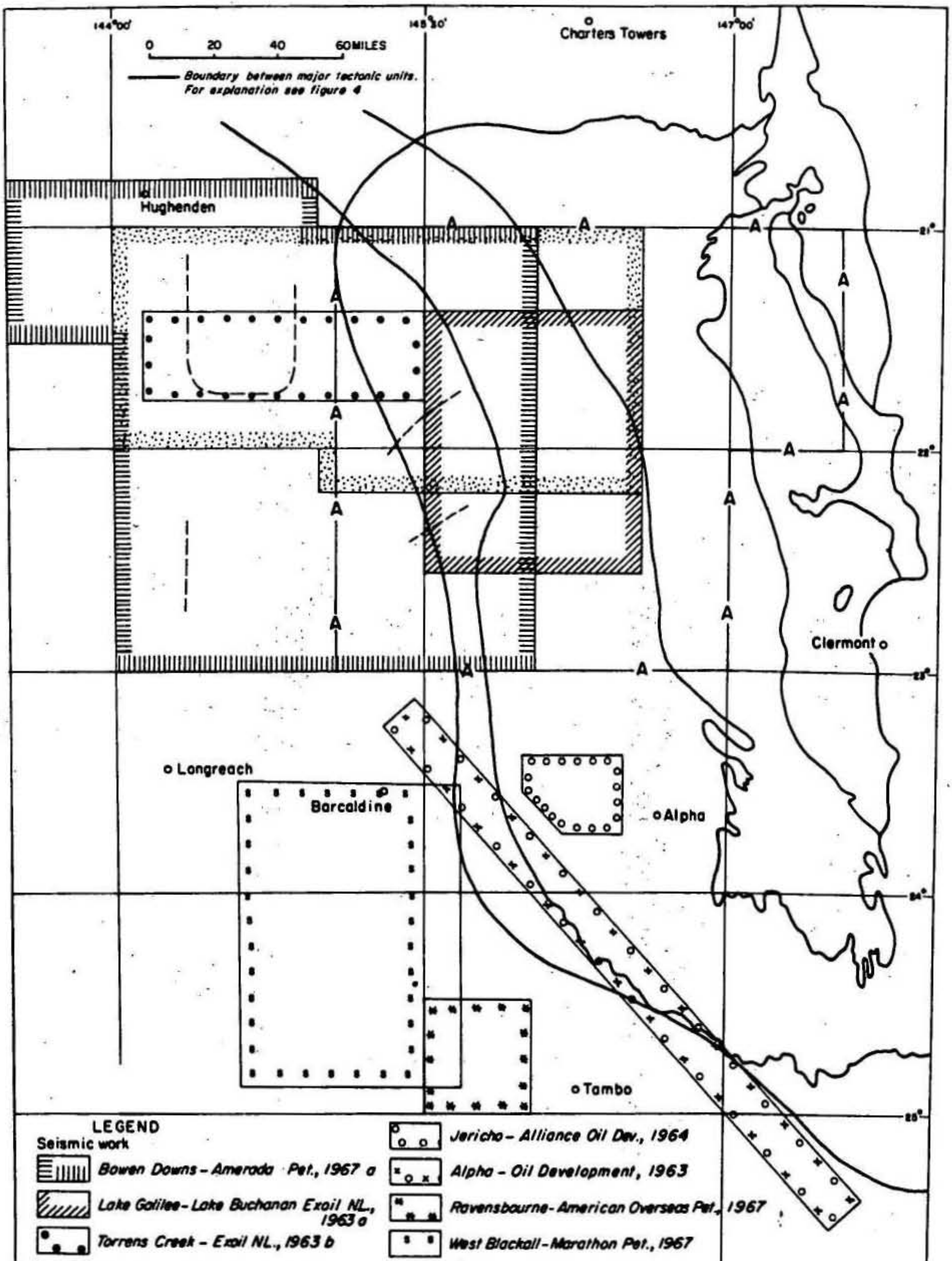

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Fig.1 - Geophysical investigations. Only relevant work has been shown.

<u>Western Plains and Tablelands</u>. This region occupies the northwestern portion of the area and a small area in the Alpha region. Most of the region consists of plains and gently undulating low tablelands covered by Tertiary detrital rocks and laterite. Where harder formations occur in the underlying Permian, Triassic, and Jurassic sediments low ranges rise a few score to a few hundred feet, usually with very gentle slopes but locally with extremely dissected, broken forms where erosion has pierced the widespread Cainozoic cover. Below these ranges are extensive, confluent, low-gradient fans several miles across with shallow, inactive, anastomosing channels. Some patches of deeply weathered clays and shales are exposed and give rise to dense scrub on heavy soils. Major streams within this physical region tend to have fairly wide alluvial flats with clearly developed levees.

<u>Northern Hills</u>. This area has broken relief and a variety of topographic types reflecting the complex geology and the varying extent of Cainozoic erosion, sedimentation, and deep weathering. In the west is a series of steep, parallel ridges 20 to 200 feet high, running more or less north-south, which have been exposed by removal of a former cover of Tertiary sediments and which are separated by strike vales up to a mile wide. Also in the western part is a group of dissected hills on the Bulliwallah and Natal Formations. In the centre is a belt of lower undulating country on little-weathered granite and rather more weathered metamorphics with occasional hills coinciding with more resistant outcrops. To the east, this gives way to extremely rocky low hills on the Bulgonunna Volcanics with local relief from 50 to 300 feet. The fringes of the Bulgonunna Volcanics are covered by remnants of a formerly extensive sheet of Tertiary sandstone. These remnants form low to high mesas, particularly well developed on the northwest side of the Bulgonunna Volcanics (Rottenstone Range). In the extreme east relics of the Tertiary mesas overlie weathered basalt on which undulating country has been cut subsequent to the removal of the Tertiary sandstones.

North-central Clay Plain. Clay plains and lowlands are widespread from the latitude of Clermont north to the northern hills. Much of the clay is associated with deep weathering profiles on Tertiary claystone and older rocks and tends to be acid at depth. More alkaline clay spreads, derived from weathered basalt and laid down in extensive fans, occur in the Diamond Downs homestead area. Extensive clay sheets of uncertain origin, generally alkaline, occur near Moray Downs homestead. Major rivers have broad alluvial flats up to 10 miles wide, and flood extensively.

Basalt Lowland. Along the eastern margin of the area, erosion has formed an extensive rolling lowland in Tertiary basalt. Isolated mesas of basalt and volcanic plugs rise steeply 100 to 1500 feet above the lowlands. Fine-textured alluvial flats margin most streams.

Central Highlands. A block of higher country, ranging from low hills to low mountains, with local relief from 100 to 1500 feet extends nearly north-south from the vicinity of Cairo homestead to just south of Mount Portwine. The height and form of these highlands vary considerably according to the geology. In the north, they consist of undulations and low hills on the Anakie High and on a partial cover of Tertiary sediments. In the centre, the Anakie rocks are less weathered, much more closely dissected, and form steeper country with local relief up to 500 feet such as occurs west of Clermont. In the south, the highlands are mainly formed by resistant elements in the Drummond Basin rocks. The highest point of the central highlands, Mount Tabletop, rising to 2700 feet, lies in this southern sector. The surviving effects of Tertiary deep weathering decrease from north to south and are hardly apparent in the southern sector. For much of their length the central highlands coincide with the Drummond Range, which is the divide between the Nogoa and the Belyando Rivers.

Eastern Lowland. This lowland belt lies on the eastern side of the central highlands and extends from Clermont south to the Nogoa River. It is developed on a variety of rock types and includes rolling country on granite and basalt, and undulating to low hilly country on Permian quartzose sediments. Extensive remnants of Tertiary deep weathering profiles and Tertiary sediments survive around Anakie. On the moderately dipping Ducabrook rocks, low, ill-defined scarps have

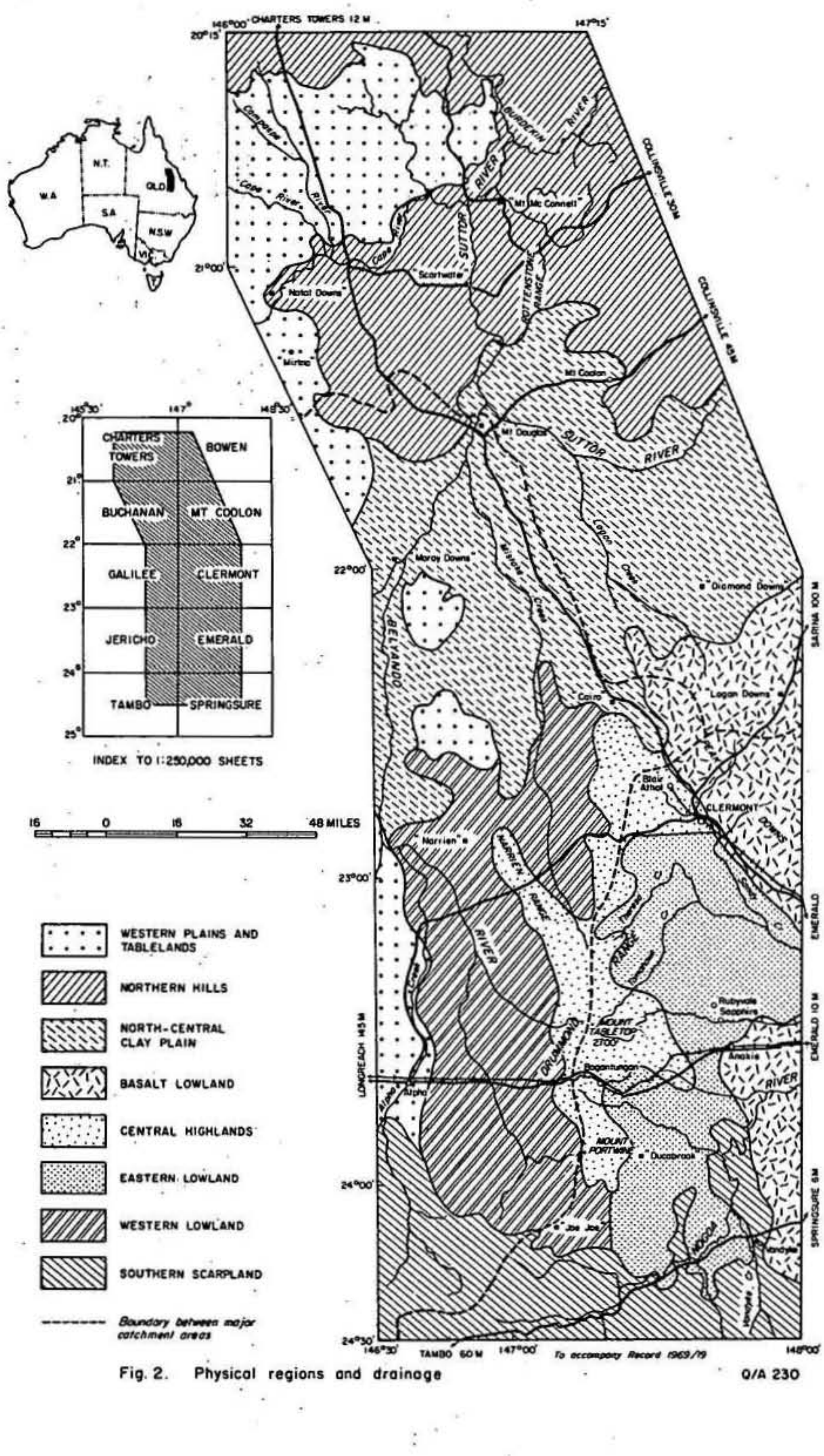

Fig. 2. Physical regions and drainage

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developed. Limited areas of much steeper country lie west of Springsure. Fairly wide alluvial flats extend along the major streams.

Western Lowland. This lowland belt extends from Narrien homestead south to Joe Joe homestead where it coalesces with the southern end of the eastern lowland. It is characterized by low undulating relief for the most part, with weakly developed scarps and strike ridges formed on the moderately dipping sedimentary rocks of the Drummond Basin. A number of rugged ranges coincide with anticlines and consist of steep strike ridges and cuestas with local relief up to 1200 feet. The central part of this lowland northeast of Alpha is characterized by spreads of gravelly clay. Considerable portions of this region are occupied by gently undulating surfaces on Cainozoic sediments. Some of the major rivers crossing this area have very wide alluvial flats, but others are somewhat incised and their alluvium is not extensive.

Southern Scarpland. The southern scarpland loops in an arc around the southern end of the survey area. Over most of this physical region the major products of Tertiary deposition and deep weathering have been stripped off and the lithology of the underlying rocks consequently largely determines the character of the country.

There is an alternation of broken, dissected hills on the resistant sandstone formations and undulating lowlands on the weaker shaly formations. Only moderately extensive alluvial flats are present on the softer rocks while on the harder the streams flow in defiles with very narrow sandy alluvial flats.

Drainage

The Nogoa River draining the southeastern part of the area flows from southwest to northeast; its most notable tributaries are Sandy Creek, draining an extensive area of the Clermont district, and Vandyke Creek, which flows north from the high Buckland Tableland in the far south. The Nogoa River is part of the Fitzroy drainage system which reaches the sea at Rockhampton to the east. The Belyando

River which drains the western part of the area, joins the Suttor River at Mount Douglas homestead. The Suttor River, which drains the northeast of the area, is also joined by the Cape River from the northwest. The Suttor River joins the Burdekin River which flows to the northeast and reaches the sea at Ayr. The Great Dividing Range, separating the area that is drained to the Pacific Ocean from the Lake Eyre internal drainage basin, is just west of the area.

GENERAL GEOLOGY

The Drummond Basin is one of a number of downwarps which developed in the Tasman Geosynclinal zone after the Tabberabberan Orogeny and which received a great thickness of continental and some marine sediments in the Upper Devonian and Lower Carboniferous. Marine sedimentation took place mainly farther to the north and east in the region of the present eastern Australian coast (Fig. 3).

The basin was a slowly subsiding intermontane region which was drained to the north; continental sedimentation kept pace with subsidence at most times, but subsidence below sealevel occurred in the north early in the history of the basin. The Drummond Basin sequence was folded in the middle of the Carboniferous in the Kanimblan Orogeny and the region transitional between the continental sedimentation of the Drummond Basin and the marine deposition of the Yarrol and Hodgkinson Basins is now occupied by younger granites and volcanics. Much of the Drummond Basin sequence, both east and west of the Anakie High, is obscured by younger sediments and the Drummond Basin outcrop belt is only a small structural remnant of the original basin of sedimentation.

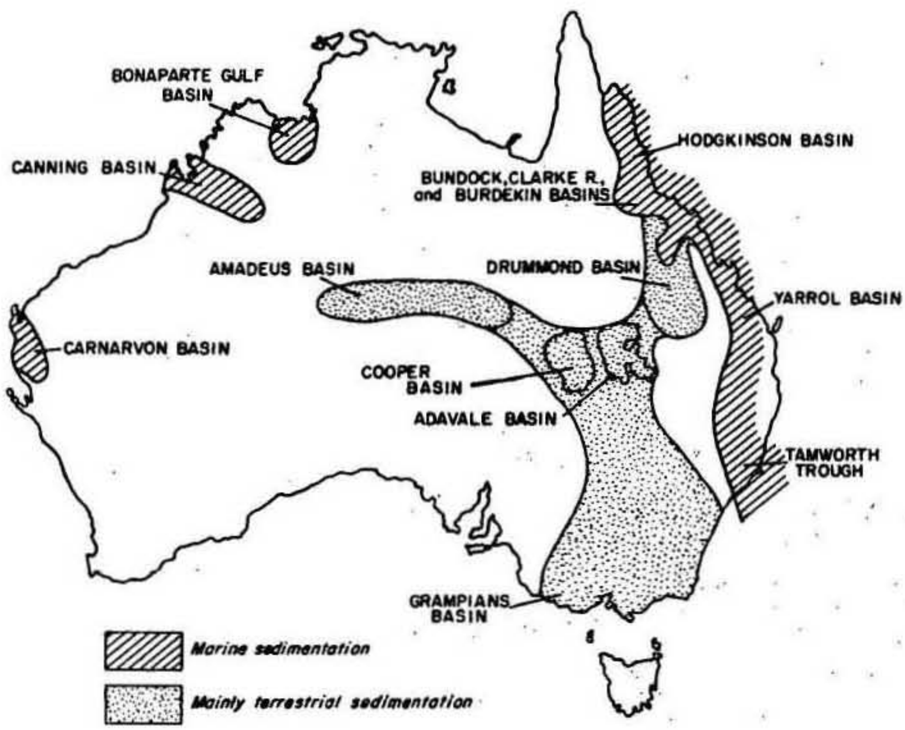

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Fig.3 - Upper Devonian-Lower Carboniferous palaeogeography.

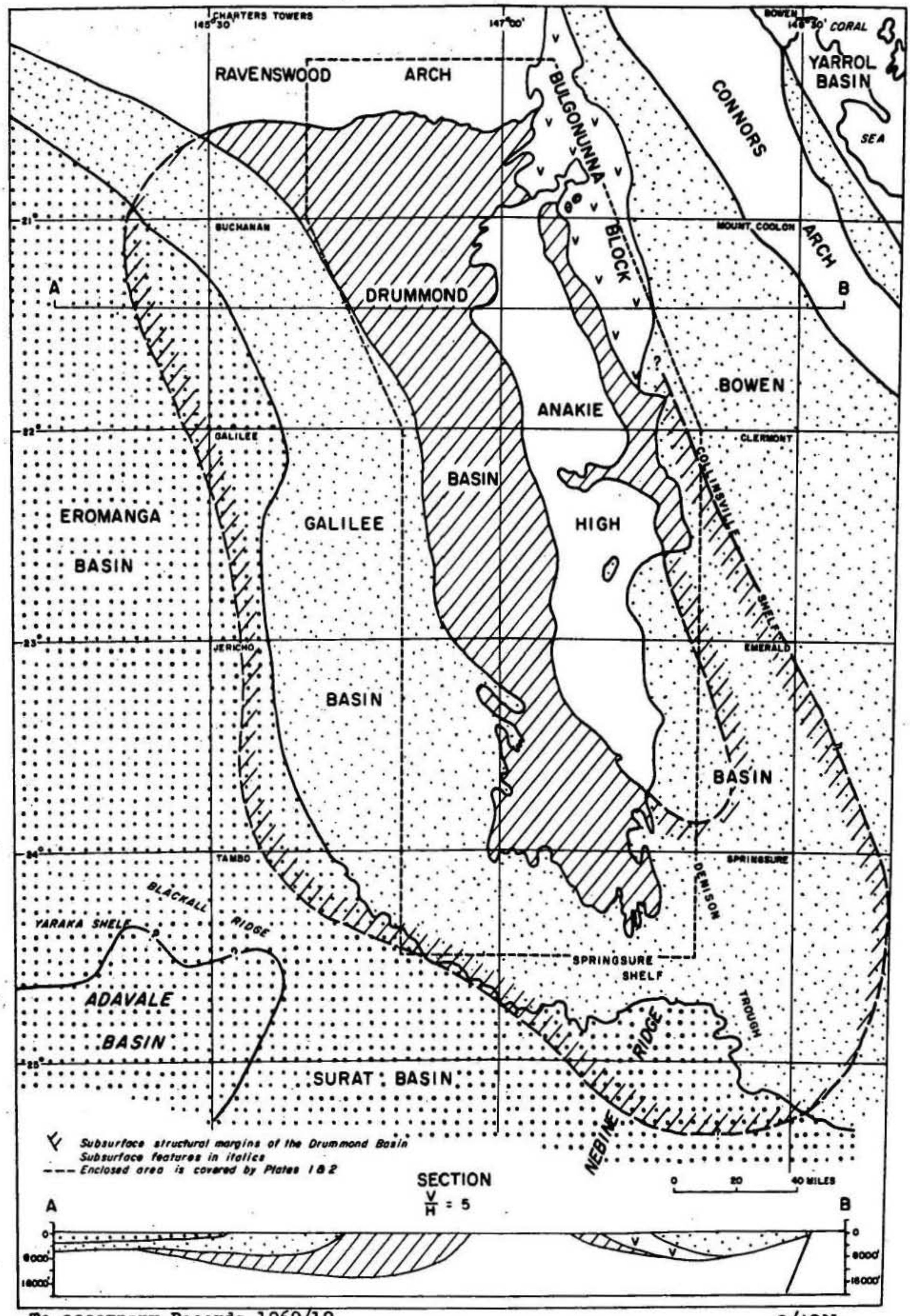

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Fig. 4 - Tectonic setting.

In the past it has been customary to include all Devonian and Carboniferous rocks in the area in the Drummond Basin sequence, however angular unconformities exist between the Middle and Upper Devonian and between the Lower and Upper Carboniferous successions in the region of the Anakie High, and only the Upper Devonian and Lower Carboniferous rocks are here included in the Drummond Basin sequence. The Middle Devonian rocks are part of the basement and the Upper Carboniferous strata are included in the Galilee Basin sequence.

The subsurface Adavale Basin southwest of the Drummond Basin (Fig. 4) contains Lower, Middle and Upper Devonian rocks. The Upper Devonian part of the succession (Buckabie Formation) is an up to 10,000 feet thick red bed sequence which may extend into the Lower Carboniferous and which overlies the marine Middle Devonian rocks (Etonvale Formation) with apparent conformity. The Buckabie Formation is the only part of the Adavale Basin sequence that can be correlated with part of the Drummond Basin sequence (Fig. 6). The red bed sequence, including pyroclastic rocks, that was encountered in the Jericho No. 1 well 60 miles west of the Drummond Basin outcrop belt may be equivalent to the Buckabie Formation.

The Drummond Basin succession has also been encountered in four other oil exploratory wells, namely Lake Galilee No. 1, Warrong No. 1, Penjobe No. 1 and Purbrook No. 1 (Table 5).

The rock units that occur on the accompanying geological map (Plate 1) are described under three major headings: (i) Basement, (ii) Drummond Basin sequence, and (iii) Post-Drummond volcanics, sediments and intrusives.

The discussion of the Drummond Basin sequence is the main purpose of this report and only brief discussions of the basement and post-Drummond rocks are included.

BASEMENT

Basement rocks crop out in the Anakie High, and Ravenswood Arch, and have been recorded from numerous oil exploration wells west and south of the Drummond Basin outcrop belt (Fig. 5). Basement consists mainly of low-grade metasediments of early Palaeozoic age, small isolated areas of Middle Devonian sediments and volcanics, and granites which range in age from Middle Ordovician to Upper Devonian.

The Middle Devonian rocks have in the past been included in the Drummond Basin sequence, however an important angular unconformity occurs between these rocks and the Drummond Basin sequence, and they are now included in the basement complex.

The relationships between the basement rocks are shown diagrammatically in Figure 6.

Anakie High

The Anakie High, originally named the Anakie Structural High or Anakie Complex (Hill & Denmead, 1960) and renamed Anakie Inlier (Veevers, et al., 1964b), is a north-northwest trending basement ridge consisting of the pre-Devonian Anakie Metamorphics, Middle Devonian volcanics and sediments, and Upper Devonian intrusive granite. It extends from Ukalunda in the north to Anakie in the south, and plunges south-southwestward under the Bowen and Surat Basins as the Nebine Ridge (Fig. 4).

The Anakie Metamorphics make up the bulk of the high. They are unconformably overlain by the Ukalunda Beds in the north, the Theresa Creek Volcanics and associated Douglas Creek Limestone near Clermont, the Dunstable Volcanics west of Springsure, and volcanics and limestone near Fletchers Awl northeast of Clermont, and near Glendarriwell homestead southwest of Emerald. These outcrops, which, except the Ukalunda Beds, are all small and consist of intermediate

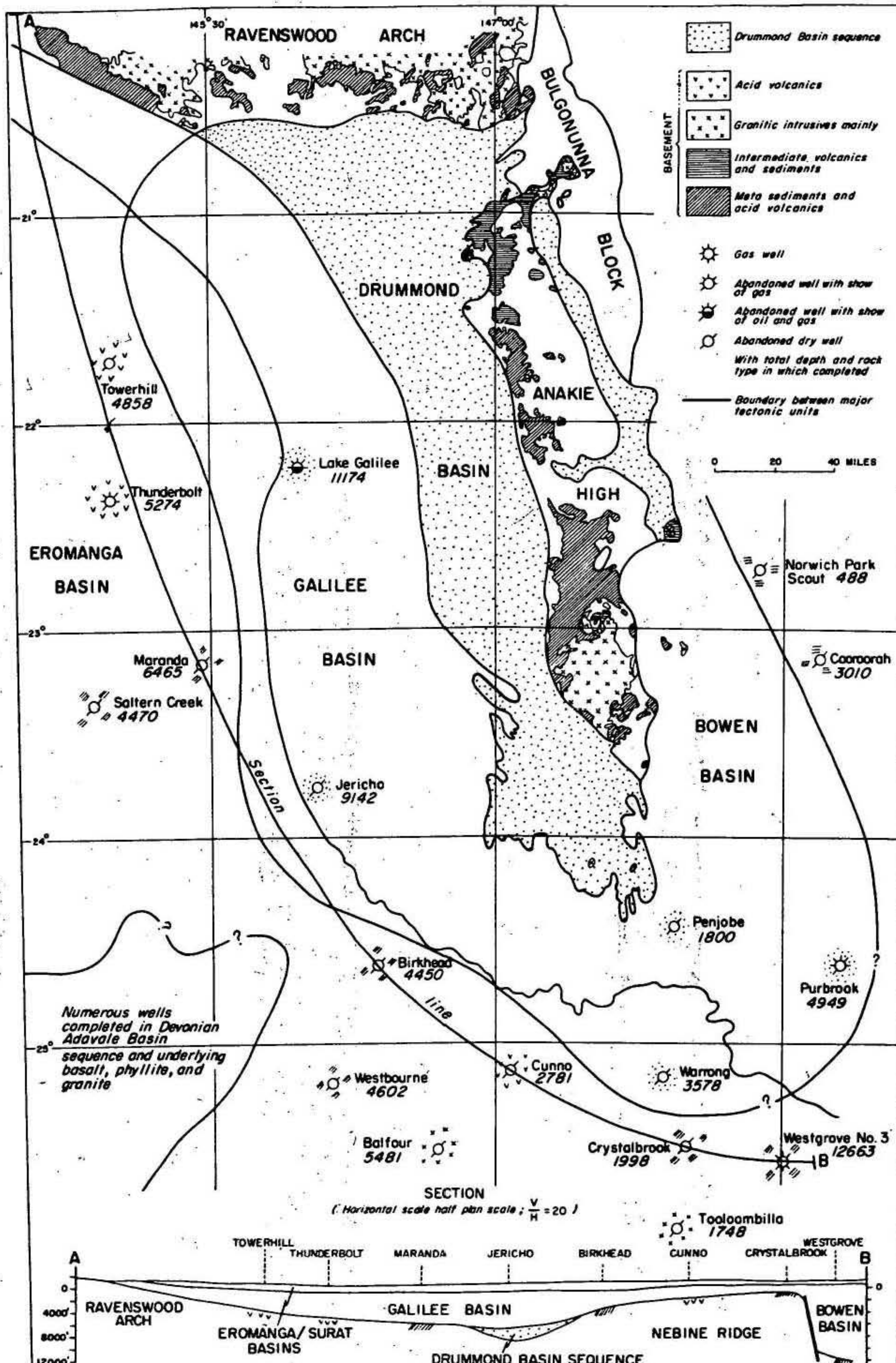

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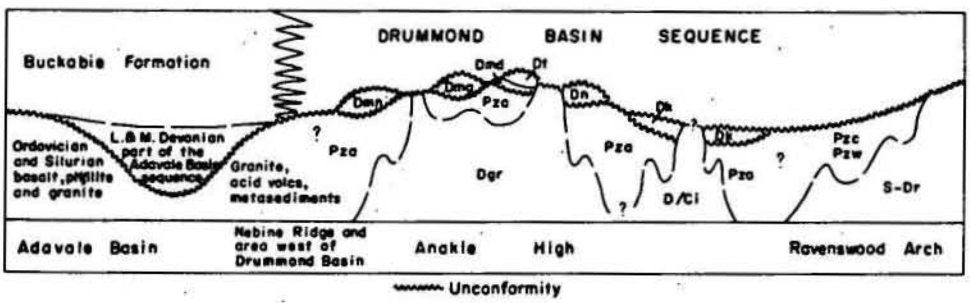
Fig.5 - Basement rocks of the Anakie High and Ravenswood Arch, and basement in wells near the subsurface margin of the basin. Wells completed in the Drummond Basin sequence are also shown.



D/Ci — Devonian or Carboniferous granite

Dgr — Retreat Granite

Dk — Ukalunda Beds

Dmn — Dunstable Volcanics

Dmg — Middle Devonian rocks at Glendarriwell Homestead

Dn — Volcanics and limestone at Fletchers Awl

Df — Theresa Creek Volcanics

Dmd — Douglas Creek Limestone

S-Dr — Ravenswood Granodiorite

Pza — Anakie Metamorphics

Pzc — Cape River Beds

Pzw — Mount Windsor Volcanics

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Fig.6 - Basement rock relationships.

volcanics, minor sediments and coralline limestone, are the remnants of an extensive Middle Devonian volcanic and marine sedimentary province. The Anakie Metamorphics and Middle Devonian rocks were in the Upper Devonian intruded by granite.

The history of the Anakie High is summarized in Figure 26. A geanticline, flanked to the west by the Drummond Basin and to the east by the Yarrol Basin developed during the Tabberabberan Orogeny in the Middle Devonian. The Drummond Basin sedimentation progressively transgressed the western part of the uplift. This western region was again uplifted in the Kanimblan Orogeny in the middle of the Carboniferous to form the Anakie High and Nebine Ridge. The Anakie High and Nebine Ridge were largely exposed during the subsequent Galilee/Bowen Basin sedimentation; only a relatively thin sedimentary cover was deposited on the Springsure Shelf where the basin crossed the Anakie-Nebine axis.

<u>Anakie Metamorphics</u> (Jensen, 1921)

Jensen used the term Anakie Series for the granite, porphyry, schist, and slate of the Anakie area. The name Anakie Metamorphics was later used on the Geological Map of Queensland (Hill, 1953) to include all Lower Palaeozoic rocks from Anakie to southwest of Collinsville.

The Anakie Metamorphics consist of quartz-mica schist, knotted schist, phyllite, quartzite, slate, lithic sandstone and some unfossiliferous limestone and volcanics. The rocks are generally tightly folded and the relationships between the rock types are obscure. Some broad structures can be discerned on the aerial photographs west of Anakie, but the unit gives rise to a uniform dendritic air-photo pattern in most areas. The age of the metamorphics is not known. Age determination work on a mica schist from west of Clermont indicates a Middle Ordovician age for the metamorphism in this region (A.W. Webb, pers. comm.). The Anakie Metamorphics may be correlated with the early Palaeozoic Cape River Beds of the Ravenswood Arch (Fig. 6).

Ukalunda Beds (Jack, 1889)

The Ukalunda Beds, which make up the northern part of the Anakie High, were named after Ukalunda, the now abandoned mining centre west of Mount Wyatt. Malone et al., (1966) recognized two lithological units within the Ukalunda Beds, one consisting mainly of siltstone and sandstone, and the other dominantly sandstone and limestone. These units were not mapped. The limestones contain rich faunas including corals, brachiopods, gastropods, pelecypods, bryozoa, stromatoporoids, and fish bones indicating a Middle Devonian age (Hill in Malone et al., 1966). The Ukalunda Beds are in places tightly folded and have been mildly regionally metamorphosed. The effects of the metamorphism vary considerably from a pronounced schistosity in some areas to slight cleavage in others. Some of the rocks mapped as Ukalunda Beds may belong to the Anakie Metamorphics which they overlie. The units are hard to distinguish and are probably infolded.

Douglas Creek Limestone (Hill, 1939)

Southwest of Clermont on the Anakie High is a small outlier of acid and intermediate volcanic rocks, and limestone. The limestone (Douglas Creek Limestone) crops out near the eastern margin of the outlier and contains a rich lower Middle Devonian fauna including corals, stromatoporoids, brachiopods, molluscs and crinoidal material (Hill, 1939, and Jones, 1941). The limestone is overlain by a thin sequence of Middle Devonian micaceous siltstone that was mapped as an unnamed unit by Veevers et al., (1964a), but was later included in the Douglas Creek Limestone (Olgers et al., 1967).

Theresa Creek Volcanics (Veevers et al., 1964a)

The Douglas Creek Limestone is apparently conformably overlain by the Theresa Creek Volcanics. All intermediate and acid volcanic rocks in the outlier southwest of Clermont were originally included in the unit. Olgers et al., (1967) subdivided the volcanics into a lower unit, consisting mainly of andesite and trachyandesite and intruded by granite, and an upper unit, consisting of spherulitic rhyolite, welded tuff and rhyolite breccia which unconformably overlies the granite. The name Theresa Creek Volcanics was retained for the lower unit; the upper volcanic sequence was correlated with the Silver Hills Volcanics.

Dunstable Volcanics (SQD, 1952)

The name Dunstable Formation, as used by Hill (1957) in place of Shell's Dunstable Series (SQD, 1952), applied to all the rocks exposed below the Telemon Formation in the core of the Nogoa Anticline in the north of the Springsure Sheet area. Mollan et al. (1969) subdivided Hill's Dunstable Formation into a lower volcanic unit comprising tough andesitic lavas and pyroclastics with lenses of coralline limestone (Dunstable Volcanics), which is unconformably overlain by a sequence of dominantly acid volcanics and minor sediments (Silver Hills Volcanics). The Dunstable Volcanics form a faulted northeast trending inlier in the core of the Nogoa Anticline. The limestones contain a rich lower Middle Devonian fauna consisting of corals, stromatoporoids, and polyzoa. (Hill, 1957, and App. in Veevers et al., 1964b).

Middle Devonian rocks at Glendarriwell homestead

The Middle Devonian rocks were first mapped by Veevers et al., (1964b); they are part of a small inlier, comprising rhyolite, shale, siltstone, tuff, pebbly sandstone and limestone, in Permian rocks. The limestone contains a rich Middle Devonian fauna (Hill in Veevers et al., 1964b). The rhyolite may be unconformably younger and belong to the Silver Hills Volcanics.

Middle Devonian rocks at Fletchers Awl

Pyroxene andesite and andesitic basalt with some interbeds of olive-green micaceous shale and siltstone and dark grey recrystallized limestone containing some poorly preserved fossils crop out in a small inlier in Permian sandstone and Tertiary basalt northeast of Clermont. These rocks, which overlie the Anakie Metamorphics, are closely associated with granite, and are unconformably overlain by the Silver Hills Volcanics. They are correlated with the Middle Devonian Theresa Creek Volcanics,

Retreat Granite (Veevers et al., 1964b)

The Retreat Granite makes up the greater part of the Anakie High in the Emerald Sheet area. It consists mainly of rocks ranging from granodiorite to adamellite, but small outcrops of gabbro, diorite, quartz diorite, and andesite have been observed. Isotopic age determination of nine samples from the main body has given ages ranging from 345-372 m.years (Upper Devonian). The Retreat Granite intrudes the Anakie Metamorphics and Theresa Creek Volcanics and is unconformably overlain by the Silver Hills Volcanics. The small outcrops of granite in the core of the Nogoa Anticline and near Fletchers Awl have tentatively been mapped as Retreat Granite because they are also unconformably overlain by the Silver Hills Volcanics.

Devonian-Carboniferous granite (D/Ci)

The northern part of the Anakie High is intruded by five large granitic bodies which crop out in a line trending roughly northeast; they are mostly irregularly shaped due to large roof pendants and embayments, and consist mainly of adamellite and granodiorite. The Middle Devonian Ukalunda Beds, Upper Devonian Mount Wyatt Beds and Upper Devonian to Lower Carboniferous Saint Anns Formation are intruded by the southerly intrusions, and they are regarded as Upper Carboniferous (Cui on Pl.1; see Table 4). The granite at Hidden Valley homestead intrudes the Ukalunda Beds and is thought to be unconformably overlain by the Upper Carboniferous Bulgonunna Volcanics (Malone et al., 1966). It is mapped as Devonian-Carboniferous.

Ravenswood Arch

The Ravenswood Arch is an easterly trending basement ridge, composed mainly of early Palaeozoic low-grade metasediments and intrusive granite, that lies north of the Drummond Basin. It probably formed an effective barrier between the Drummond Basin and the Burdekin Basin to the north during most of the Devonian and Carboniferous; current features measured in the Raymond Formation just south of the arch suggest that the Drummond Basin drainage system flowed northerly across the eastern part of the arch into the sea in the Burdekin Basin during at least part of the time.

Ravenswood Granodiorite Complex (Wyatt et al., 1965)

The Ravenswood Granodiorite Complex makes up the bulk of the Ravenswood Arch. It consists mainly of granodiorite, but granite, adamellite, diorite, and gabbro occur. Recent isotopic dating by the Rb/Sr whole rock method has shown that most of the complex is Middle Ordovician in age (454 ± 30 m.years); some of the specimens dated yielded an isochron of 394 ± 30 m.years (Upper Silurian or Lower Devonian), which is the same age as the Lolworth Igneous Complex (Clarke and Paine, in prep.) farther to the west.

Cape River Beds (Paine et al., 1965)

The type area of the Cape River Beds is in the Hughenden Sheet area from where the unit extends eastward into the Charters Towers Sheet area. The Cape River Beds crop out in a large number of irregularly shaped inliers within the Ravenswood Granodiorite Complex. Several distinct rock types occur, but the variation in metamorphic grade and discontinuity of outcrop make correlation and subdivision of the sequence impossible. However, belts composed mainly of acid volcanics have been mapped out in places (Mount Windsor Volcanics).

The Cape River Beds consist mainly of schist, quartzite, and phyllite, and the metamorphism appears to have been caused by the intrusion of the Ravenswood Granodiorite Complex (Wyatt et al., 1967). Preliminary isotopic age determination work on samples from the Mount Windsor Volcanics suggests an Upper Cambrian age for the volcanics, and for this reason, the Cape River Beds are regarded broadly as Cambrian to Ordovician (Clarke and Paine, in prep.). The presence of the Middle or Upper Devonian plant Calamophyton in the Palamana homestead area indicates that inliers of younger rocks occur. The older rocks in the Cape River Beds can probably be correlated with the Anakie Metamorphics, and the younger inliers are probably equivalent to the Ukalunda Beds.

Subsurface basement

A large number of oil exploration wells have been drilled in the Galilee, Eromanga, and Bowen Basins. Only those nearest the Drummond Basin outcrop belt are considered here (Fig. 5). Most of the wells penetrate Mesozoic and Upper Palaeozoic rocks and bottom in basement (Table 1) consisting of granite (Balfour and Tooloombilla), acid volcanic rocks (Towerhill, Thunderbolt, and Cunno), and low-grade metasediments and sediments (Saltern Creek, Maranda, Birkhead, Westbourne and Crystalbrook). Five wells (Table 5) bottomed in the Drummond Basin sequence (Lake Galilee(?), Jericho, Warrong, Penjobe and Purbrook), and two (Cooroorah, and Norwich Park) sunk to the east of the Anakie High bottomed in andesitic volcanics and interbedded sediments (Table 1).

The subsurface Adavale Basin southwest of the Drummond Basin has also been extensively drilled. It is to the east, south and west largely bounded by areas of post-Devonian uplift and erosion. Onlapping limits of deposition have been recognized to the north and northwest. The basin contains a thick sequence of mainly Devonian sediments over Ordovician and Silurian basalt, phyllite, and granite.

TABLE 1 - SUBSURFACE BASEMENT IN WELLS (See Figure 5 for location)

Well	Basement rock	Hydrocarbon shows	Remarks
Amoco Towerhill No. 1 (Hayworth, 1968)	Ignimbrite: Tough, massive, pink and grey mottled rock consisting of feldspar (40%), and quartz (20%) in a fused devitrified ashy matrix	None	The volcanics in Towerhill and Thunderbolt wells can possibly be correlated with the Silver Hills Volcanics. The volcanics in Cunno No. 1 are similar in description. They may be older and equivalent to the Mt. Windsor Volcanics (see page 15).
Amerada Thunderbolt No. 1 (Amerada Petroleum, 1967d)	Igneous wash composed of weathered angular pebbles of metamorphic and igneous origin, overlying dacite that is badly fractured and partly weathered	Shows in several Permo-Carboniferous sands below 4500 feet, but no recovery from drill stem tests	
Oil Development Maranda No. 1 (Le Blanc, 1963)	Steeply dipping contorted and brecciated green, slightly calcareous, slightly pyritic, recrystallized sheared mudstone	None	
Longreach Oil Saltern Creek No. 1 (Mott and Ass., 1964)	Mainly grey to green fine-grained silicified sugary quartzite interbedded with green, grey, white and purple tuff. Some schistosity in the quartzite.	None	Sediments may be equivalent to the Adavale Basin sequence
South Pacific Birkhead No. 1	Hard brittle shale, calcite veined. Some pyrite. Light grey limestone	None	The basement rocks may be equivalent to the Adavale Basin sequence. Could be older.
Amoseas Westbourne No. 1 (Gerrard, 1964)	Indurated black and steel grey, steeply dipping (40°) banded shale. It is brittle and splintery and fractured across the bedding and has incipient slaty cleavage	None	Similar to basement rocks in Birkhead No. 1
Amoseas Cunno No. 1 (Gerrard, 1966b)	Dacite: Pale grey porphyritic with phenocrysts of quartz and feldspar set in a groundmass of dominantly feldspathic material. Volcanic shards are evident	None	K/Ar age: 187 $\pm$ 20 m. years (Triassic). The volcanics are overlain by Permian sediments and the young age of the volcanics is due to a later tectonic event.
Amoseas Balfour No. 1 (Gerrard, 1966a)	Partly recrystallized feldspar porphyry. Grey, mottled with pink and orange and minor dark greens. Holocrystalline, porphyritic with fine-grained matrix. Phenocrysts are mainly plagioclase feldspar, orthoclase, and quartz	Faint fluorescence in the Triassic Clematis Sandstone	Age determined at 420 $\pm$ 20 m. years (Silurian)
Planet Crystalbrook No. 1 (Meyers, 1964a)	Grey and greenish-grey fine-grained quartzite. Also some phyllite with slight slaty cleavage. Quartz-filled fractures	None	Probably older than the Timbury Hills Formation because of cleavage
AAO Westgrove No. 3 (Minad, 1963a)	Extremely hard rocks; not determined but possibly metamorphic rocks or granite.	Gas well. Production from thick Permian sequence	Drilled just east of Nebine Ridge in the Denison Trough. Permian on unidentified basement.
AFO Cooroorah No. 1	Andesite, andesitic tuff, quartzite, sandstone, siltstone	None	Probably equivalent to Middle Devonian volcanics farther to the west on the Anakie High (Theresa Creek Volcanics, Dunstable Volcanics, etc.).
AFO Norwich Park Scout	Andesitic volcanics and sediments	None	
Planet Tooloombilla No. 1 (Meyers, 1964c)	Granite porphyry	None	Triassic rocks directly overlie the granite

Only the Upper Devonian to Lower Carboniferous(?) Buckabie Formation is equivalent to part of the Drummond Basin sequence; the Middle Devonian part of the sequence is equivalent to the Middle Devonian rocks of the Anakie High (Fig. 6), however they are, unlike the Anakie rocks, relatively undisturbed and overlain with apparent conformity by the Buckabie Formation.

The volcanics in the basement are all described as grey quartz-feldspar porphyries. Cobbles and pebbles of these rocks occur in the Mount Hall Formation at Mount Donnybrook, in the Narrien Range, and in the Telemon Anticline. The volcanics may be related to the Silver Hills Volcanics, but could be older and equivalent to the acid volcanics of the Mount Windsor Volcanics.

Low-grade metamorphic rocks are widespread in the basement. The age of these rocks is unknown but they are probably mainly equivalent to the Lower Palaeozoic Anakie Metamorphics of the Anakie High and the Cape River Beds of the Ravenswood Arch. Equivalents to the Ukalunda Beds may be present.

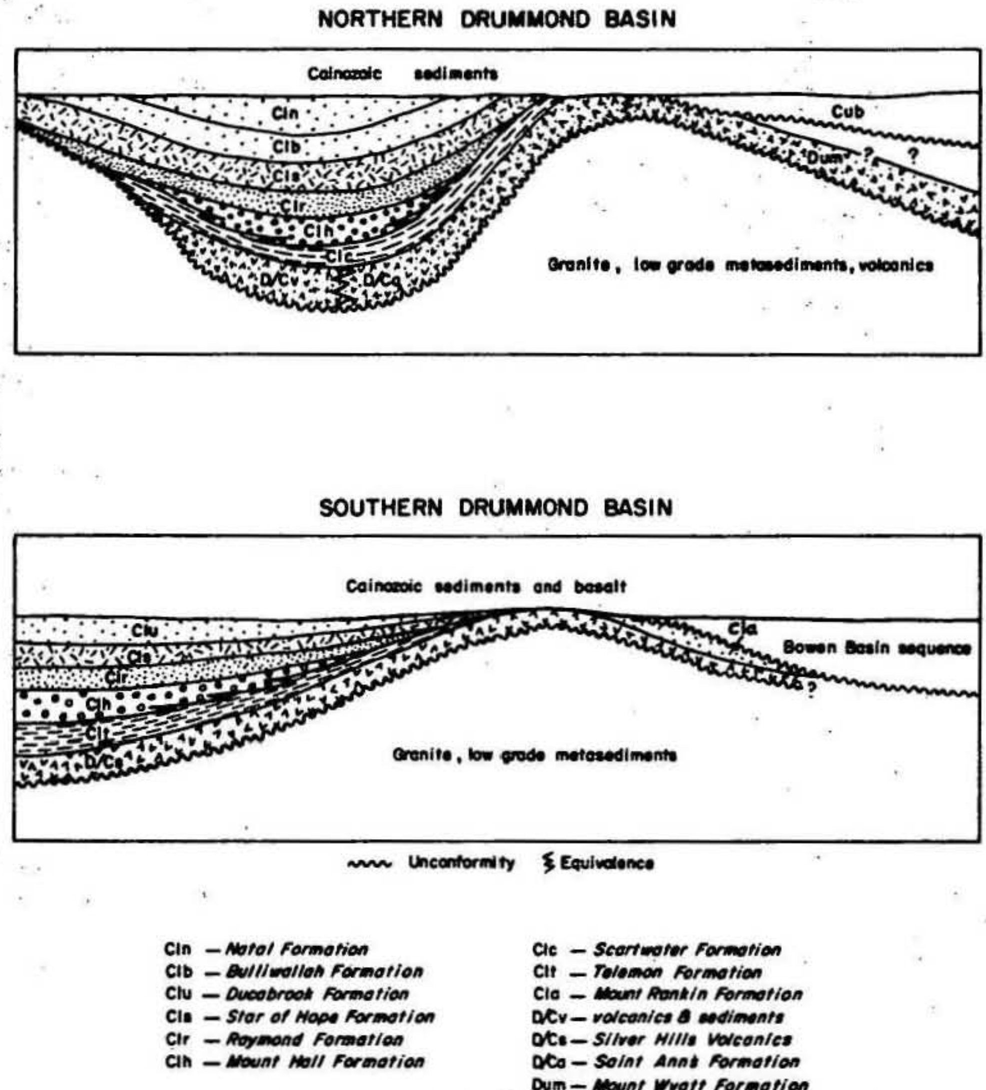
The granite in Balfour No. 1 was dated at 420 $\pm$ 20 m. years and was correlated with the granite underlying the Devonian rocks of the Adavale Basin. The Retreat Granite of the Anakie High is considerably younger at 345-372 m.years (Webb, Cooper, and Richards, 1963), and the Ravenswood Granodiorite Complex is slightly older at about 454 m. years.

The wells east of the Anakie High, struck andesitic volcanics and interbedded sediments. These rocks are probably equivalent to the Middle Devonian rocks which crop out in small isolated areas on the Anakie High (Dunstable Volcanics, Theresa Creek Volcanics etc.). Their presence in close proximity to the eastern margin of the Anakie High indicates that the Drummond Basin sequence does not extend far to the east below the Bowen Basin sequence (Fig. 4).

The section of Figure 5 shows that the basement west of the Drummond Basin slopes gently to the south from about 2000 feet above sea level in the Ravenswood Arch to about 5600 feet below sea level at Maranda. The Bouguer Anomaly map (Plate 2) shows a gravity low in this northern area, which was interpreted as a basement low (Gibb, 1966), but is now believed to be due to the presence of widespread low-density rocks including acid volcanics and granite in the basement. South of Maranda, basement deepens to more than 7800 feet below sea level; if the Drummond and Adavale Basins were continuous in the Upper Devonian and Lower Carboniferous, then the connection was in this area (see Fig. 27a). Southeastward the basement gradually rises to 2900 feet below sea level at Birkhead, 970 feet at Cunno, and 340 feet at Crystalbrook. This rise in the basement is the Nebine Ridge which is the southerly extension of the Anakie High. The Nebine Ridge has a steep easterly slope, and basement is at least 11,000 feet below sea level at Westgrove No. 3, in the Denison Trough just to the east of the ridge. The ridge consists of granite, acid volcanics, and low-grade metamorphic rocks and it probably supplied much of the sediment laid down in the Drummond and Adavale Basins in the Upper Devonian and Lower Carboniferous.

DRUMMOND BASIN SEQUENCE

The Drummond Basin sedimentation commenced in the Upper Devonian with the deposition of marine sediments in the northern part of the area. The sea extended into this region from the Yarrol and Hodgkinson Basins to the north and east where widespread marine sedimentation took place (Fig. 3).



To accompany Records 1969/19 Q/A234

Fig.7 - Diagrammatic relationships, Drummond Basin sequence.

Uplift and associated vulcanism occurred toward the end of the Devonian. The sea regressed to the north and continental sedimentation commenced in a large intermontane basin. The original extent of the basin is not fully known. The present southern margin is formed by the Nebine Ridge and adjacent basement rocks to the west beneath the Surat Basin. The subsurface Adavale Basin to the southwest, which also received continental sediments during the Upper Devonian and perhaps in the Lower Carboniferous, was probably connected with the Drummond Basin; however they are now separated in the subsurface by a basement ridge, the Blackall Ridge. The western margin of the basin is indicated by seismic work. It is truncated, but probably close to the maximum western extent of the depositional basin; the eastern margin lies beneath the Bowen Basin (Fig. 4).

Sedimentation in the Lower Carboniferous was probably predominantly fluvial and lacustrine and up to 40,000 feet of sediment accumulated. The sediments were transported into and distributed through the basin by a north-flowing river system.

Isostatic and depositional conditions in the region were stable over long periods and even after minor epeirogenic events, causing abrupt changes in sedimentation, these same conditions were re-established. The Drummond Basin sedimentation can, on this basis, be subdivided into three distinct cycles, separated from each other by minor epeirogenic events, and each starting with torrential and ending with mature deposition. The marine and continental sediments of the first cycle were laid down in the Upper Devonian in the north and west of the region. The eastern part of the area was at that time probably being eroded. Widespread vulcanism in the north and east interrupted this pattern of sedimentation in the late Devonian or early Carboniferous (Fig. 27A). The volcanic episode was followed by the deposition of a thick continental sequence in a narrow deeply subsiding basin west of the Anakie High (Cycle 2, Fig. 27B, C & D). The last cycle commenced after renewed uplift and vulcanism in the areas bordering the basin; the Drummond Basin was, during this time, developed to the fullest extent.

The formations in the basin are described in three groups corresponding to the sedimentary cycles during which they were laid down. The volcanics, which were extruded between cycles 1 and 2, are described with cycle 1 because, in the north and southwest of the basin, they are intimately related to the sediments of that cycle.

The evolution of the nomenclature used is set out in Table 2 which also provides a basin-wide correlation of stratigraphic units; the relationships of the formations are shown in Figure 7.

CYCLE 1: Mount Wyatt Formation, Unit D/Cv, Saint Anns Formation, (Silver Hills Volcanics).

The distribution of the units and their relationships are shown in Figure 8.

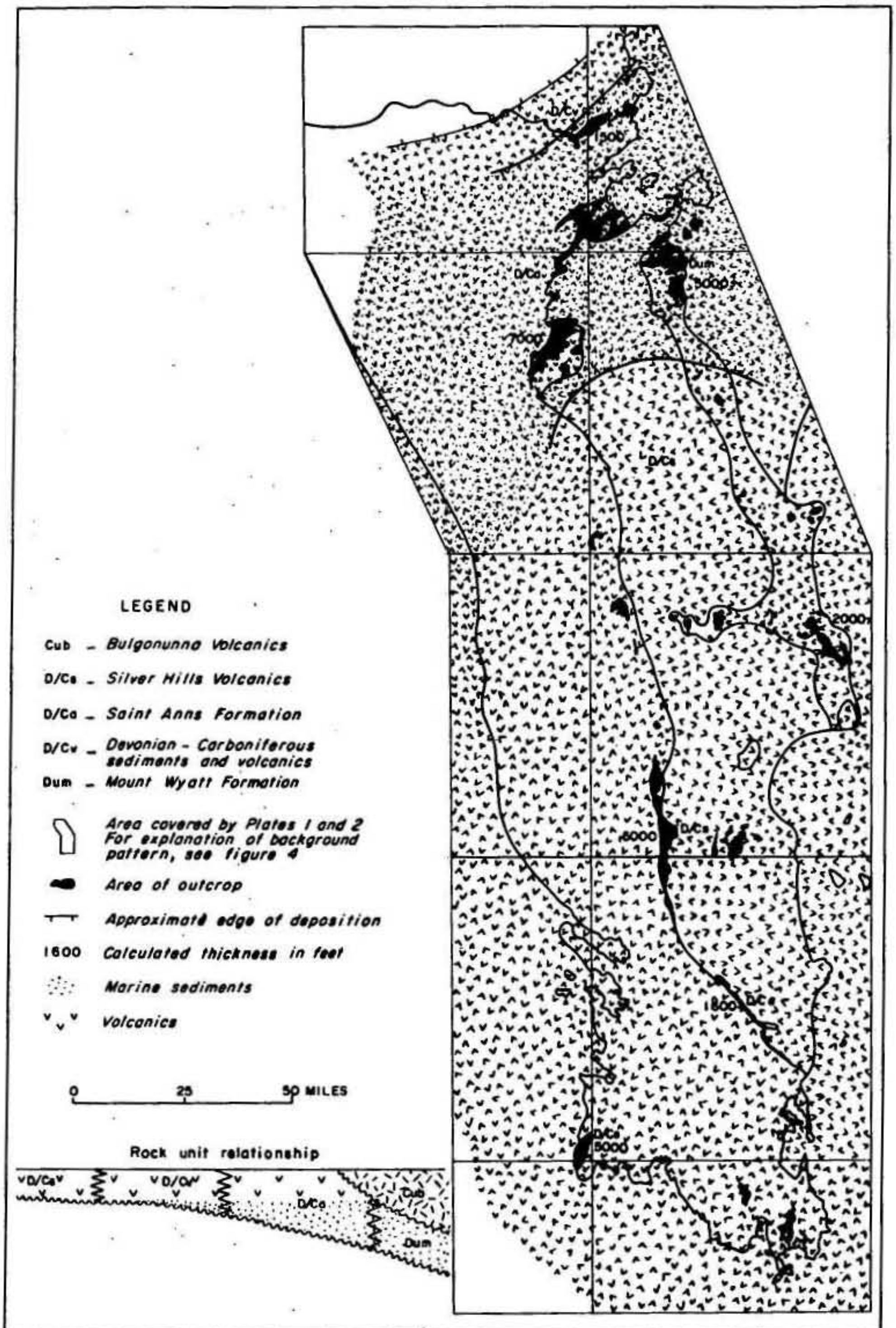
Mount Wyatt Formation (Daintree, 1870)

The Mount Wyatt Beds are renamed here Mount Wyatt Formation. The type area is in the Sellheim River area southeast of Rutherfords Table where the formation is exposed in the north limb of a large syncline (Fig. 9). The formation crops out on the northern margin of the Anakie High north of Mount Wyatt, along its eastern margin between the type area and Mount Coolon, and in two inliers in the Bulgonunna Volcanics east of the type area. Malone et al., (1966) mapped the upper part of the sequence south of the Sellheim River as an unnamed Devonian-Carboniferous volcanic unit, however these rocks are here included in the Mount Wyatt Formation because they are lithologically indistinguishable. Most of the volcanics that were reported from the area by Malone et al., and on which the volcanic unit was presumably based, are quartz-feldspar porphyry and rhyolite sills intruded into the sediments, and outliers of the unconformably younger Bulgonunna Volcanics.

TABLE 2 – Evolution of Drummond Basin stratigraphic nomenclature

Sheet area		SPRINGSURE				EMERALD			CLERMONT		GALILEE ...		BUCHANAN, CHARTERS TOWERS, and BOWEN.	
Reference		SQD, 1952	Hill, 1957	Mollan, in press	This report	Veevers et al, 1964b	de Bretizel, 1966	Olgers, 1966a This report	Veevers et al, 1964a	Olgers, 1966b This report	de Bretizel, 1966	Olgers et al, 1967 This report	de Bretizel, 1966	Olgers et al, 1967 This report
Bowen/Galilee Basin sequence	Upper Carboniferous	Joe Joe Creek Formation	Joe Joe Formation	Joe Joe Formation	Joe Joe Formation	Joe Joe Formation	Joe Joe Formation	Joe Joe Formation				Joe Joe Formation		Bulgonunna Volcanics
Drummond Basin sequence	Lower Carboniferous	Ducabrook Series	Ducabrook Formation (Drummond Series)	Ducabrook Formation	Ducabrook Formation	Ducabrook Fm (Drummond Group)	Ducabrook Formation	Ducabrook Formation	Ducabrook Fm. (Drummond Beds)	Ducabrook / Mount Rankin Formation		Ducabrook Formation	Bulliwallah Formation (Drummond Beds; Bulgonunna Volcanics)	Natal Fm; Bulliwallah Formation
					Star of Hope Formation		Star of Hope Formation	Star of Hope Formation		Star of Hope Formation	Star of Hope Formation	Star of Hope Formation	Star of Hope Formation	Star of Hope Formation
		Flaggy Sandst. Group (Snake Range Series)	Raymond Flaggy Sst. (Snake Range Group)	Raymond Sandstone	Raymond Formation	Raymond Sst	Raymond Sandstone	Raymond Formation	Raymond Sst.	Raymond Formation	Raymond Sandstone	Raymond Formation	Saint George Ck Formation	Raymond Formation
		Mount Hall Congl.	Mount Hall Congl.	Mount Hall Conglomerate	Mount Hall Formation	Mount Hall Congl.	Narrien Conglomerate	Mount Hall Formation	Mount Hall Fm	Mount Hall Formation	Narrien Conglomerate	Mount Hall Formation	Bingeringo Conglomerate	Mount Hall Formation
				Telemon Formation	Telemon Formation		Upper Telemon Formation	Telemon Formation	Telemon Fm	Telemon Formation	Upper Telemon Formation	Telemon Formation	Scartwater Formation	Scartwater Formation
	Upper Devonian	Multi-coloured Group; Congl. Group (Telemon Series)	Telemon Formation	Silver Hills Volcanics	Silver Hills Volcanics	Telemon Formation; Silver Hills Volcanics	Lower Telemon Formation	Silver Hills Volcanics	Silver Hills Volcs.; Theresa Creek Volcanics (Mount Rankin Beds)	Silver Hills Volcanics	Lower Telemon Formation	Silver Hills Volcanics	Mount Wyatt Beds	Mt Wyatt Fm: Llanarth Volc. M.; Saint Anns Fm
Basement	Middle Devonian	Dunstable Series	Dunstable Formation	Dunstable Volcanics	Dunstable Volcanics	Volcanics and limestone at Glendarriwell Limestone	Dunstable Formation	Volcanics and limestone at Glendarriwell Limestone	Siltstone; Douglas Ck Lms.	Theresa Ck Volcanics; Douglas Creek Limestone ([illegible])	Silver Hills Volcanics; Anakie Metamorphics	?	Ukalunda Beds	Ukalunda Beds
	Pre-Devonian	Anakie Metamorphics	Anakie Metamorphics	Anakie Metamorphics	Anakie Metamorphics	Anakie Metamorphics	Anakie Metamorphics	Anakie Metamorphics	Anakie Metamorphics	Anakie Metamorphics		Anakie Metamorphics		Anakie Metamorphics

/ Correlation within Sheet areas. / Correlation between Sheet areas; only shown where lateral correlation does not apply.



To accompany Records 1969/19 Q/A235

Fig.8 - Cycle 1 sedimentation (Mount Wyatt Formation, Saint Anns Formation, unit D/Cv) and Silver Hills Volcanics.

The Mount Wyatt Formation consists of a great variety of lithological types; sediments predominate but volcanics are present, particularly near the top of the exposed sequence in the Rosetta Creek area (3 miles south of the southern boundary of Figure 9 along the Mount Coolon road).

North of Mount Wyatt, the formation consists mainly of thinly bedded olive-green siltstone, shale, and tuffaceous feldspathic-lithic sandstone. Conglomerate, containing pebbles of granite, chert, and volcanic and sedimentary rocks, crops out in Percy Douglas Creek and in Wynne Creek near their junction. The conglomerate in Wynne Creek contains abundant marine fossils, mainly Cyrtospirifer. Plant fossils, including Leptophloeum australe are present in the finer grained sediments directly overlying the conglomerate (Appendix).

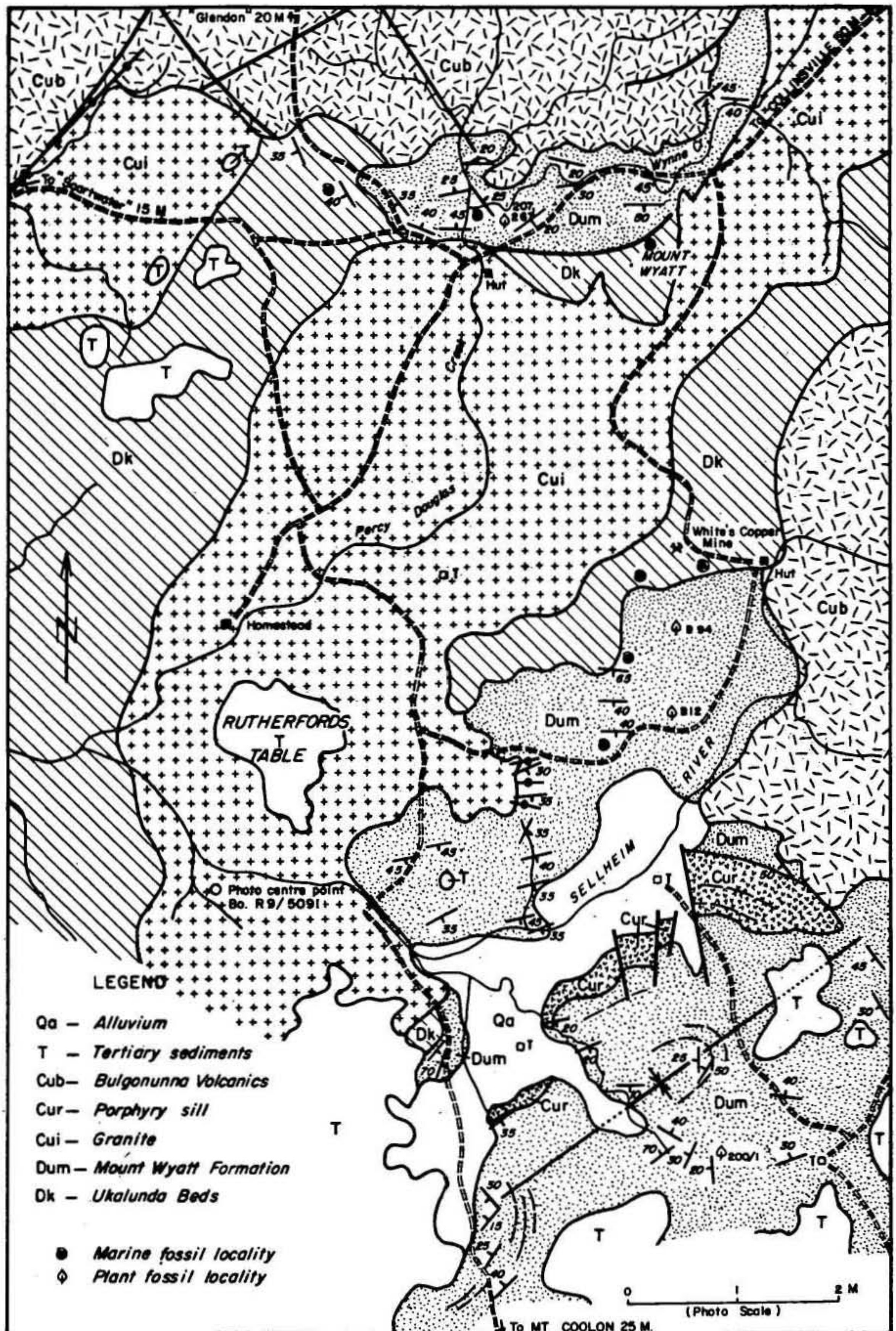
In the type area and farther to the south, the lower part of the formation consists mainly of green, khaki and grey shale, siltstone and lithic sandstone containing marine fossils and plants. Some thin beds of conglomerate, containing pebbles of granite and quartz, are interbedded. This basal sequence, which is lithologically similar to the rocks at Mount Wyatt, is overlain by well bedded chert, poorly sorted lithic-feldspathic sandstone, shale, and siltstone containing plant debris, thin beds of conglomerate, some tuff, and at the Sellheim River, thick-bedded feldspathic-lithic sandstone containing pieces of flaggy siltstone up to 4 inches in diameter. The sandstone is cross-bedded and ripplemarked. Many of the finer grained rocks also show cross-bedding and ripplemarking. South of the Sellheim River, the outcrop is poor. It consists mainly of greenish and grey feldspathic-lithic sandstone, olive-green mudstone, and conglomerate containing abundant volcanic pebbles. Some beds of tuff and crystal tuff occur in this upper part of the sequence.

Farther south at the Mount Coolon to Ukalunda road crossing of Rosetta Creek, the formation consists of khaki-brown tuffaceous lithic sandstone, siltstone, conglomerate, and some tuffs and thin flows. The rocks at Rosetta Creek crop out in the centre of a syncline and they are probably the youngest exposed rocks of the Mount Wyatt Formation.

The Mount Wyatt Formation is the only unit in the Drummond Basin sequence which contains marine fossils. Most of these belong to a species closely allied to Cyrtospirifer cf. reidi (Maxwell). They were found at several localities in the type area and in one locality northwest of Mount Wyatt, all in the lower part of the formation. Plants, including Leptophloeum australe, are abundant (Appendix). The fossils date the lower part of the formation as high Upper Devonian (Famennian).

The thickness of the Mount Wyatt Formation is not known because the top of the unit is not preserved and the base is probably faulted in the type area, but at least 5000 feet are exposed in the type area.

The Mount Wyatt Formation unconformably overlies the Ukalunda Beds and is unconformably overlain by the Upper Carboniferous Bulgonunna Volcanics. The lower unconformity is only exposed in a small tributary of Percy Douglas Creek two miles west-northwest of Mount Wyatt (Fig. 9) where conglomerate unconformably overlies sheared siltstone and bryozoal limestone of the Ukalunda Beds. All other contacts are faulted, brecciated, or intrusive. At Mount Wyatt, the formation dips southerly apparently under the Ukalunda Beds which make up the summit of the mountain; however the boundary is faulted and partly intruded by a trachyte dyke. The contact with the underlying Ukalunda Beds in the type area is poorly exposed. The rocks are extensively brecciated, probably due to faulting.



To accompany Records 1969/19 F55/A/111

Fig.9 - Main areas of outcrop of the Mount Wyatt Formation.

The formation is intruded by granite at Mount Wyatt and east and south of Rutherfords Table. Thin zones of highly sheared and brecciated Ukalunda Beds lie between the granite and Mount Wyatt Formation at several localities, notably west of Mount Wyatt just west of Percy Douglas Creek.

The Mount Wyatt Formation can be correlated with the sediments which, in places, make up the lower part of Unit D/Cv and which crop out north of the Burdekin River along the southern margin of the Ravenswood Arch, and with the lower dominantly sedimentary part of the Saint Anns Formation which crops out along the northern and western margins of the Anakie High (Fig. 8). The youngest rocks of the Mount Wyatt Formation, cropping out in Rosetta Creek, are probably equivalent to the middle part of the Saint Anns Formation. The Mount Wyatt Formation can possibly partly be correlated with the sequence encountered in Lake Galilee No. 1 between 9320 and 11175 feet (see Table 5). This sequence is partly of early Upper Devonian age extending probably into the late Upper Devonian. The lower exposed part of the Mount Wyatt Formation is late Upper Devonian.

The Mount Wyatt Formation is the only unit in the basin containing marine fossils. They are closely associated with plant fossils, mainly stems. The sediments were laid down in a near-shore shallow water marine and paralic environment with sediment being brought in by streams draining neighbouring areas composed of low-grade metasediments, granite and volcanic rocks. These deposits were little reworked as indicated by the presence of well preserved shells and no fragmental shell material in the conglomerate. Vulcanism occurred, particularly in the late history of the formation.

Saint Anns Formation (Olgers et al., 1967)

The Saint Anns Formation is a new unit defined here as the sequence of rocks that unconformably overlies the Ukalunda Beds and is conformably overlain by the Scartwater Formation. The formation was laid down in the northern part of the basin and crops out along the northwest margin of the Anakie High. The best exposures are in the vicinity of Saint Anns homestead where the type area is.

In the type area, the formation is about 7000 feet thick and can roughly be subdivided into three parts: a sedimentary sequence about 2200 feet thick at the base, which grades into a dominantly volcanic sequence with interbedded limestone in the middle (1100 feet), and a volcanic unit, 3700 feet thick, at the top. In the Saint Anns area, this upper volcanic sequence has a distinctive air-photo pattern and it was mapped as the Llanarth Volcanics (Olgers et al., 1967). Subsequent mapping has shown that north of the type area the Llanarth Volcanics could not be recognized as a separate unit. It is clear that the lower part of the Saint Anns Formation consists mainly of sediments and the upper part is largely made up of volcanics, but facies changes, complex structure, and poor outcrop make subdivision impossible. Consequently, the name Llanarth Volcanics is changed here to Llanarth Volcanic Member of the Saint Anns Formation.

The basal sedimentary sequence of the formation crops out in a more or less continuous belt west of the Anakie High from Mount Douglas homestead in the south to Pyramid homestead in the northeast. It consists of many different rock types, including conglomerate, sandstone, mudstone, and limestone, and rapid changes in lithology, both lateral and vertical, do occur. Outcrop is generally poor. The sediments are mostly thin-bedded, fine to coarse-grained, and commonly have a partly calcareous matrix. Conglomerate and conglomeratic sandstone containing pebbles and fragments of granite, and acid volcanic and schistose rocks occur in many areas at the base of the sequence. The conglomerates are overlain by lithic sandstones, containing fragments of schist, black and green chert, and varying quantities of quartz and feldspar, thin-bedded chert, olive-green mudstone, and oolitic and algal limestone. The limestones are in most places impure, containing fragments of quartz and feldspar and pieces of schist; they are commonly irregularly silicified and contain in places numerous worm tubes. The limestones are most common in the Saint Anns homestead area. Volcanic rocks, including agglomerate and tuff, are present in the lower part of the formation, but they are rare. At the top of the sedimentary sequence southwest of Saint Anns homestead are two beds of phosphatic sandstone containing up to 15% P_2O_5, separated by fine-grained acid tuffs. The sedimentary sequence in the Saint Anns homestead area grades upward into a succession dominated by fine-grained acid tuffs, crystal lithic tuff containing fragments of schist and acid volcanic rocks, and lapilli tuff, with some interbeds of algal limestone and fine-grained sediments. The top of this middle sequence is, two miles south of Saint Anns homestead, marked by a massive conglomerate containing abundant material derived from the underlying sediments including large slabs of limestone, and schistose rock fragments from the Anakie High. The remainder of the formation above the conglomerate is made up of the fine-grained acid tuffs of the Llanarth Volcanic Member.

The basal dominantly sedimentary sequence north of the type area is overlain by interbedded volcanics and sediments with a marked increase in the proportion of volcanics to sediments toward the top of the formation. The sediments are mainly lithic and tuffaceous, sandstone, with interbeds of conglomerate, calcareous and ferruginous siltstone, mudstone, and some limestone containing worm tubes. The volcanics are mainly tuff, lithic tuff, agglomerate, and flows of rhyolite and porphyritic dacite.

The Saint Anns Formation unconformably overlies the Middle Devonian Ukalunda Beds. The unconformity is best exposed northeast of Scartwater homestead where steeply east-dipping Ukalunda beds are overlain by gently west-dipping rocks of the Saint Anns Formation. At the contact are thick lenses of boulder conglomerate. Near the base of the Saint Anns Formation west of Pyramid homestead is a conglomerate containing fossiliferous limestone pebbles derived from the Ukalunda Beds.

The lower sedimentary part of the formation was laid down in a near-shore shallow water marine or paralic environment and can be correlated with the Mount Wyatt Formation and the lower part of Unit D/Cv. The volcanic sequence at the top of the formation, which was laid down partly on land and partly in water, is equivalent to the upper part of unit D/Cv and the Silver Hills Volcanics (Fig. 8).

The Saint Anns Formation contains a rich flora (Appendix). The age of the formation is not exactly known, but it is, on stratigraphic grounds, considered to be mainly Upper Devonian, but possibly extends into the Lower Carboniferous.

Devonian-Carboniferous volcanics and sediments (D/Cv)

A sequence of rocks composed mainly of purplish acid volcanics including flow banded rhyolite, quartz-feldspar porphyry, volcanic breccia, agglomerate, crystal tuff, and tuff with minor vulcanolithic and lithic sandstone is exposed along the northern margin of the Drummond Basin. The extent of these rocks is not known because of overlap by the Upper Carboniferous Bulgonunna Volcanics in the east, and the Lower Carboniferous Scartwater Formation in the west. About 1500 feet of volcanic rocks crop out north of Cranbourne homestead.

North of the Suttor/Burdekin River junction and eastward along the margin of the Drummond Basin, the typical purplish volcanic sequence is underlain by khaki, brown, and greenish vulcanolithic conglomerate and sandstone, crystal and crystal lithic tuff, and siltstone. This sequence, which is extensively faulted and intruded by porphyry dykes, is not present below the volcanics north of Cranbourne homestead. It is probably equivalent to the Mount Wyatt Formation and the lower part of the Saint Anns Formation. The volcanics are equivalent to the upper part of the Saint Anns Formation and the Silver Hills Volcanics (Fig. 8).

<u>Silver Hills Volcanics</u> (Veevers et al., 1964b)

The formation is named after Silver Hills homestead, 13 miles west-northwest of Anakie in the Emerald Sheet area. The type area is one mile west of the homestead.

The Silver Hills Volcanics were originally mapped only west of the Anakie High in the Emerald and Clermont Sheet areas, but they have since been recognized on and to the east of the high and in the core of the Nogoa Anticline west of Springsure. The volcanics were laid down over a large area in the south and central region of the Drummond Basin. They are best exposed in the core of the Mount Beaufort Anticline and along the western margin of the Anakie High, where they form a prominent range.

The formation consists mainly of spherulitic and flow-banded rhyolite, trachyte, and acid welded tuff. Andesite, agglomerate, tuff, lithic sandstone, and mudstone are also present.

In the type area the formation consists mainly of spherulitic rhyolite and trachyte with minor siltstone. In the Mount Beaufort Anticline, Veevers et al. (1964b) mapped only the rhyolite at Mount Beaufort as Silver Hills Volcanics; the overlying volcanic rocks and interbedded sediments, including red beds, and containing <u>Leptophloeum australe</u> were included in the Telemon Formation. The Telemon Formation in the type area does not contain any flow rocks, and the entire volcanic sequence in the Mount Beaufort Anticline is now included in the Silver Hills Volcanics. Mount Beaufort consists largely of spherulitic and flow-banded rhyolite and is probably a volcanic dome. Some outcrops in the northeast of the Clermont Sheet area consist of vertically flow-banded rhyolite; they are probably also vents.

The Silver Hills Volcanics are a sequence of mainly terrestrial volcanics which were extruded over a large area in the south of the region over a terrain made up of the folded Anakie Metamorphics, the Retreat Granite, and small isolated areas of lower Middle Devonian volcanics and limestone. The unconformity is well exposed southwest of Clermont where a thin sequence of sedimentary rocks containing granitic and metamorphic debris lies between the basement rocks and the volcanic sequence, and in the Fletchers Awl area where the unconformity is marked by a conglomerate containing pebbles of intermediate volcanics, granite, and metamorphics. In Eastern Creek, the basal beds of the Silver Hills Volcanics contain boulders of the Anakie Metamorphics.

The Silver Hills Volcanics can be correlated with a similar volcanic sequence that was extruded along the northern margin of the basin (the upper part of unit D/Cv), and with the upper part of the Saint Anns Formation (Fig. 8). The sequence of rocks, including red beds and tuffs, which was encountered between 5507 and 9142 feet in the Jericho No. 1 well 60 miles west of the Mount Beaufort Anticline, and which has been correlated with the Buckabie Formation of the Adavale Basin (red beds), is probably equivalent to the Silver Hills Volcanics in the core of the Mount Beaufort Anticline (flow rocks, tuffs and red beds).

The volcanics are probably late Upper Devonian extending into the Lower Carboniferous because they overlie the Upper Devonian Retreat Granite, and contain in sedimentary interbeds, the plant fossil Leptophloeum australe (Appendix).

The greatest known thickness of 5000 feet occurs along the western margin of the Anakie High west of Clermont. A similar thickness may be present in the Mount Beaufort Anticline. The formation thins towards the north, and only a thin veneer remains in places on the Anakie High. At least 2000 feet are present east of the high.

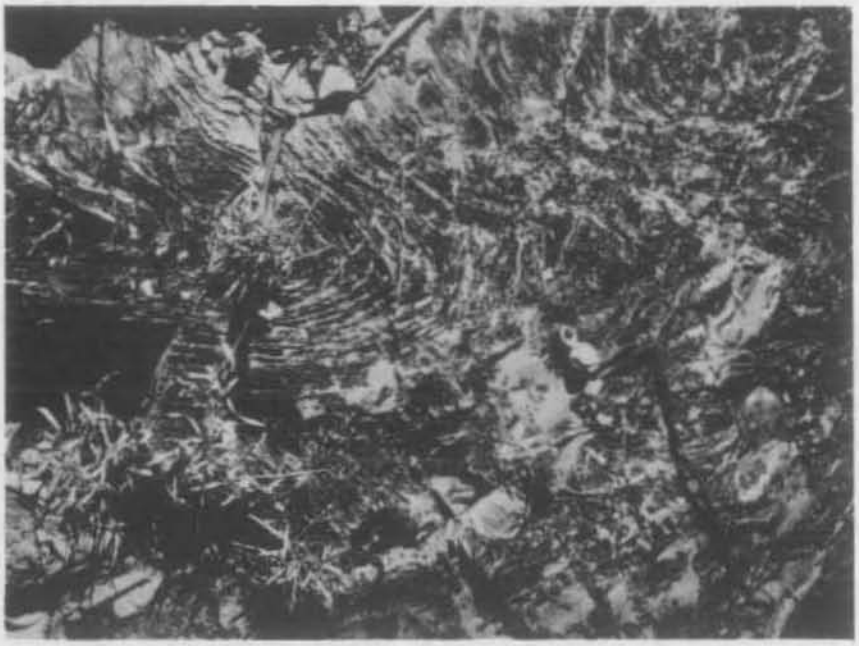


Fig.10 - Flow-banded rhyolite of the Silver Hills Volcanics, Red Mountain, 28 miles west of Clermont. (Neg.No.GA/1530)

CYCLE 2: Telemon, Scartwater, Mount Hall, and Raymond Formations.

The relationships between the units are shown in Figure 7. The succession consists largely of fluvial sediments. The Mount Hall Formation, the best marker formation in the basin, consisting of grey quartz sandstone, pebbly quartz sandstone and conglomerate, was laid down in the central part of the basin west of the Anakie High in an elongate meander belt comprising mainly pointbar and channel lag deposits, which were largely laid down by a north-flowing river system. These deposits are underlain by, and laterally grade into and interfinger with floodplain deposits, also largely derived from the south, and with piedmont alluvial plain deposits derived from the lateral margins of the basin. These sediments have been mapped as the Telemon Formation in the south, and the Scartwater Formation in the north (Fig. 28). The Mount Hall, Telemon, and Scartwater Formations are overlain by the fine-grained fluvial sandstones and mudstones of the Raymond Formation.

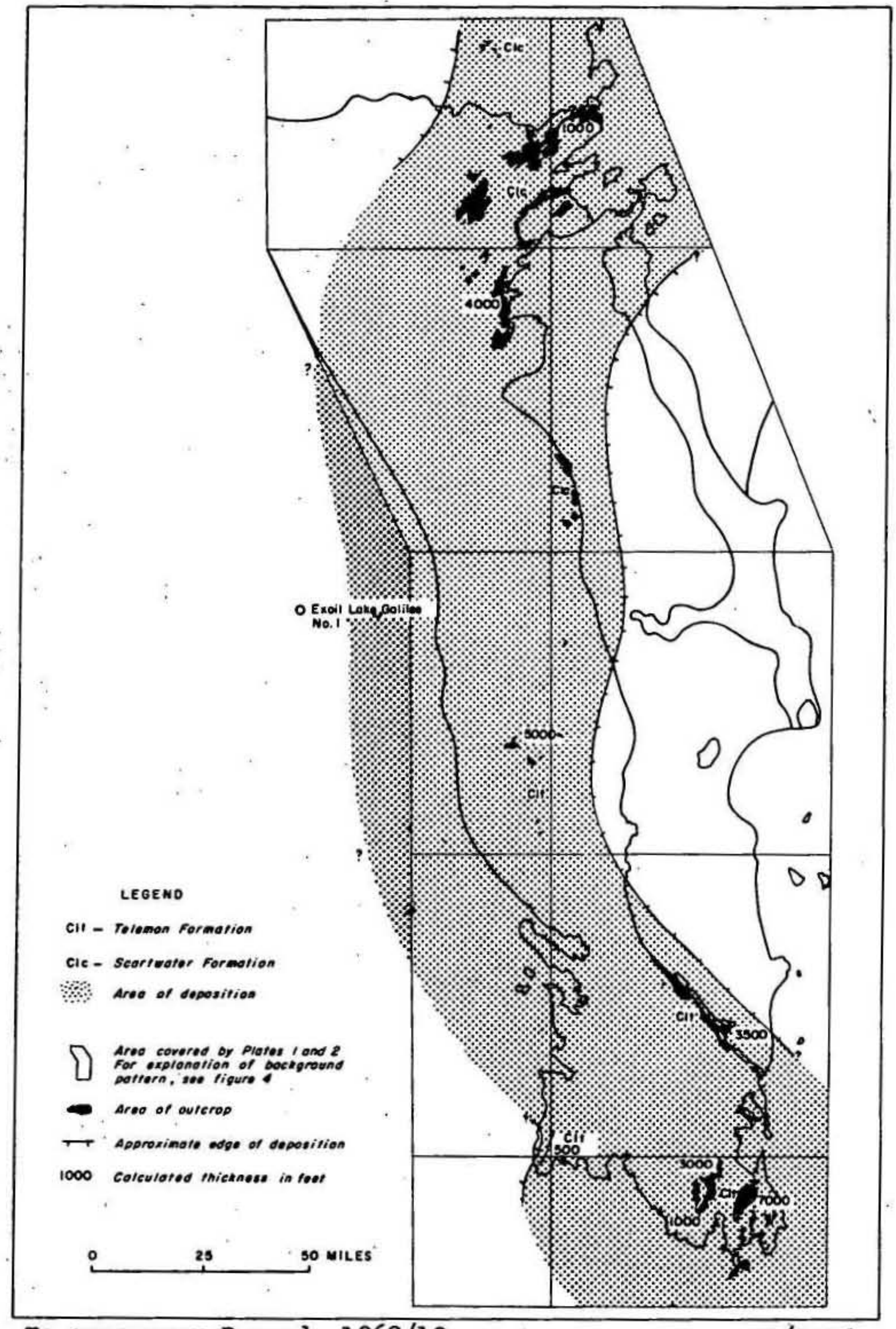
Telemon Formation (Hill, 1957)

The Telemon Formation crops out in the cores of the Telemon, Nogoa and Mount Beaufort Anticlines in the south of the area, along the eastern margin of the basin west of Anakie, and in the central region in the cores of the Narrien and Beresford Anticlines. Equivalent sediments of the Scartwater Formation crop out in the northern Drummond Basin (Fig. 11).

In the Nogoa Anticline, the formation rests unconformably on the Silver Hills Volcanics, and in the Telemon Anticline it is unconformable on the Silver Hills Volcanics, Anakie Metamorphics and Retreat Granite. The Telemon Formation and underlying Silver Hills Volcanics are also exposed in the Mount Beaufort Anticline and along part of the eastern margin of the basin; however the relationship between the units is not clear. Conglomerates occur in most areas at the contact and the relationship is probably disconformable. The base of the Telemon Formation is not exposed in the Narrien and Beresford Anticlines. The Telemon Formation is overlain by and interfingers with the Mount Hall Formation, and is overlain by the Raymond Formation where the Mount Hall Formation was not deposited. The relationship between the Telemon Formation and Mount Hall Formation is transitional and is discussed with the Mount Hall Formation. The relationship with the Raymond Formation is disconformable. West of Clermont, the Telemon Formation is overlapped by the Raymond Formation.

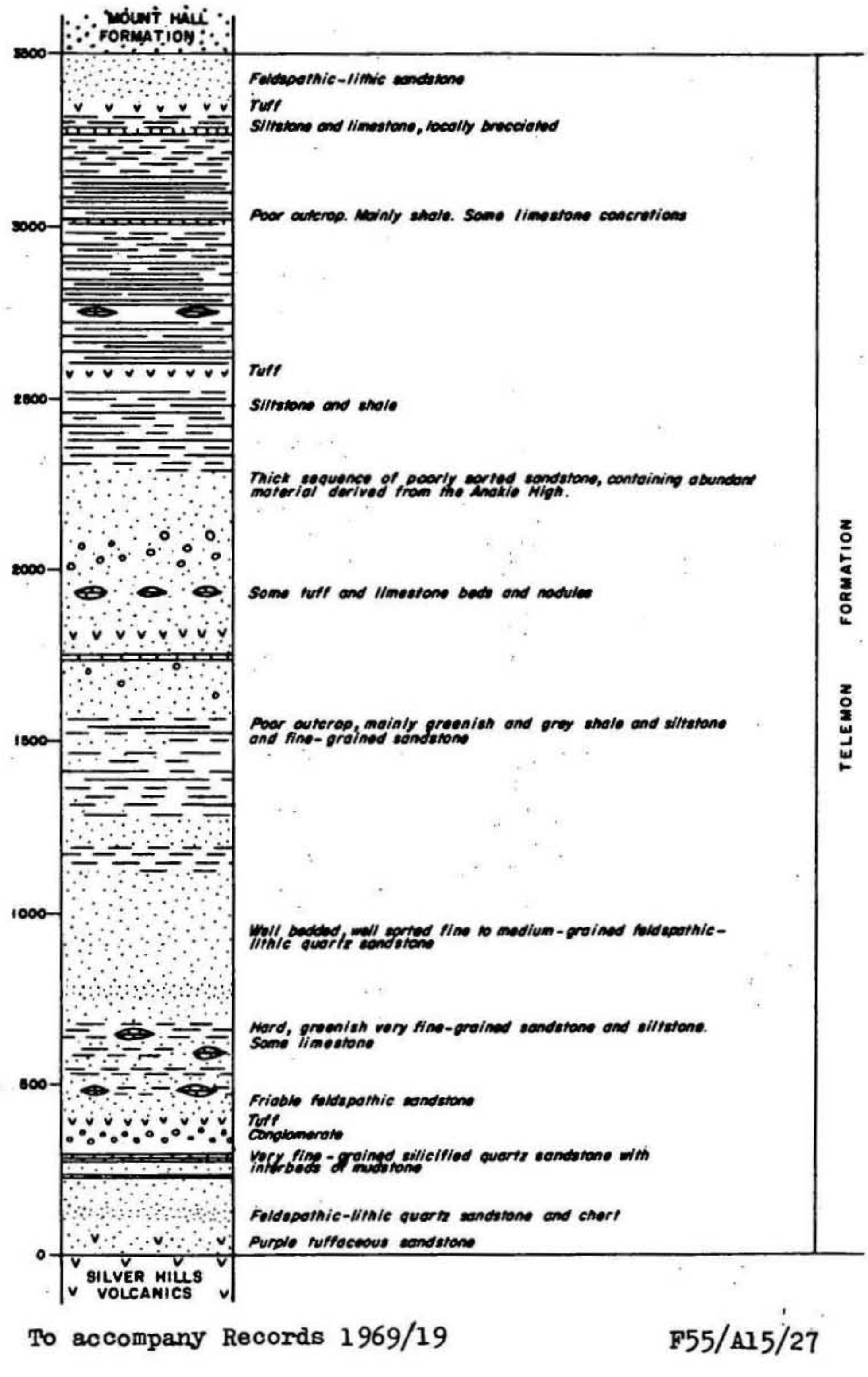
In the Nogoa and Telemon Anticlines, the formation can be subdivided into a basal sequence of conglomerate and conglomeratic sandstone, and an upper sequence of fine-grained sediments and limestone. The conglomerate is commonly cross-bedded and consists of well rounded pebbles and cobbles of milky quartz, quartzite, schist, feldspar-porphyry and various other igneous rocks set in a coarse, poorly sorted matrix of rock fragments, quartz and feldspar. Most of the pebbles and cobbles in the basal conglomerate in the Telemon Anticline consist of volcanics similar to those in the underlying Silver Hills Volcanics. The conglomerates are interbedded with reddish-brown flaggy lithic sandstone,chert, shale, mudstone, and tuffaceous sandstone.

The finer grained upper part of the formation consists mainly of olive-green, brown, and red sandstones including quartz sandstone, arkose, and lithic sandstone, interbedded with varicoloured mudstone and hard red siltstone. Thin bands of concretionary and algal limestone occur throughout the upper part of the formation, usually interbedded with the mudstone. The individual algal colonies are commonly spheroidal, dome-shaped, and cylindrical. The sediments are generally cross-bedded; faint graded bedding is evident in some of the sandstones, and sole marks and current striations are also present.



To accompany Records 1969/19 Q/A236

Fig.11 - Telemon and Scartwater Formations palaeogeography.



To accompany Records 1969/19 F55/A15/27

Fig.12 - Measured section in the Telemon Formation northeast of Withersfield, Emerald Sheet area.

West of Anakie, the Telemon Formation is generally finer grained than in the south of the area and cannot be subdivided. It consists mainly of olive-green mudstone and shale with thick interbeds of sandstone and some conglomerate. The conglomerate makes up only a small part of the formation in this area and occurs at the base and in the upper part of the sequence (Fig. 12). The sandstones are green and grey, fine to coarse-grained, poorly sorted, and generally well bedded. They consist mainly of quartz (65-75%), feldspar and rock fragments in varying proportions, and little matrix. The rock fragments are mainly chert, quartzite, mica schist, sedimentary rocks, and some grains of granite. Some of the sandstones are pebbly or conglomeratic containing mainly quartz pebbles, but also purple acid volcanics, low-grade metamorphics, and chert. Thin beds and concretions of limestone are interbedded.

In the Mount Beaufort Anticline, the formation crops out in a narrow belt in the east limb. Most of the rocks in the anticline were previously included in the Telemon Formation (Veevers et al., 1964b), but they are now mapped as Silver Hills Volcanics (see page 27). At the base of the Telemon Formation is a boulder conglomerate containing boulders of flow-banded and spherulitic rhyolite up to two feet in diameter set in a pebbly lithic sandstone matrix. Thin beds of lithic sandstone are interbedded with the conglomerate. It is overlain by purple siltstone, thin beds of agglomerate and tuff, and olive-green mudstone containing cushions of algal limestone and thin interbeds of lithic sandstone.

In the Narrien Anticline, the formation crops out in two small areas and consists of feldspathic quartz sandstone and green mudstone with minor fine and coarse-grained acid tuff. In the Beresford Anticline, the Telemon Formation consists of a thick sequence of olive-green and brown mudstone with some limestone, overlain by 2000 feet of interbedded quartz sandstone and mudstone which can be regarded as transitional between the Telemon and overlying Mount Hall Formation.

The thickness of the Telemon Formation varies considerably from 7000 feet in the Nogoa Anticline, to 500 feet in the Mount Beaufort Anticline (Fig. 11). The lower conglomeratic sequence thins rapidly to the west and north from 2000 feet in the Nogoa Anticline to about 50 feet in the Telemon and Mount Beaufort Anticlines and along the eastern margin of the basin west of Anakie.

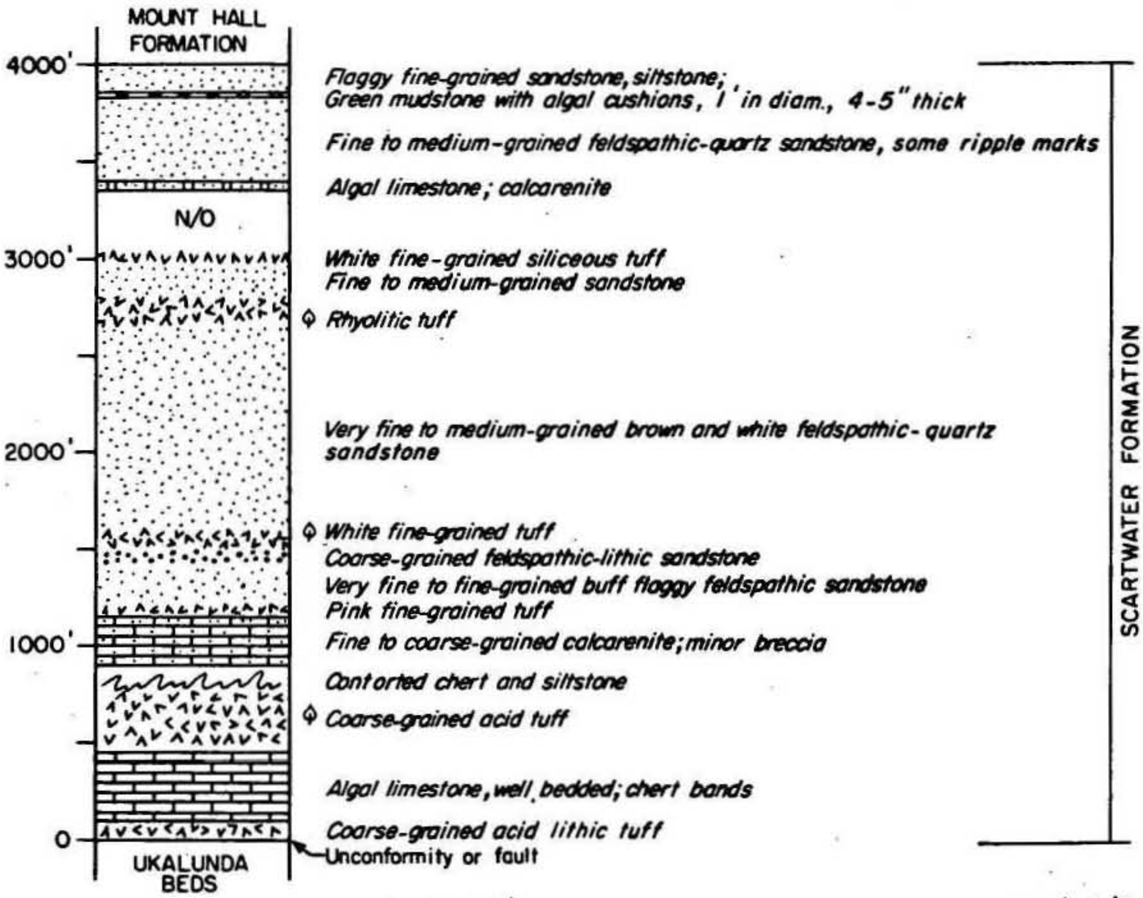
The only fossils found in the formation are plants (Appendix), algae, fish scales, and the brachiopod Leaia (SQD, 1952). None of these fossils is diagnostic, and the age of the formation is not exactly known but is, on stratigraphic grounds, considered to be Lower Carboniferous.

Scartwater Formation (de Bretizel, 1966).

The name Scartwater Formation was first used by de Bretizel for the sequence of rocks between the Saint Anns Formation below, and the Mount Hall Formation above. The name is derived from Scartwater homestead in the northeast of the Buchanan Sheet area. The type area is 10 miles south of the homestead.

The formation crops out in the northern part of the Drummond Basin in a long and narrow belt along its eastern margin, in isolated areas of outcrop west of Scartwater homestead, and in a northeast trending belt from Dandenong Park homestead to Glenroy homestead.

The Scartwater Formation consists of brown, grey, and greenish-grey sandstones composed mainly of quartz with small amounts of feldspar, rock fragments and clay matrix. They are generally well sorted and well bedded, and range from very fine to coarse-grained. Small-scale cross-bedding occurs and ripple marks have been observed. Interbedded with the sandstones are olive-green mudstones which commonly contain calcareous concretions up to 12 inches in diameter and 2 or 3 inches thick. The sandstones and mudstones are the characteristic rock types of the formation. Interbedded are thin beds of limestone, conglomerate, tuff, and lithic sandstone.



To accompany Records 1969/19 F55/A6/8

Fig.13 - Reference section, Scartwater Formation, west of Saint Anns homestead, Buchanan Sheet area.

In the type area (Fig. 13), the formation consists mainly of fine-grained sandstone; a thick sequence of algal limestone occurs near the base, and several beds of tuff are present. The proportion of mudstone to sandstone increases northward from the type area; south of Cranbourne homestead, the formation consists of about equal proportions of sandstone and mudstone, and along the northern margin of the basin north of the Burdekin River, it consists mainly of mudstone.

The lower part of the formation is well exposed northwest of Cranbourne homestead where it disconformably overlies the acid volcanic sequence of unit D/Cv and consists of, from the base upward, conglomerate containing volcanic rock pebbles up to 5 inches in diameter, olive-green mudstone with thin interbeds of fine-grained sandstone and a bed of nodular limestone containing fish scales, some lithic sandstone, and a massive conglomerate containing cobbles of porphyritic acid volcanic rocks up to 8 inches in diameter. The conglomerate is overlain by interbedded green mudstone and fine-grained sandstone. About 1500 feet above the base of the formation in this area is a thin sequence of plant-bearing tuff and crystal-lithic tuff interbedded with mudstone and sandstone. The upper part of the section is exposed southwest of Cranbourne homestead and is mainly made up of thin to thick-bedded, well bedded, fine to medium-grained sandstone and mudstone.

The formation is about 4000 feet thick in the type area; it thins to about 1000 feet in the Burdekin River area.

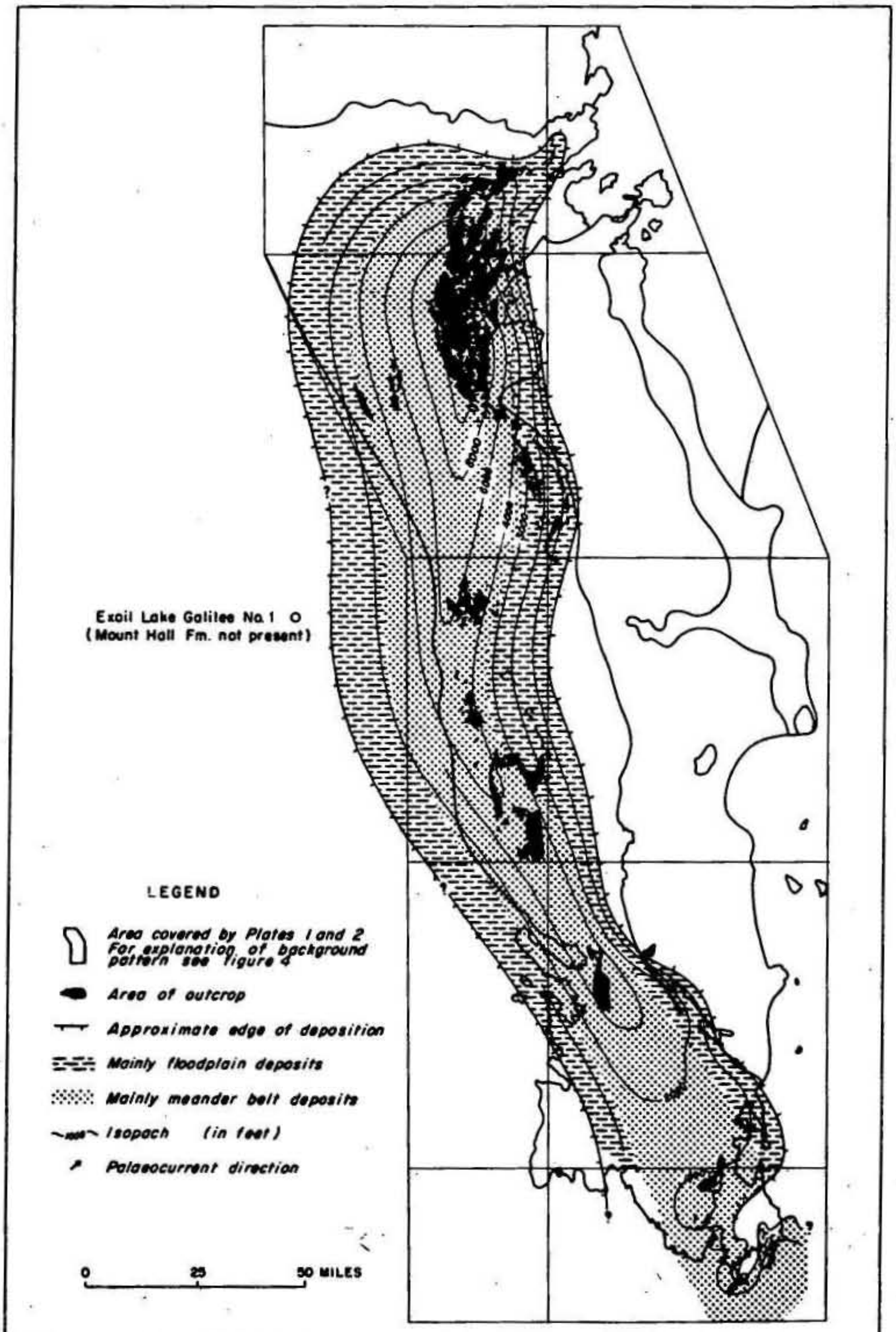
The Scartwater Formation contains a rich Lower Carboniferous flora; it disconformably overlies the Saint Anns Formation and Unit D/Cv, is overlain by and interfingers with the Mount Hall Formation, and can be correlated with the Telemon Formation of the southern part of the basin.

Mount Hall Formation (SQD, 1952)

The Mount Hall Formation was originally named Mount Hall Conglomerate (SQD, 1952) after Mount Hall in the Telemon Anticline, where the type locality is. The formation crops out in the cores of a large number of anticlines and along the eastern margin of the basin west of Anakie and southeast of Mount Douglas homestead; it was probably encountered in Warrong No. 1 Well south of the Drummond Basin outcrop belt (Fig. 5 & Table 5).

Figure 14 shows the areas of outcrop of the formation, isopachs, the prevailing current directions, and the probable limits of the depositional basin with a subdivision into a central belt comprising mainly meander belt deposits, flanked by areas of mainly flood plain deposition.

The Mount Hall Formation consists mainly of grey quartz sandstone, pebbly quartz sandstone, and conglomerate, rock types which are characteristic of the formation and enable it to be readily mapped as a marker formation throughout the basin. The sandstones consist nearly wholly of angular quartz grains with little kaolinitic cement. Some are well sorted and fine-grained, but most are poorly sorted, coarse-grained, and pebbly. The sandstones are thin to thick-bedded and generally cross-stratified. Low-angle planar and trough cross-beds are common and occur in units up to 10 feet thick. Slumping is also common. The pebbles in the pebbly sandstones are scattered throughout the rock, but more commonly occur in pockets, in thin bands parallel to the bedding, or they are concentrated on the foreset beds. The conglomerates consist dominantly of milky quartz pebbles set in a poorly sorted quartz sandstone matrix, but black and green chert, quartzite, and porphyritic volcanic rock pebbles occur also. The coarsest conglomerates contain rounded cobbles up to 12 inches in diameter, mainly of volcanic rocks, but quartz pebbles ranging from 1 to 2 inches in diameter are most common. The conglomerates are also cross-stratified on a large scale and cut and fill structures are common.



To accompany Records 1969/19 Q/A237

Fig.14 - Mount Hall Formation palaeogeography.

Along the central axis of the basin, where the Mount Hall Formation attains the greatest thickness (Fig. 14), the unit consists mainly of conglomerate and pebbly quartz sandstone (Fig. 16). Some thin beds of fine-grained sandstone and mudstone were observed. The very coarse conglomerates containing cobbles up to 12 inches in diameter occur in this part of the basin, particularly in the south. Their most northerly occurrence is in the Mount Gregory area. Some of the larger cobbles are grey quartz-feldspar porphyry which are probably equivalent to the acid volcanic rocks encountered at the bottom of the Thunderbolt and Towerhill wells to the west. Farther to the north in the area of the Bingeringo Anticline and east of the Bulliwallah Syncline, the Mount Hall Formation is mainly composed of pebbly quartz sandstone containing pebbles up to 2 inches in diameter, and quartz sandstone.

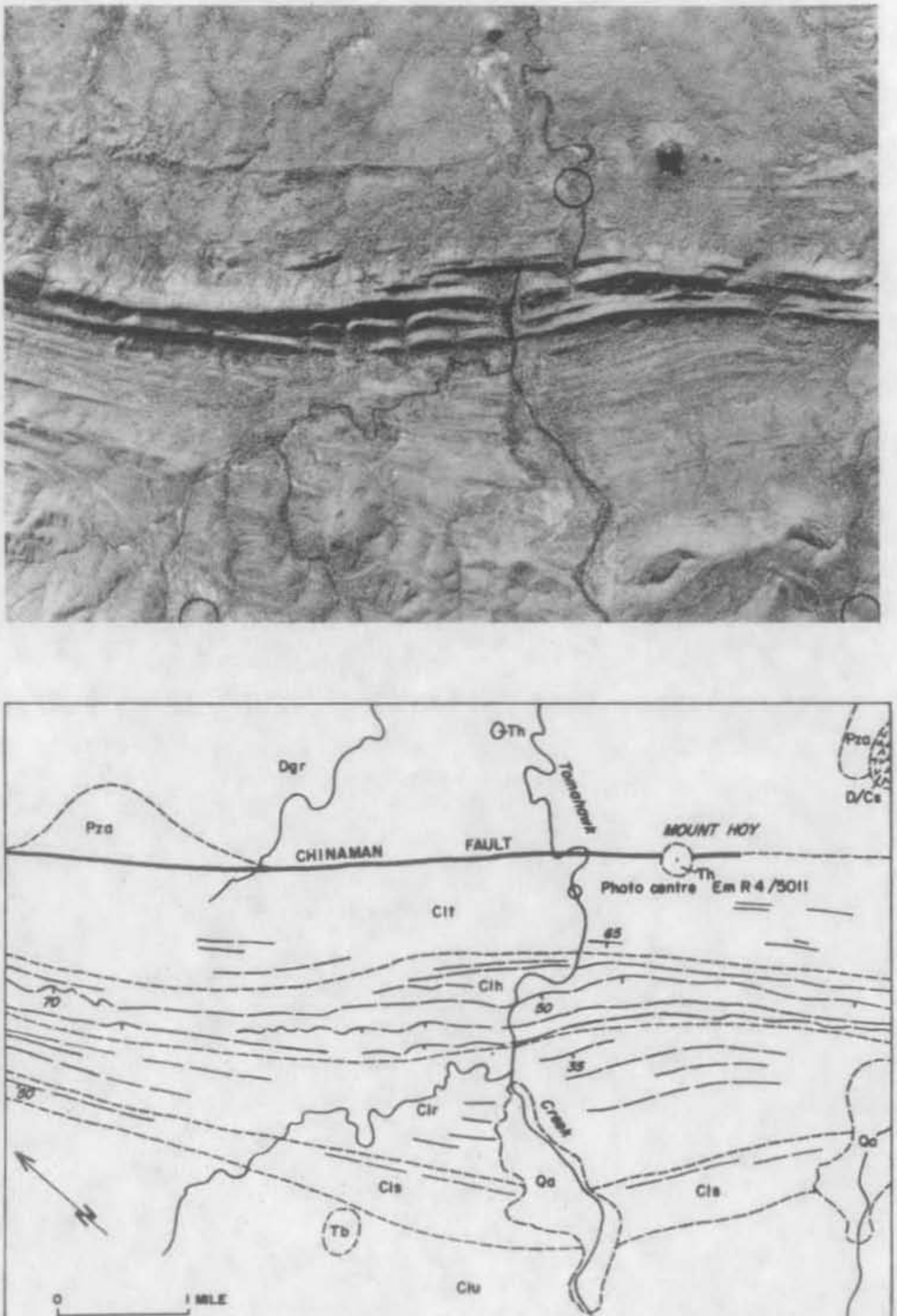
Along the eastern margin of the basin southeast of Mount Douglas homestead and west of Anakie, and in the Vandyke Anticline, the typical grey quartz sandstone and pebbly quartz sandstone of the formation occurs in a number of sharply defined beds which are separated by thick beds of olive-green mudstone and lithic and feldspathic quartz sandstone which are lithologically similar to the rocks of the Telemon Formation. West of Anakie, the quartz sandstone beds can be traced for many miles on the air-photographs (Fig. 15). They range in thickness from 30 to 100 feet but individual beds attain a uniform thickness over a great distance. Lensing, however, does occur. This is most noticeable in the Nogoa Anticline where the formation is represented by a number of isolated lenses up to two miles wide and up to 100 feet thick. In the areas where the typical Mount Hall Formation sands are interbedded with rock types reminiscent of the Telemon and Scartwater Formations, the whole sequence from the base of the lowest sand to the top of the upper sand has been mapped as Mount Hall Formation because it is on a regional scale not practicable to separate them. The interfingering relationship between the two units east of Withersfield is illustrated in Figure 17. The Mount Hall sands pinch out against a high in the basement. Farther to the southeast, south of this high, the sands reappear, interbedded with Telemon Formation sediments.

A similar interfingering relationship with the Scartwater Formation occurs in the northern part of the basin southwest of Cranbourne homestead where a thick sequence of grey quartz sandstone and pebbly quartz sandstone of the Mount Hall Formation interfingers with and grades northeastward into a sequence of greenish quartz sandstone and olive-green mudstone of the Scartwater Formation. East of the Suttor River, in this same region, the Mount Hall Formation consists of two more or less continuous beds of cross-bedded and slumped grey quartz sandstone, up to 50 feet thick, which join near Mount McConnell; from there this bed can be traced northward to the Burdekin River where it lenses out. The two sandstone beds south of Mount McConnell are separated by a sequence of sandstone and mudstone, which has been mapped as Scartwater Formation. At Mount McConnell homestead the formation is 80 feet thick; northeastward it grades into sandstone of the Scartwater Formation.

The thickness of the Mount Hall Formation varies considerably. The greatest thickness was laid down in a narrow north-trending belt directly west of the Anakie High in the central part of the depositional area with a maximum of about 10,000 feet in the north; from the central axis, the formation thins rapidly towards the margins of the basin (Fig. 14).

The formation is in most areas cross-stratified on a large scale. Units up to 10 feet thick but more commonly 2 or 3 feet thick occur in the central part of the basin, and smaller scale cross-bedding in units of 1 or 2 feet are more common near the margins. The cross-bedding is predominantly of the planar and trough types, with dips of foresets ranging from 15 to 30 degrees.

About 300 cross-bed measurements were made at 28 localities, some of which are shown in Figure 14. All readings were stereographically corrected for tilt. The number of measurements at each locality ranges from two in some of the thin sands to 23 in the central part of the basin. The measurement of cross-bedding features was hampered by the broken-up rubbly nature of many of the outcrops and by poor access in some areas. Also, the Mount Hall Formation crops out in a number of widely spaced anticlines along the axis of the basin and along the eastern margin west of Anakie, and measurements



To accompany Records 1969/19

F55/A15/28

Fig.15 - Margin of the Drummond Basin 25 miles west-north west of Anakie. Note lensing and cyclic sedimentation in the Mount Hall Formation (Clh) and to a lesser extent in the Raymond Formation (Clr). (Compare figure 16; see Plate 1 for explanation of symbols)

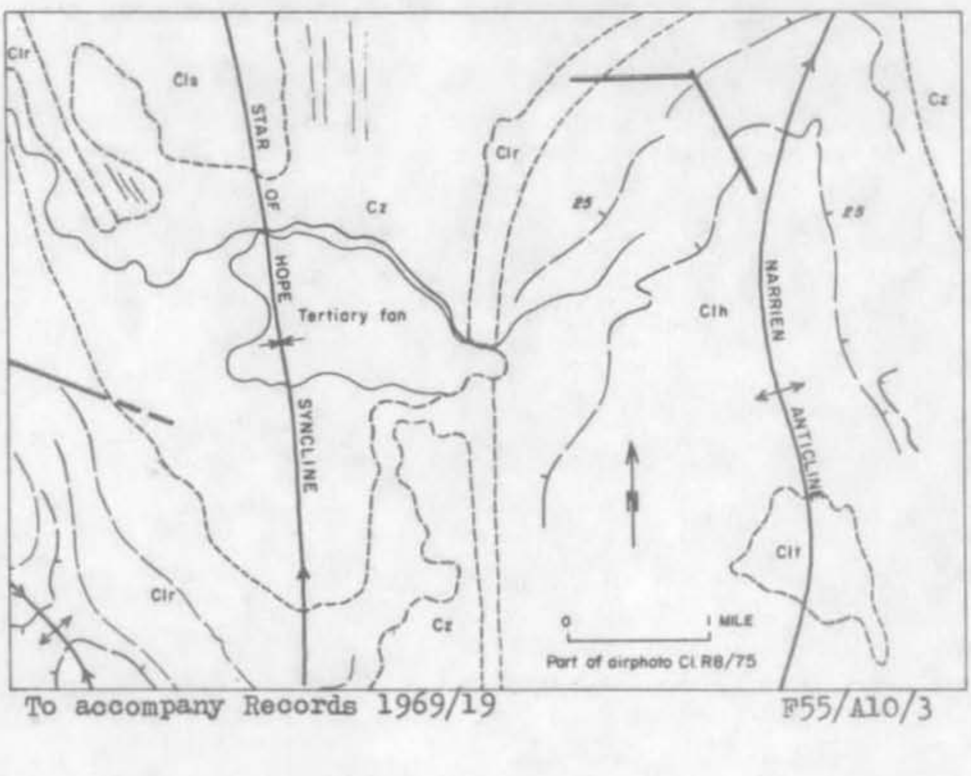


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Fig.16 - Massive conglomerate and sandstone of the Mount Hall Formation in the core of the Narrien Anticline in the central region of the basin (Compare Figure 15; see Plate 1 for explanation of symbols). Note remnants of a Tertiary piedmont alluvial fan in the Star of Hope Syncline.

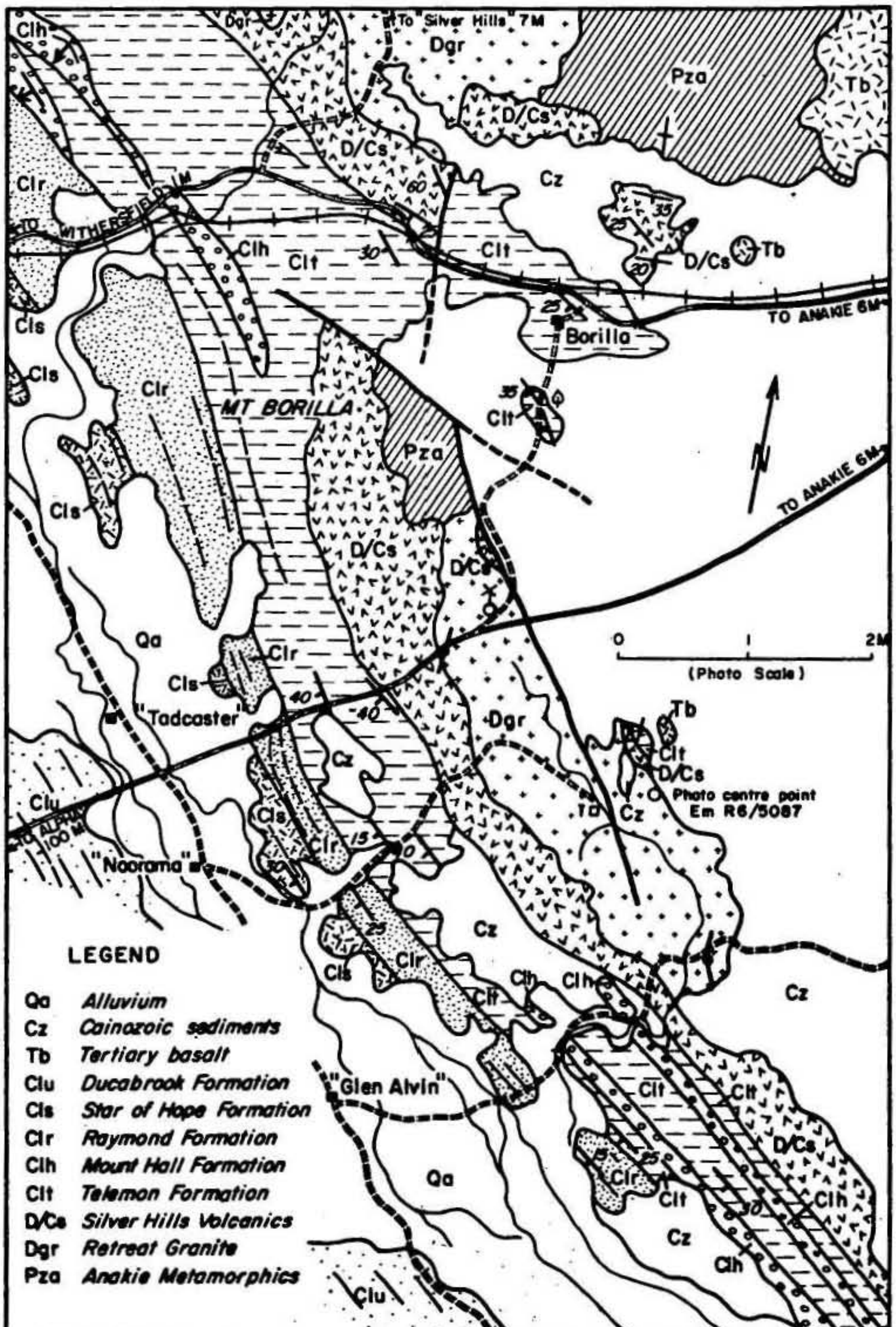

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Fig.17 - Eastern margin of the Drummond Basin west of Anakie. Note the Mount Hall Formation wedge-out against a rise in the basement.

Fig.18 - Mount Hall Formation at Mount Donnybrook, Galilee Sheet area. (Neg.No.GA/1526)

could therefore not be made in as systematic a manner as is desirable in a study of this type. The measurements were made at suitable locations regardless of their positions within the sequence and covering, in each place, as great a vertical section as possible. The consistency of the data indicates that the results of the work may be applied to the formation as a whole and that they are adequate to indicate the transportation direction within the basin throughout the time of deposition of the Mount Hall Formation. This direction probably also applies to the closely related over and underlying sediments.

The current direction from the Springsure area in the south to the area southwest of Scartwater homestead in the north ranges from northerly to northwesterly. North and northwest of Scartwater homestead, the direction is southwesterly swinging to southerly. Just west of Scartwater homestead these southerly and northerly directions abruptly swing to the east. The easterly cross-bedding direction in the Scartwater homestead area is at right angles to the closely spaced isopachs, suggesting that the formation was not laid down much farther to the east. Had the downwarp in which the formation was deposited extended eastward, then the isopachs would have paralleled the cross-bedding direction.

The Mount Hall Formation was laid down in a basin at least 300 miles long and 40 to 50 miles wide. The limits of deposition are known in the Burdekin River area, southwest of Cranbourne homestead, south of Peak Vale homestead, east of Withersfield, and in the Nogoa Anticline, places where the formation lenses out; the limits of deposition are approximately known in the east limbs of the Mount Beaufort Anticline and Mistake Syncline where the formation is overlapped by the Raymond Formation. The easterly and northerly limits of sedimentation can reasonably well be deduced from these observations. The westerly limit of sedimentation is approximately known only in the Mount Beaufort area, and the basin probably extended southward beyond Warrong No. 1 Well.

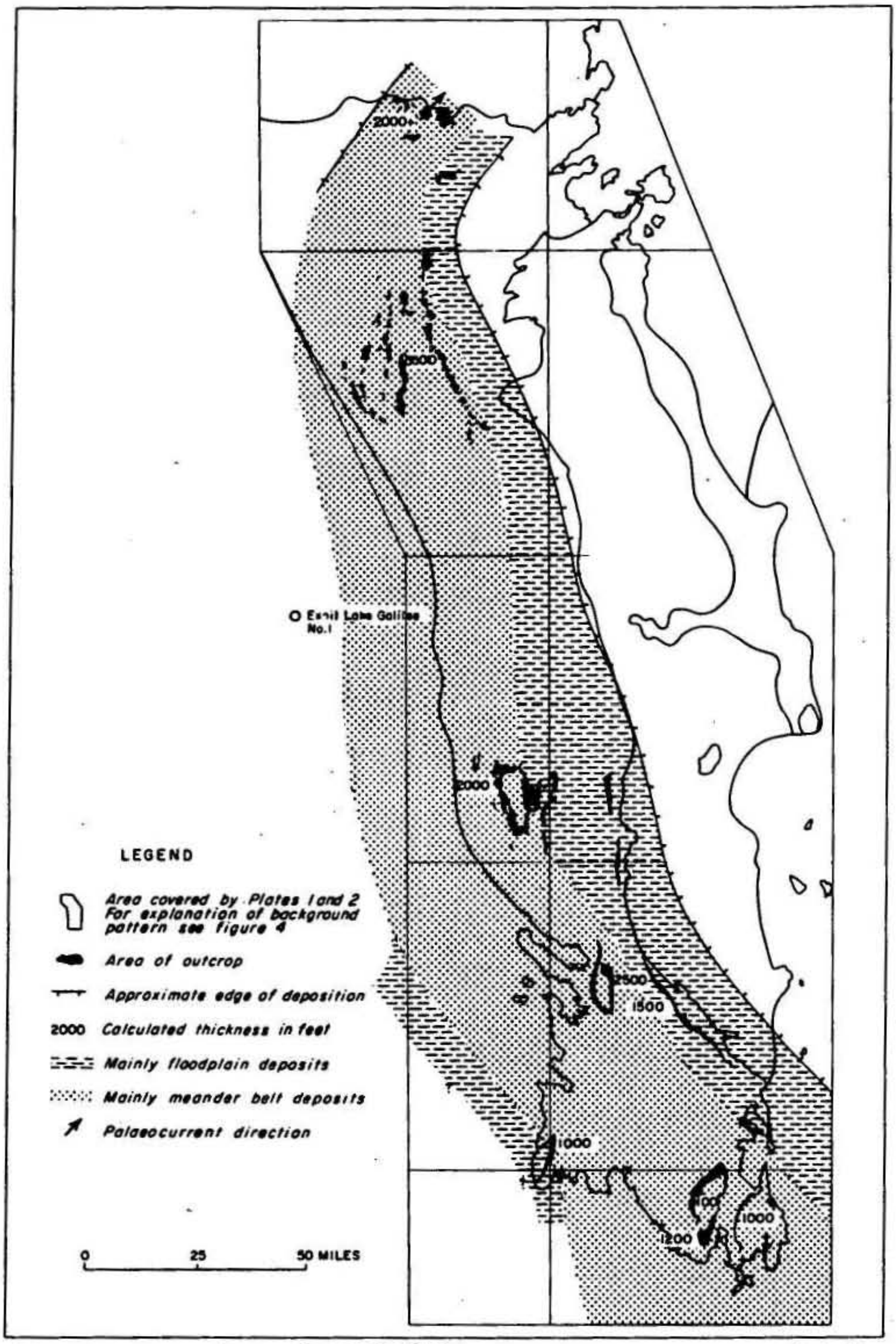
Raymond Formation (Hill, 1957)

The Raymond Formation was first named the Flaggy Sandstone Group (SQD, 1952). The name was later changed to Raymond Flaggy Sandstone (Hill, 1957) and Raymond Sandstone (Veevers et al., 1964b). The type area is in the south of the Telemon Anticline in the vicinity of Raymond Creek in the Springsure Sheet area.

In the southern part of the basin the formation crops out in a large number of anticlines, in the Star of Hope Syncline, and along the eastern margin of the basin west of Anakie and Clermont; in the north it occurs in the Bingeringo and Hopkins Anticlines, and in a narrow sinuous roughly north-trending belt from the Belyando River in the south to Palamana homestead in the north (Fig. 19). The formation was probably encountered in Warrong No. 1 (Table 5).

The typical rock types of the formation are well bedded fine to medium-grained quartz sandstone and olive-green mudstone. In the type area the formation consists dominantly of flaggy, medium-bedded, fine to medium-grained quartz sandstone; it is commonly buff, greenish-brown, and creamy-white, and carbonaceous fragments and mica flakes are common on the bedding planes. The sandstones are well sorted. The quartz grains are generally angular and make up about 80% of the rock. Rock fragments, including chert and schist, and feldspar, are present. The sandstones are very well bedded, and individual beds can be traced for several miles on the air-photographs. Cross-bedding units, 1 to 2 feet thick, and ripple marks are common. Thin beds of mudstone are interbedded with the sandstones. West of Anakie, the formation consists mainly of mudstone and shale with interbeds of grey and greenish-grey flaggy fine-grained quartz sandstone (Fig. 15). Thin lenticular beds of limestone and bands of concretions are present in the mudstone.

In the Narrien Anticline-Mistake Syncline area, the formation is made up of about equal proportions of sandstone and mudstone. Near the base is a 10 foot thick bed of limestone that has a distinct bituminous smell when fractured. Limestone concretions occur in places in the mudstone.



To accompany Records 1969/19 Q/A238

Fig.19 - Raymond Formation palaeogeography.

Fig.20 - Sandstone of the Raymond Formation in the northern part of the Mount Beaufort Anticline. (Neg.No.GA/1531)

Fig.21 - Bedding plane covered in mud pellets and plant debris, Raymond Formation, Narrien Anticline. (Neg.No.GA/1528)

In the northern part of the basin, the formation consists mainly of sandstones similar to those of the type area. They are well sorted and contain up to 75% angular quartz grains, the remainder being made up of feldspar, rock fragments, and little matrix. South of Mount Elsie and Harvest Home homesteads the formation is mainly made up of mudstone with interbeds of sandstone.

Cross-bedding and ripple marks are common in the sandstones. Large-scale festoon cross-beds up to one foot thick occur in the northern part of the basin. Measurements were difficult to obtain, but 12 readings in the Palamana homestead area indicate a north-easterly current direction (Fig. 19). Scattered readings throughout the basin suggest that the current direction was everywhere northerly. Ripple marks, ripple laminations, and small-scale festoon cross-bedding in units about ½ inch thick were observed throughout the basin.

The absence of marine fossils, presence of plant debris, the close relationship of the Raymond Formation with the fluvial deposits of the Mount Hall Formation, and the abundant occurrence of small-scale festoon cross-bedding and ripple laminations indicates fluvial deposition.. The coarser sands were deposited in a long and narrow belt along the axis of the basin, and fine-grained sandstone and interbedded mudstone were laid down on the flood plains.

Figure 19 shows the areas of outcrop of the formation, and its possible westerly extent; the division between areas of dominant sandstone sedimentation as compared with dominant mudstone deposition is also shown. The lateral change from sandstone to mudstone sedimentation can be observed only in the east limb of the Mount Beaufort Anticline, where the formation, in the northern part of the anticline, is completely made up of very well bedded, finely cross-bedded sandstone (Fig. 20) with mudstone becoming progressively more common towards the south.

The Raymond Formation is a transgressive unit; it conformably overlies the Mount Hall Formation, and where the Mount Hall sediments were not laid down, it rests disconformably on older sediments. In the Nogoa and Mount Beaufort Anticlines, the Raymond Formation rests on the Telemon Formation, in the Palamana homestead area on the Scartwater Formation and Cape River Beds, and in the Red Mountain area west of Clermont on the Silver Hills Volcanics.

The Raymond Formation is throughout the basin overlain by the Star of Hope Formation, except in the southeast where the Ducabrook Formation overlaps the Star of Hope Formation and rests directly on the Raymond Formation (Plate 2).

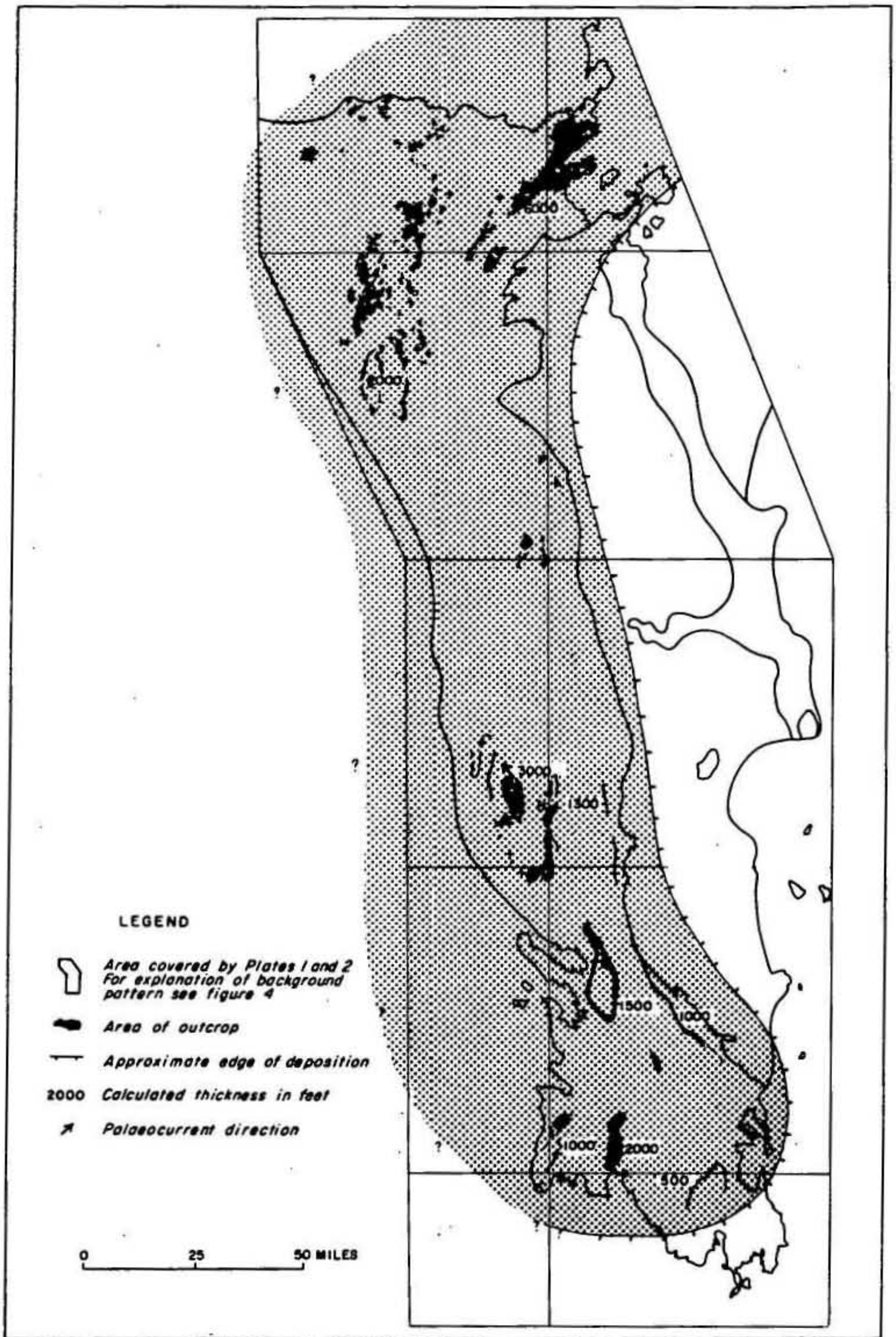
The formation is intruded by an Upper Carboniferous granite stock northwest of Withersfield, and basalt sills, probably of Tertiary age, also occur in this area.

CYCLE 3 : Star of Hope, Ducabrook, Mount Rankin, Bulliwallah, and Natal Formations

A very abrupt change in sedimentation was brought about by widespread vulcanism. The change from grey quartz sandstone and olive-green mudstone to red vulcanolithic sandstone and tuff and conglomerate can readily be mapped throughout the basin. Subsidence and vulcanism were most pronounced in the northern part of the basin. A gradual change from torrential to more mature fluvial and lacustrine sedimentation occurred, but intermittent volcanic activity continued throughout the period. Sedimentation came to an end with the onset of the Kanimblan Orogeny.

Star of Hope Formation (de Bretizal, 1966)

The name was first used by de Bretizel for the sequence of rocks between the Raymond and Ducabrook Formations in the Narrien Anticline and environs. In effect, de Bretizel mapped the lower part of Hill's (1957) Ducabrook Formation as Star of Hope Formation, retaining the name Ducabrook Formation for the upper part of the sequence. This subdivision is now used throughout the southern



To accompany Records 1969/19 Q/A239

Fig.22 - Star of Hope Formation palaeogeography.

part of the Drummond Basin. In the northern part of the basin, the formation similarly overlies the Raymond Formation or older rocks where the Raymond Formation was not laid down, and is overlain by the Bulliwallah Formation.

The Star of Hope Formation is a marker formation throughout the basin because it contains varicoloured sediments and volcanics which can easily be distinguished, particularly in the southern part of the basin, from the grey and greenish quartz sandstone, feldspathic quartz sandstone and green mudstone of the overlying and underlying formations.

The lithology of the unit varies considerably from quartz pebble conglomerate in the type area to vulcanolithic sandstone and tuff in the southern part of the basin, interbedded quartz pebble conglomerate and tuff in the northwest, and a variety of sedimentary rocks and volcanics in the northeast in the Mount McConnell Syncline. These sediments were, regardless of their lithological variation, all mapped as Star of Hope Formation because of their identical stratigraphic position and genetic relationship.

In the type area in the Star of Hope Syncline, the formation consists nearly wholly of cross-bedded, slightly feldspathic, pebbly quartz sandstone and pebble conglomerate, similar to the rocks of the Mount Hall Formation. The pebbles in the sandstone and conglomerate are predominantly quartz, but jasper, black chert, and fine-grained sandstone and siltstone occur also. Interbedded are some beds of green mudstone, fine-grained feldspathic lithic quartz sandstone and fine-grained tuff.

To the south, along the margin of the basin and in the Pebbly Creek, Zamia, Mount Beaufort, Medway and Telemon Anticlines, the formation consists of a largely purplish-red sequence of sediments and fine-grained volcanics. Vulcanolithic sandstones are most common. They are fine to coarse-grained, generally poorly sorted, and contain abundant angular and rounded volcanic detritus and angular grains of feldspar. Low-grade metamorphic and sedimentary detritus is also present. The purple volcanic grains which closely resemble the rocks of the Silver Hills Volcanics give the sediments their characteristic purplish-red colour. Poorly sorted pebbly sandstone and conglomerate containing angular and rounded pebbles of volcanic rocks and sediments up to 2 inches in diameter and some rounded quartz pebbles are interbedded with the sandstones. Local developments of pebbly quartz sandstone, similar to the rocks of the type area, were observed in some places along the eastern margin of the basin. Interbedded with these poorly sorted, coarse-grained clastic rocks are beds of purple and green mudstone and fine-grained tuffs and crystal lithic tuffs. The tuffs are generally associated with the finer grained sediments.

In the flanks of the Blowhard and Bulliwallah Synclines and Bingeringo Anticline, the formation consists of acid tuff and tuffaceous and vulcanolithic sandstone. A minor pebbly quartz sandstone, in places associated with a bed of green coarse-grained vulcanolithic sandstone and fossil wood occurs at or near the base of the volcanic sequence.

To the north of this area and south of the Cape River, the Star of Hope Formation is tightly folded and consists of a sequence of interbedded pebbly quartz sandstone and thin-bedded acid tuff. The pebbly sandstones predominate in the west, and the acid volcanics in the east of this area.

Farther to the north still, between the Cape River and the basement rocks of the Ravenswood Arch, the formation is deeply weathered and crops out poorly; it consists mainly of fine-grained clastic rocks, including vulcanolithic sandstone, mudstone, fine-grained tuff, and crystal lithic tuff. Conglomerates are common in the Fitzroy River area. One of these, containing cobbles and boulders of volcanic rocks, crops out spectacularly in the Fitzroy River two miles downstream of its junction with the Suttor River.

The abrupt change from fine-grained quartz sandstone and mudstone sedimentation (Raymond Formation) to the deposition of vulcanolithic sandstone, quartz pebble conglomerate and tuff signifies that renewed uplift and vulcanism took place in the provenance areas, probably mainly in the less stable regions to the east and south. Cross-bedding measurements were made at two localities in the Star of Hope Syncline indicating a northwesterly and west-southwesterly current direction (Fig. 22). By far the greatest thickness of sediment accumulated in the northern part of the basin.

The Star of Hope Formation contains in some places a rich flora, notably four miles east of Lornsleigh homestead (Appendix). Several fossil tree trunks in their original position occur 2 miles east of Mount McConnell homestead in the north bank of the Sellheim River.

The Star of Hope Formation is transgressive in the northern part of the basin. It overlies the Raymond Sandstone and basement rocks in the northwest, and the Mount Hall and Scartwater Formations in the northeast. In the southern part of the basin, it conformably overlies the Raymond Formation and lenses out in the southern nose of the Telemon Anticline. The formation is conformably overlain by the Ducabrook Formation in the south and the Bulliwallah Formation in the north of the basin. The contact with the Bulliwallah Formation is gradational.

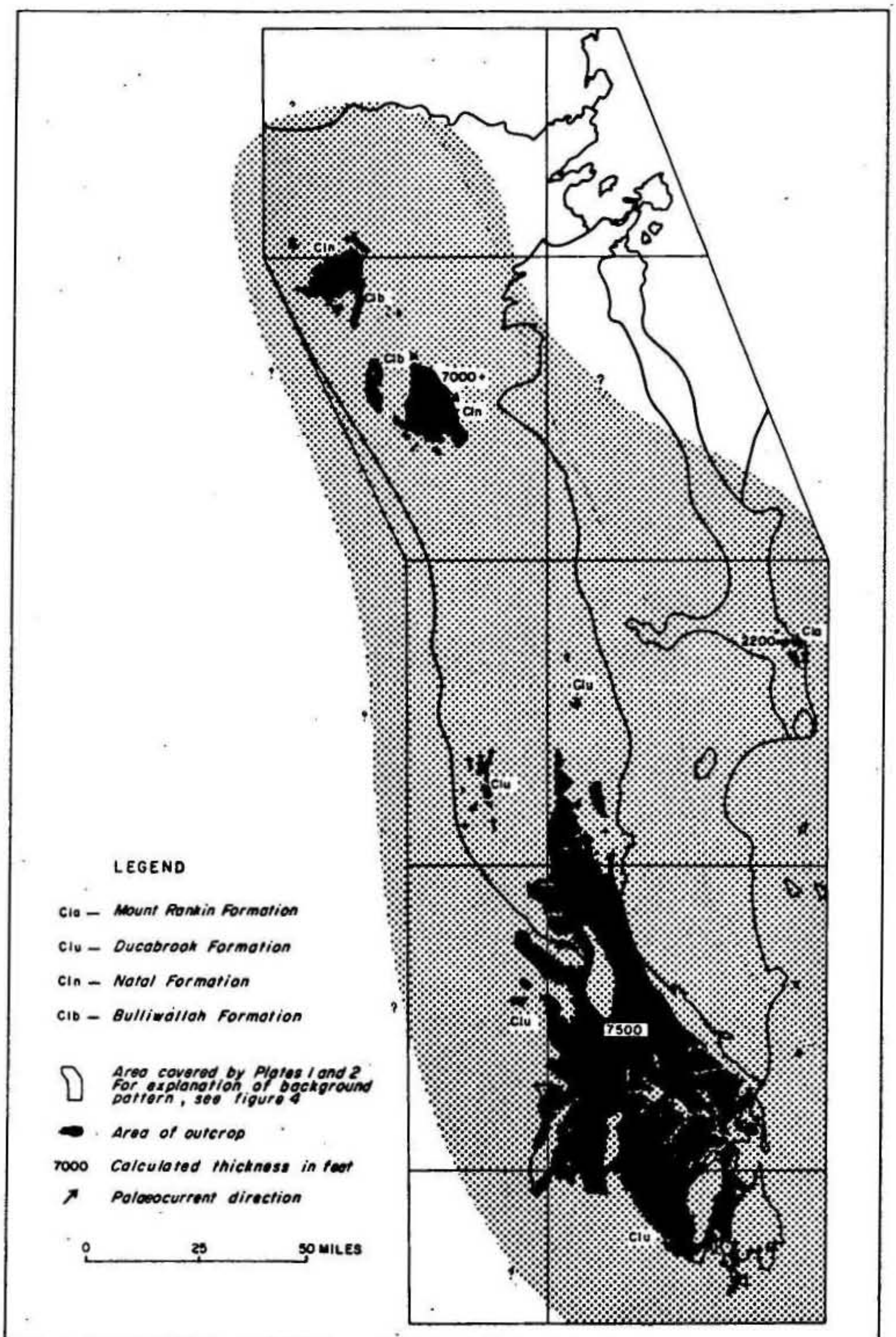
<u>Ducabrook Formation</u> (Hill, 1957)

The Ducabrook Formation was originally named the Ducabrook Series by Shell (SQD, 1952) after Ducabrook Pastoral Holding in the Emerald Sheet area. De Bretizel (1966) mapped the lower part of the formation in the Narrien Anticline as Star of Hope Formation, retaining the name Ducabrook Formation for the upper part of the sequence.

The Ducabrook Formation, the youngest unit in the Drummond basin sequence, occurs in the southern part of the basin only. It can be correlated with the Bulliwallah and Natal Formations of the northern Drummond Basin and with the Mount Rankin Formation east of the Anakie High. The formation makes up the greater part of the outcrop in the south. The topography formed by the formation varies from fairly flat to gently hilly terrain to rugged range country, and its air-photo pattern is distinctive.

The formation, which is up to 7000 feet thick, is essentially a very well bedded sequence of interbedded sandstone and mudstone with some beds of tuff, reworked tuff, conglomerate, and limestone. Regional subdivision of the formation, apart from the separation of the Star of Hope Formation at the base, has not been possible. Pallister (in Schneeberger, 1942), who mapped the Bogantungan-Zamia area west of Anakie in some detail reports: 'For local correlation, subdivisions were made of the Ducabrook Series .... This subdivision is based on the variable predominance of certain lithological types, and no distinct boundary horizons can be traced. Therefore the groups are not expected to be of wide application nor are their separate thicknesses closely comparable even within the limits of the area'. Pallister's remarks apply to the whole area of outcrop of the formation. Local lithological changes both vertical and lateral are abrupt and common throughout the region.

The sandstones are green and khaki-brown, thin to thick-bedded, in places flaggy; they consist mainly of quartz grains with varying amounts of feldspar and lithic fragments, predominantly schist. The amount of matrix is small in most sandstones. Some are calcareous. Sorting is generally good but the grains are angular, particularly the quartz and feldspar. The sandstone is commonly cross-bedded, with current striations on the bedding planes. Current ripple marks are also common. Mud clasts and flakes are common near the base of some sandstone beds. The sandstones are interbedded with purplish, khaki, and olive-green mudstone that is generally massive and rarely shaly. Lenses and irregular aggregates of algal limestone commonly occur in the mudstones and calcareous nodules and cone in cone limestone were observed in a few places.



To accompany Records 1969/19 Q/A240

Fig.23 - Mount Rankin, Ducabrook, Bulliwallah, and Natal Formations palaeogeography.

Fig.24 - Typical outcrop of the Ducabrook Formation. Road cutting, Clermont to Alpha road. (Neg.No.GA/1527)

Silty limestone with layers of oolites and oolitic limestone, in places containing abundant fish scales, are present; the oolites are generally less than an eighth of an inch in diameter. Beds of pink rhyolitic vitric tuff up to 10 feet thick are interbedded with the sediments particularly in the upper part of the formation. The lithology of the formation in specific areas has been discussed in detail by Schneeberger (1942) and by Veevers et al., (1964b).

The Ducabrook Formation conformably overlies the Star of Hope Formation. The contact is exposed along the eastern margin of the basin west of Anakie, and in the core of the Zamia Anticline east of Bogantungan; the tracing on the air-photographs of a marker bed near the base of the formation from the margin of the basin to the east limb of the Zamia Anticline clearly indicates that considerable thinning takes place to the east. The formation also thins northerly to the Mistake Syncline area west of Clermont.

The Ducabrook Formation is unconformably overlain by the Joe Joe Formation or by the Colinlea Sandstone where the Joe Joe Formation was not laid down (Fig. 34), and about 7000 feet of sediment are preserved. The unit is intruded by 5 olivine dolerite and gabbro plugs of the Hoy Basalt, and probably related dolerite sills have been observed at numerous locations.

The Ducabrook Formation contains fish remains, including scales, a spine of the estuarine or freshwater acanthoidian fish Gyracanthides murrayi Smith Woodward, and palaeoniscid fish remains, the brachiopod Leaia, and plants (Appendix), indicating a Lower Carboniferous age.

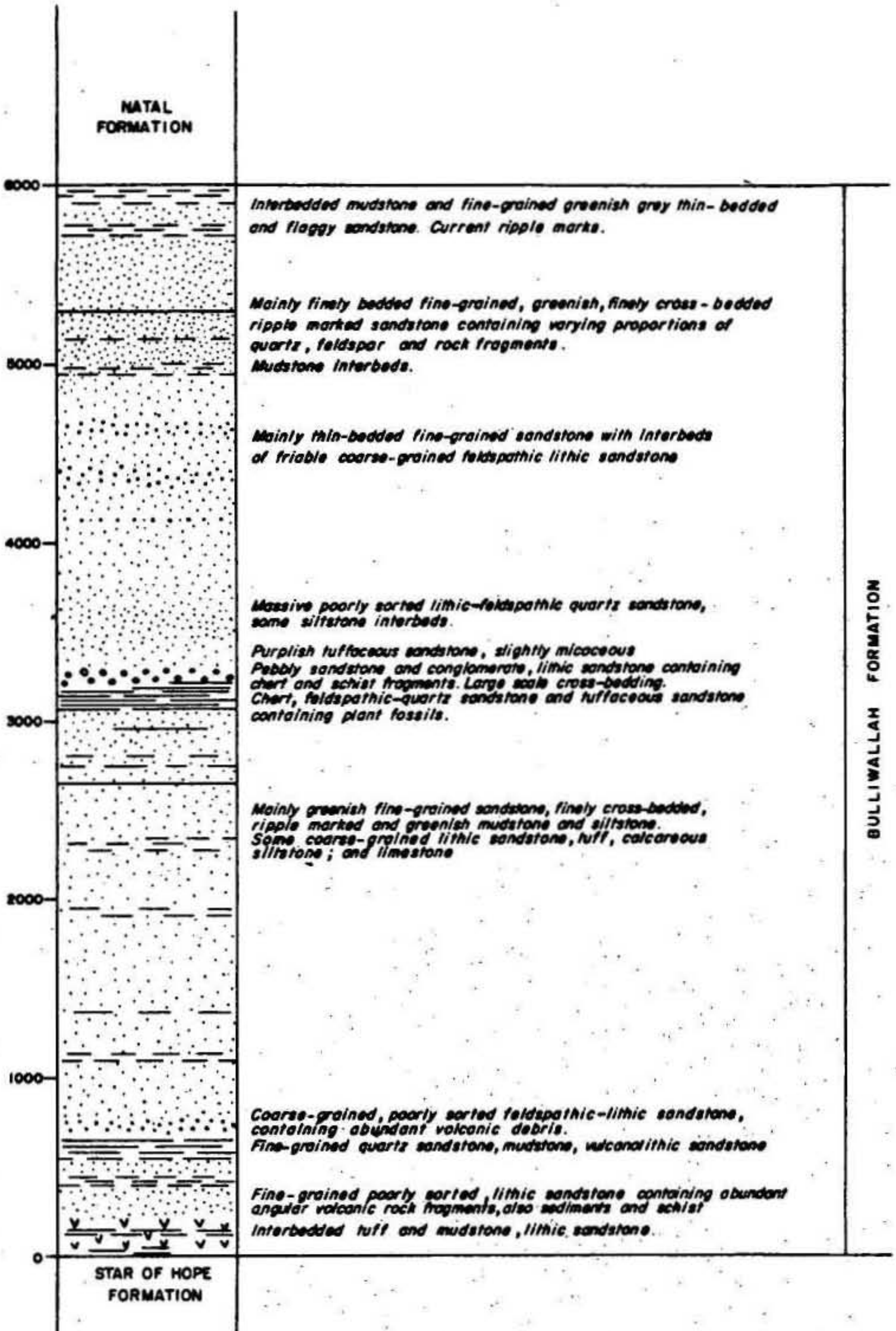
The environment of deposition of the formation is not fully understood but thought to be shallow water non-marine, probably fluvial and lacustrine.

Mount Rankin Formation

The sequence of volcanic and sedimentary rocks which crops out along the eastern margin of the Anakie High disconformably overlies the Silver Hills Volcanics and is unconformably overlain by the Bulgonunna Volcanics in the north and the Bowen Basin sequence in the south; it was originally mapped as an unnamed unit (Veevers et al., 1964a; Malone et al., 1964) which was later named the Mount Rankin Beds (Malone, 1966). The Mount Rankin Beds in the northeast of the Clermont Sheet area were later subdivided into a lower volcanic unit correlated with the Silver Hills Volcanics, and an upper sedimentary sequence for which the name Mount Rankin Beds was reserved (Olgers, in prep. b). The name is here changed to Mount Rankin Formation. Malone's (1966) Mount Rankin Beds north of Mount Coolon, consisting mainly of sedimentary rocks, are now included in the Mount Wyatt Formation, and the dominantly acid volcanic sequence between Mount Coolon and Mount Rankin is mapped as Silver Hills Volcanics.

The Mount Rankin Formation crops out in a small syncline and anticline east of Mount Rankin. The upper part of the formation is overlapped by the Bowen Basin sequence, and only the lower 2,200 feet of the unit are exposed.

The Mount Rankin Formation consists of, from the base upward: well bedded feldspathic and lithic quartz sandstone and lithic sandstone interbedded with green and grey mudstone and chert; intraformational conglomerate containing abundant debris derived from the underlying sediments and the Silver Hills Volcanics; well bedded grey chert; some tuff; greenish poorly sorted sandstone, containing up to 70% quartz and varying amounts of feldspar and lithic fragments including chert and mica schist, interbedded with green mudstone, feldspathic sandstone, and some beds of conglomerate containing abundant pieces of green sedimentary rock. The formation disconformably overlies the Silver Hills Volcanics and contains a rich Lower Carboniferous flora (Appendix).



To accompany Records 1969/19 F55/A6/9

Fig.25 - Generalized section, Bulliwallah Formation, east limb of the Bulliwallah Syncline.

Bulliwallah Formation (de Bretizel, 1966)

The name Bulliwallah Formation was first used by de Bretizel (1966) for the sequence of rocks conformable on the Raymond Formation in the Bulliwallah Syncline in the east of the Buchanan Sheet area. During the 1966 regional mapping programme, de Bretizel's Bulliwallah Formation was subdivided into 2 units. The name Bulliwallah Formation was retained for the lower part of the formation and comprises about 6,000 feet of sedimentary rocks. The upper unit comprises 1000 feet of sediments in the centre of the Bulliwallah Syncline and more than 4000 feet in the area northeast of Natal Downs homestead. The name of the upper unit is Natal Formation. The Bulliwallah Formation derives its name from the Bulliwallah Range in the east of the Buchanan Sheet area where the type area is. It occurs only in the northern part of the Drummond Basin and crops out in the Bulliwallah and Blowhard Synclines, in an isolated area south of Natal homestead, and in a north-trending belt between Natal homestead and the Gregory Developmental Road; it can be correlated with part of the Ducabrook Formation of the southern Drummond Basin.

The formation is essentially a sequence of very well bedded sandstone. Greenish-grey fine-grained quartz sandstone containing poorly rounded quartz, feldspar and lithic grains, including chert, volcanics and metasediments, is most common. Interbedded are thick beds of lithic sandstone and feldspathic sandstone. Some are pebbly. Small-scale cross-bedding and current ripple marks are common, and larger scale cross-beds, up to 4 feet thick, occur in some of the coarser grained sandstones. Tuff and vulcanolithic sandstone are interbedded with the sandstones near the base of the formation, and thin beds of olive-green mudstone occur throughout the sequence.

Only poorly preserved plant material including Stigmaria ficoides Bgt has been found in the formation (Appendix), indicating a Lower Carboniferous age.

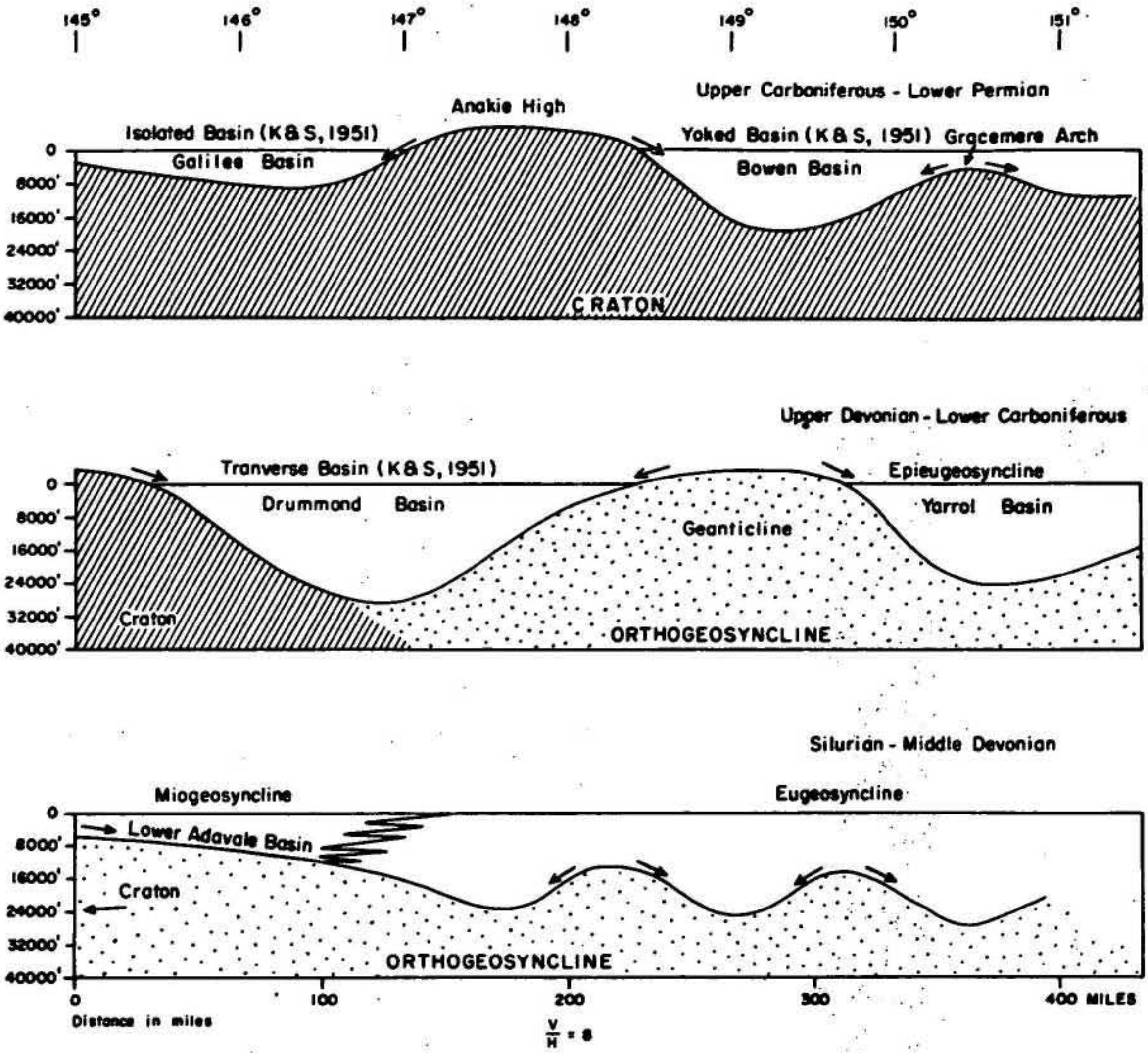
The abundance of plant debris and small-scale festoon cross-bedding, and the presence of mudcracks, ripple marks and some large-scale festoon cross-bedding (up to 3 feet thick) suggests that the sediments were laid down in a shallow fresh water probably fluvial or lacustrine environment. Vulcanism occurred particularly during the deposition of the lower part of the formation. Current bedding measurements in the east limb of the Bulliwallah Syncline indicate a southeasterly current direction (Fig. 23).

Natal Formation (Olgers et al., 1967)

The formation is defined as the sequence of rocks conformable on the Bulliwallah Formation. The name is derived from Natal Downs homestead in the north of the Buchanan Sheet area. The reference area of the formation is northeast of the homestead along the track to Peggurrimma yard.

The Natal Formation crops out in the trough of the Bulliwallah Syncline and in the area northeast of Natal Downs homestead and extending northerly into the northern part of the basin. It consists of a monotonous sequence of thin very well bedded fine-grained feldspathic quartz sandstone with olive-green siltstone and mudstone interbeds. The sandstones are greenish-grey and khaki and are generally well sorted. They are commonly ripple marked and finely cross-bedded. Their main distinguishing features from the underlying sandstones of the Bulliwallah Formation are uniform thin bedding, fine-grained nature, and good sorting.

About 1000 feet of the Natal Formation is preserved in the trough of the Bulliwallah Syncline, the top having been removed by erosion. A considerable thickness, in the order of 4000 feet, crops out northeast of Natal Downs homestead, where the top of the unit is concealed by Cainozoic superficial deposits.



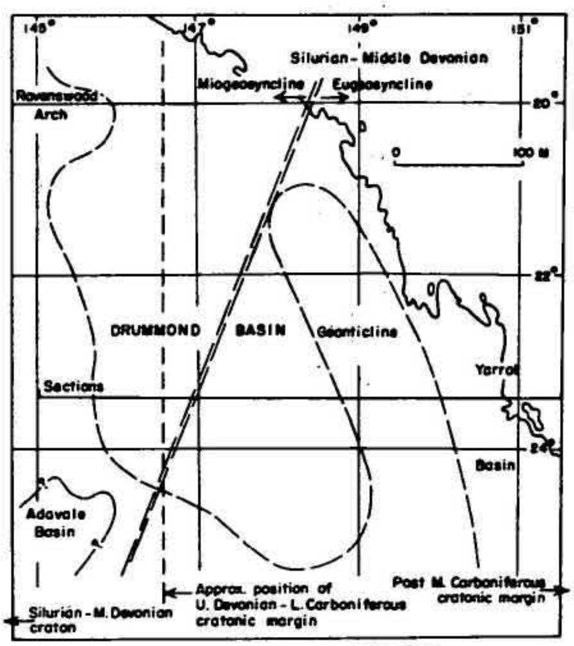


Fig.26 - Restored sections through the central Queensland part of the Tasman Geosyncline. The oldest geosynclinal development is shown in the lowest cross-section. The nomenclature is based on Kay (1951) unless otherwise stated. (K&S-Krumbein and Sloss)

To accompany Records 1969/19

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The Natal Formation contains some poorly preserved plant material; it is of Lower Carboniferous age and can be correlated with part of the Ducabrook Formation of the southern Drummond Basin. It was probably also laid down in a fluvial or lacustrine environment.

Geological history

The development and subsequent depositional history of the Drummond Basin is closely linked to the overall geological history of the Tasman Geosyncline. The history of the central Queensland part of the geosyncline can readily be traced back as far as the Lower Devonian. Miogeosynclinal sediments were laid down in the west of the region in the Lower and lower Middle Devonian (lower Adavale Basin sequence and Ukalunda Beds); the eugeosyncline was farther to the east (Dunstable and Theresa Creek Volcanics, Douglas Creek Limestone, and volcanics and sediments at Fletchers Awl and Glendarriwell homestead) (Fig. 26). Most of these rocks were deformed in the late Middle Devonian Tabberabberan Orogeny; the region of the miogeosynclinal Adavale Basin was not affected by the orogeny and sedimentation continued, without a break, into the Upper Devonian, however, the marine deposition (Etonvale Formation) gave way to continental red bed sedimentation (Buckabie Formation). During the orogeny, a geanticline rose in the orthogeosynclinal belt and the intermontane Drummond Basin formed to the west of the geanticline obliquely across the craton margin; the basin derived the bulk of its sediments from the geanticline (Fig. 26).

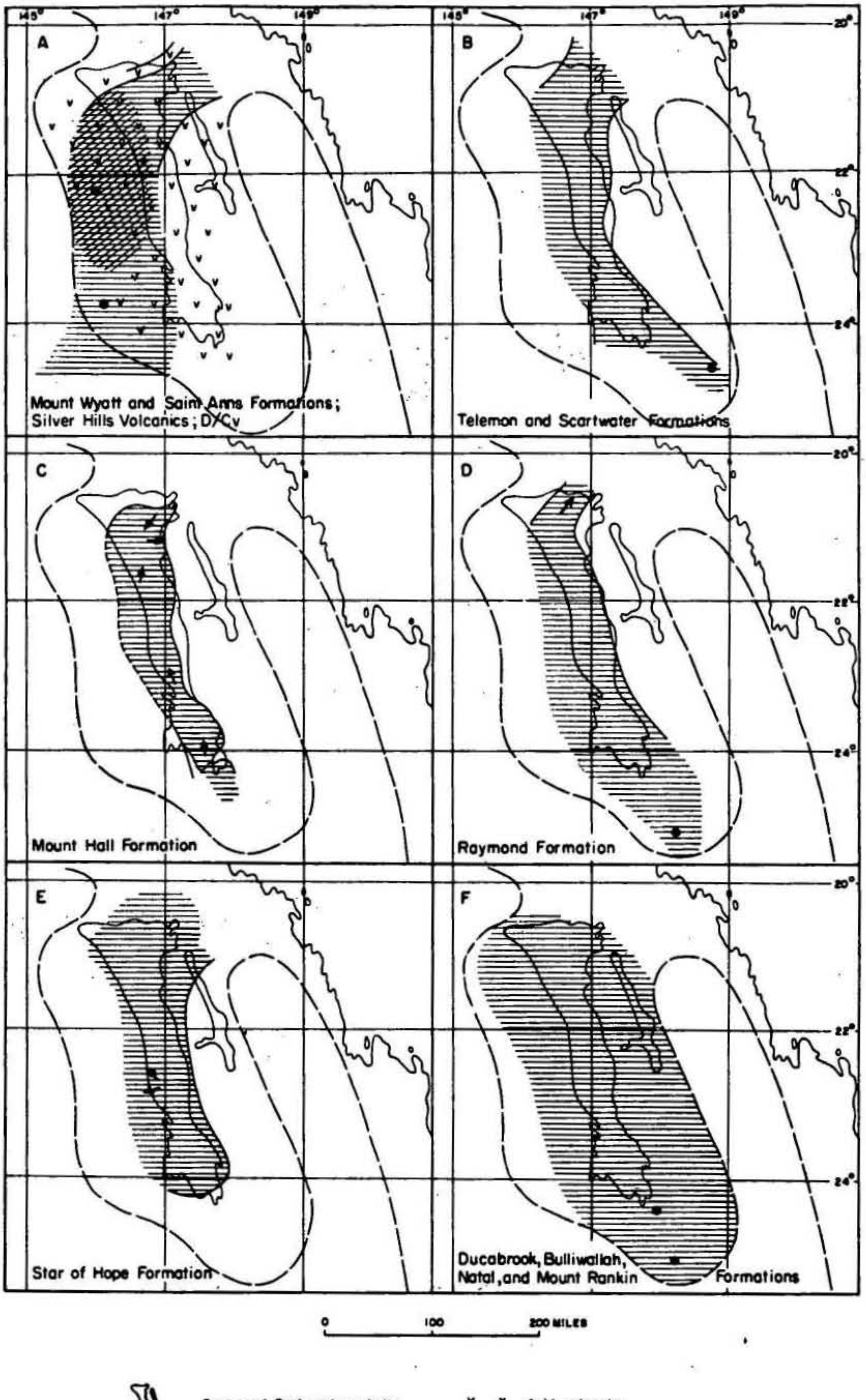
The Drummond Basin can be termed an exogeosyncline (Kay, 1951: 'One in which thick detrital sediments within the craton were derived from uplift beyond the margin of the craton'), or a transverse basin (Krumbein and Sloss, 1951: 'one which extends into the craton margin as a prong from the orthogeosynclinal zone'). The term transverse basin is here used because it is preferred not to use the term geosyncline for marginal and intracratonic basins.

(It is for that same reason that the terms isolated and yoked basins are used in Figure 26 for the intracratonic Galilee and Bowen Basins rather than Kay's (1951) autogeosyncline and zeugogeosyncline).

The oldest sediments in the Drummond Basin were laid down in a shallow sea bordered to the northwest by the Ravenswood Arch and to the southeast by the geanticline (Fig. 27). To the northeast, the environment merged with the marine and paralic conditions that prevailed in the northern Yarrol Basin (Campwyn Beds; Clarke, Paine and Jensen, 1968); the southerly extent of the sea west of the geanticline is not known. There is no evidence that the Upper Devonian sediments encountered in Lake Galilee No. 1 were deposited in the sea; they are possibly transitional (deltaic?) between the marine sediments northeast of the well and the continental red bed sequence (Buckabie Formation) that was laid down to the southwest and which was encountered in Jericho No. 1 and in numerous wells in the Adavale Basin (Fig. 27A).

Only a small part of this extensive Upper Devonian depositional basin, the strait or embayment between the two basement blocks is now exposed in the northern part of the area. The area to the northeast, between it and the Yarrol Basin, is now occupied by younger intrusive and extrusive rocks, and its westerly and southerly extent is obscured by younger sediments.

Sediment was brought into the sea in the northern part of the basin by streams draining the neighbouring land areas. Conglomerate, pebbly sandstone and cross-bedded poorly sorted sandstone containing abundant coarse-grained terrigenous material and some plant debris were deposited near the margins, and finer grained sediment was laid down in the central part of the basin in a shallow sea. The littoral deposits were little reworked as indicated by the well preserved shells and absence of fragmental shell material in some of the conglomerates. Beds and lenses of limestone containing algae and worm casts and incorporating in places abundant angular fragments of terrigenous material, accumulated near the shore, and thin beds of phosphorite were laid down locally in quiet waters along the margin of the basin.



To accompany Records 1969/19 Q/A242

Fig.27 - Upper Devonian-Lower Carboniferous palaeogeography of the Drummond Basin.

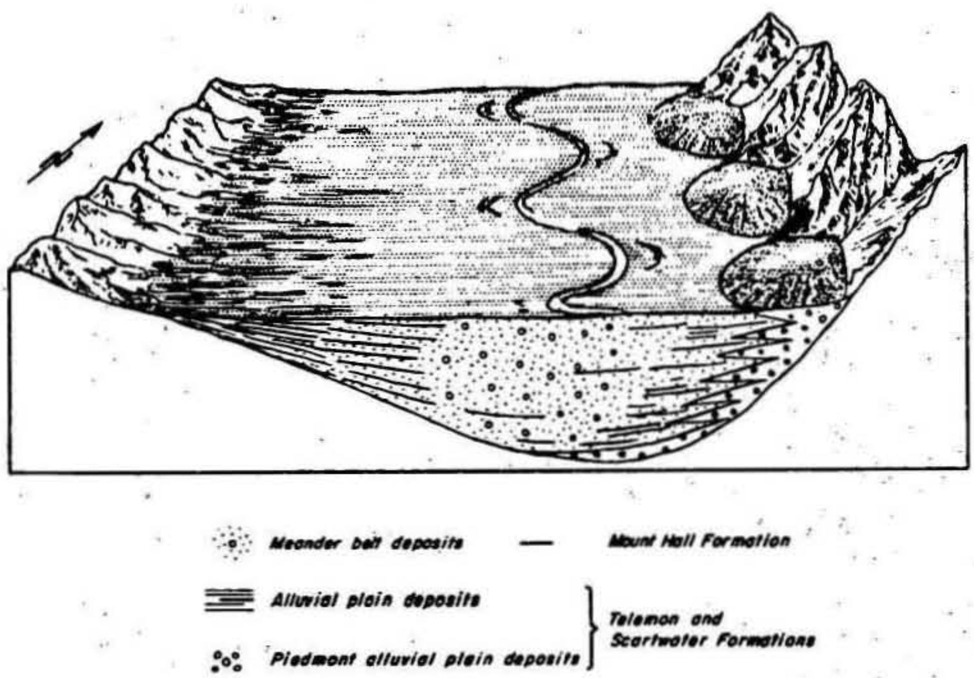
Sedimentation was toward the end of the Upper Devonian interrupted by vulcanism, and acid flows and pyroclastics were laid down on land and in water over most of the area (Fig. 27A). The volcanic activity was concentrated in the north and east where the basement was exposed; the intervening shallow sea received mainly tuffs, at first interbedded with sediments, but later possibly also deposited subaerially. Vulcanism came, in most areas, abruptly to an end in the late Upper Devonian or possibly early in the Lower Carboniferous, and widespread subsidence occurred along the entire western flank of the geanticline from the Ravenswood Arch in the north to at least southwest of Springsure, and sedimentation started again in this long and narrow intermontane basin (Fig. 27B). The geanticline was actively being eroded. Conglomerate and intercalated sandstones were transported by torrential streams and deposited near the margins of the basin in large piedmont alluvial fans; finer grained sediments were laid down away from the margins on the alluvial plains (Fig. 28). Lakes were intermittently formed in which algal and oolitic limestones, some containing fish scales, were laid down, and the minute brachiopod Leaia, indicating shallow freshwater conditions, occurred. Fluvial and lacustrine sedimentation probably prevailed initially in most of the basin, but shallow epi-continental marine incursions may have occurred, particularly in the north, where locally thick limestones accumulated; however there is no fossil evidence to support this.

A change in this pattern of sedimentation was brought about by an increase in the rate of uplift of the basin margins, particularly the southern margin, or by a change of climatic conditions to a period of increased rainfall. Conglomerate, pebbly quartz sandstone and quartz sandstone were transported into and distributed through the basin mainly by a north-flowing river system (Figs. 27C & 28). The main provenance area was to the south, but the other margins of the basin were also actively being eroded as indicated by the very coarse-grained conglomerates along the axis of the basin as far north as Mount Gregory, and the deposition of locally derived lithic sandstones along the margin of the basin. Coarse-grained cross-bedded conglomerates and pebbly sandstones were laid down as pointbar deposits; interbedded with these are some finer grained sandstones and mudstone. Fine-grained floodplain deposits accumulated nearer the margins of the basin. The river system is intermittently swept across the marginal areas depositing coarser sands and pebbly sands over the floodplain deposits; however the river was confined largely to the central most rapidly subsiding part of the basin where a great thickness of coarse sediment accumulated. The consistency of the current bedding direction indicates that the palaeoslope was reasonably steep and the stream channel probably had a fairly low sinuosity. The river system, after having deposited its load in the basin west of the geanticline and south of the Ravenswood Arch, flowed east across the northern part of the geanticline into the sea farther to the east.

The torrential stream deposition in the central part of the basin diminished gradually with the advance of erosion in the provenance areas. The margins of the basin were eroded back and fine-grained quartz sandstone and mudstones were laid down overlapping most older deposits (Fig. 27D). Sandstone was laid down in the axial part of the basin and interbedded sandstone and mudstone along the margins. The river system in the northern part of the basin had changed its course from east to northeast (Fig. 27 C & D) and now flowed out to sea across the eastern part of the Ravenswood Arch.

This mature fluvial deposition came abruptly to an end when renewed epeirogeny and vulcanism occurred in the areas bordering the basin and tuff, vulcanolithic sandstone and conglomerate were laid down throughout the basin (Fig. 27E). The initially torrential deposition gradually changed with the advance of erosion to more mature fluviatile and lacustrine deposition (Fig. 27F). Shallow epicontinental marine incursions may have occurred. Intermittent volcanic activity in the bordering areas provided the ashfall tuffs which were laid down, particularly in the southern part of the basin.

Sedimentation came to an end in the middle of the Carboniferous with the onset of the Kanimblan Orogenic event. The Drummond Basin sequence was folded and the eastern part of the fold belt was, with the western part of the geanticline (Anakie High), uplifted to form during the Upper Carboniferous, Permian and Mesozoic a cratonic arch which supplied detritus to the Galilee and Bowen Basins.



To accompany Records 1969/19 F55/A/112

Fig.28 - Model illustrating the relationships between the alluvial facies of the Mount Hall, Telemon, and Scartwater Formations.

Plutonic intrusion and vast outpourings of acid volcanic rocks over the truncated Drummond Basin structures occurred in the northern part of the region between the Ravenswood Arch and Anakie High, destroying the physical connection between the Drummond and Yarrol Basin rocks.

Structure

The major tectonic units in the region are shown in Figure 31. The relationships between these units have been discussed; the fold system and the associated faults in the Drummond Basin are described here and this is followed by a brief structural interpretation.

Subsidence of the basin was slow and continuous and sedimentation kept pace with it. Occasional abrupt epeirogenic movements accompanied by vulcanism occurred in the bordering areas causing cyclic sedimentation, and local transgression and regression. Deformation commenced during sedimentation, but the main folding phase was in the middle of the Carboniferous during the Kanimblan Orogeny when the region was stabilized.

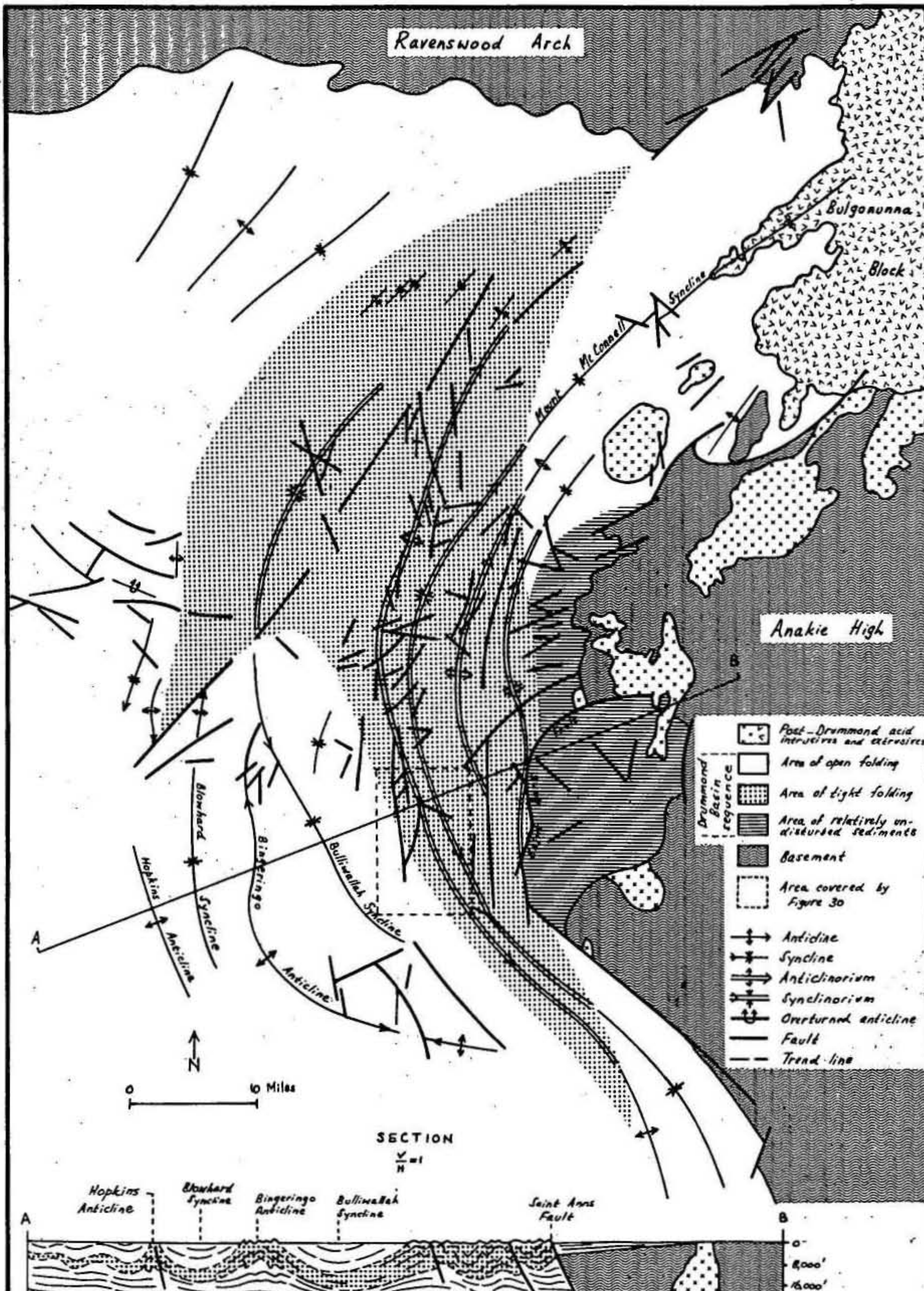
The deformation of the Drummond Basin sequence resulted mainly in the formation of a large number of gentle anticlines and synclines; a zone of tight folding was produced in the north directly west of the Anakie High (Figs. 29 & 30).

The most striking feature of the folding is the variation in axial trend from one area to another. In the south, west of the Anakie High-Nebine Ridge axis, it is north-northeast swinging to north-northwest and north, thus forming a structural embayment, an area where the axial traces of the folds are concave toward the outer edge of the fold belt (Badgley, 1965, p. 57). It is here referred to as the Bogantungan Embayment. A structural salient, the Scartwater Salient (Fig. 29), is formed in the northern part of the area where the fold axes are draped around the northern part of the Anakie High.

Extensive faulting accompanies the folding. The only major faults are the Chinaman Fault in the south and the Saint Anns Fault in the north, both reverse faults along the mobile eastern margin of the basin, and an important northeast trending fault zone occurs in the northern part of the basin.

The Bogantungan Embayment is named after the township of Bogantungan which is near its centre. The southern limb of the embayment comprises, along its western margin where it overlies the edge of the Nebine Ridge, a series of en echelon north-northeast trending supratenuous folds with long sinuous axes. The structures are most prominent in the Drummond Basin sequence, and the Mount Beaufort Anticline is the most prominent one of these. The core of the anticline is made up of a rhyolite dome which formed a high during the deposition of the Telemon and Mount Hall Formations and which was completely overlapped by the Raymond Formation and subsequent units. Flank dips of 45° are the result of differential deposition and compaction and middle Carboniferous tectonism. Toward the south, the rocks in which the folds are closed become progressively younger, ranging from Upper Carboniferous to Cretaceous, and the dips are considerably smaller and gradually decrease southward from 10-15° in the Joe Joe Formation, about 5° in the Permian strata, about 3° in the Triassic, about 1° in the Jurassic, and less than 1° in the Cretaceous rocks. Structure is only due to differential deposition and compaction, and decreases in intensity as a result of increasing depth to basement. East of this zone of long sinuous folds, between it and the eastern margin of the Nebine Ridge, are a number of very gentle north, northeast, and east trending flexures (Fig. 31). The lack of a distinctive fold pattern in this area may be due to the absence of a pronounced basement trend in the central part of the Nebine Ridge.

The north limb of the Bogantungen Embayment trends north-westerly. It is partly faulted against the Anakie High and comprises three sets of north-northwest and northtrending en echelon folds. The southerly set of folds comprises large gentle anticlines and synclines, including the Pebbly Creek and Zamia Anticlines, and is separated from the Anakie High by the Chinaman Fault.



To accompany Records 1969/19 F55/A/113

Fig.29 - Structural map of the Scartwater Salient, northern Drummond Basin. Most of the minor folds are not shown. Figure 30 illustrates the small-scale folding in part of the south limb of the salient.

The axes of the folds are sinuous and the west flanks are generally steeper. The northwesterly and southeasterly extensions of this zone of folding are obscured by younger sedimentary rocks and basalt. The Chinaman Fault is a large left reverse oblique slip fault. Farther to the north and in direct continuation of the fault is another set of en echelon folds which includes the Narrien Anticline and a number of smaller flexures to the southeast and northwest of it. The fold zone, which plunges to the northwest under younger sediments, is cut by a number of transverse faults which trend at right angles to the fold axes. The most northerly set of en echelon folds, comprising the tightest folds in the embayment, covers a small area near Mount Gregory. It is surrounded by Cainozoic deposits. The change in axial trend from north-northeast in the south limb of the embayment to north-northwest in the north limb occurs abruptly just south of the Bogantungan Syncline (Plate 1 and Fig. 31).

The Scartwater Salient is named after Scartwater homestead. It is an arcuate belt of completely folded and faulted Drummond Basin sediments draped around the northwest margin of the Anakie High (Fig. 29). The high is overlain by and separated from the salient by a sequence of gently west-dipping sediments. The east central part of the salient consists of a large number of tight folds (Fig. 30). It is partly separated from the relatively undisturbed sediments to the east by the Saint Anns Fault, and the remainder of the eastern boundary is suspected also to be faulted. The folds are concentric and angular and their amplitude decreases to the west. Dips are generally steep. Two anticlinoria and two synclinoria plunging to the north-northeast and south-southeast can be recognized within this tightly folded zone that grades to the north, south and west toward the outer edge of the salient into larger, more open structures, the most prominent of which are the Bulliwallah Syncline and Bingeringo Anticline (Fig. 29). The change from tight to open folding is abrupt east of the Bulliwallah Syncline (Fig. 30). The tight folding in this area is restricted to the outcrop belt of the Mount Hall Formation, whereas farther to the north it also involves the Raymond and Star of Hope Formations.

The Scartwater Salient is cut by a major northeast trending fault zone (Figs. 29 & 31), the southern part of which consists of oblique faults cutting across the regional trend, and longitudinal faults parallel to the regional trend make up the northern part of the zone. The regional distribution of rock units suggests that the movement on the faults was right reverse oblique slip. The Saint Anns Fault along the eastern margin of the salient is an important reverse fault, east block up, on which also some clockwise movement occurred (left reverse oblique slip).

Numerous smaller faults arranged mainly in four sets, occur in the area: the first directly west of the Anakie High and north of the Saint Anns Fault consists of oblique faults; it is separated from an arc shaped zone of oblique faults along the western margin of the Mount Hall Formation outcrop belt by two large longitudinal faults. The fourth set at the apex of the exposed part of the salient consists mainly of transverse faults (Fig. 29).

Structural interpretation

The Scartwater Salient, the most striking tectonic feature of the region, was formed by a primary compressional force from the east (Fig. 31). Movement took place along northwest and northeast trending reverse faults and fault zones, and the Drummond Basin sediments were folded into a series of flexures draped around the apex of the west moving block. The northern limb of the salient was squeezed between this block and the Ravenswood Arch. A decollement was formed at the base of the Drummond Basin sequence (section, Fig. 29). Extensive secondary faulting, both transverse and longitudinal, took place. Movement also occurred along at least two and possibly more major fault zones which formed parallel to those bounding the primary moving block. The most prominent of these is the Chinaman megashear, part of which (Chinaman Fault) forms the southwest margin of the Anakie High. Regional coupling caused by movement on the Chinaman Fault formed a set of en echelon folds in the southwest wall of the fault, and farther to the

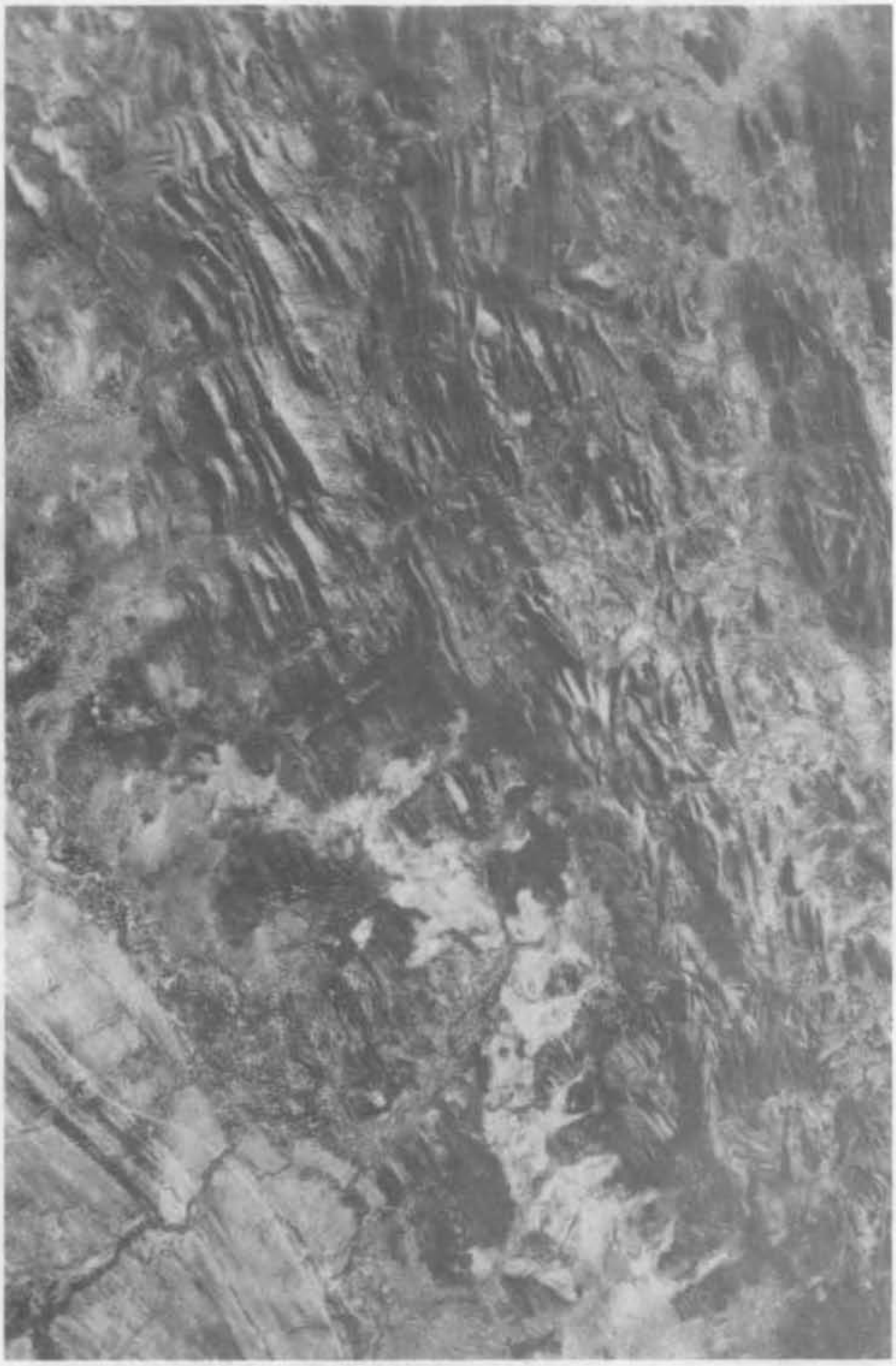
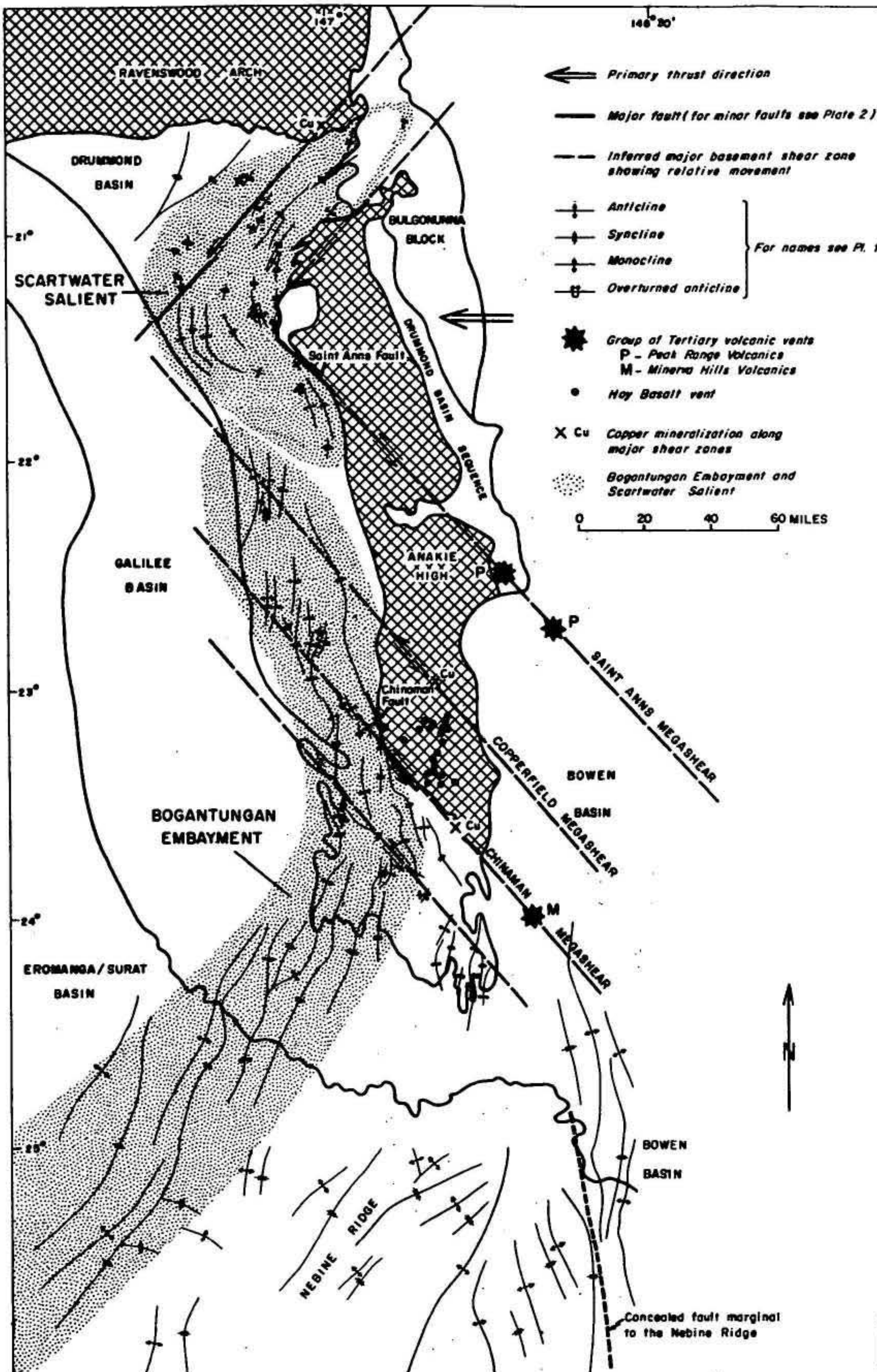


Fig.30A - Tight folding in the Mount Hall Formation and open folding in the overlying units in the southern limb of the Scartwater Salient, northern Drummond Basin. The east limb of the Bulliwallah Syncline is in the bottom left hand corner. (Part of airphotograph Buchanan R4/5014. For location see Figure 29)

To accompany Records 1969/19 F55/A6/10

Fig.30B - Explanation of figure 30A.



To accompany Records 1969/19 Q/A266

Fig.31 - Structural sketch map. Only major structures are shown.

northwest, where the megashear is not exposed at the surface as a fault, simple shearing in the basement resulted in the formation of a set of en echelon folds in the Drummond Basin sediments directly overlying the megashear. These folds are cut by a series of slightly en echelon faults which strike perpendicularly across the fold axes (Plate 1). This fault pattern is in sympathy with the shearing interpretation of the fold pattern.

The supratenous folds of the southern limb of the Bogantungan Embayment have been discussed (p. 54). They were mainly formed by differential deposition and compaction over north-northeast trending basement ridges.

Probably closely associated with the westward thrusting in the northern region are a number of post-orogenic Upper Carboniferous granitic intrusives (Table 4) and related widespread acid volcanic outpourings (Bulgonunna Volcanics). Three stocks, two northeast of Scartwater homestead and one west of Silver Hills homestead, were emplaced within the Drummond Basin sequence also at this time (Plate 2).

Igneous activity occurred again in the Tertiary and it appears closely related to the earlier developed megashears. The Peak Range Volcanics were intruded and extruded along a zone in direct continuation of the Saint Anns megashear and the Minerva Hills Volcanics along the Chinaman megashear, where that shear zone is intersected by the fault bounding the eastern margin of the Nebine Ridge (Fig. 31). The Tertiary Hoy Basalt plugs were emplaced mainly in basement rocks between the Chinaman and Copperfield megashears. A northeast trend is discernable, and the plugs were possibly intruded along zones of weakness created by the coupling effect of the megashears. The greater angle between these zones of weakness and the megashears compared with the angle between the Chinaman megashear and the axes of the en echelon folds developed over it in the Drummond Basin sequence is due to the greater competency of the basement rocks. (This phenomenon can be compared with development of slaty and fracture cleavage in interbedded incompetent and competent beds in a fold whereby the angle between the fracture cleavage and bedding is greater than the angle between the slaty cleavage and bedding.

PORT-DRUMMOND SEDIMENTS, VOLCANICS, AND INTRUSIVES

After the middle Carboniferous folding of the Drummond Basin sequence and the uplift of the Anakie High and eastern part of the Drummond Basin fold belt, volcanic rocks were extruded in the northeast of the area east of this uplifted block, and the Bowen and Galilee Basin sequences were laid down to the east, south, and west. The volcanic activity in the north was probably closely associated with the emplacement of Upper Carboniferous acid and basic intrusives in that region. An isolated granite stock was emplaced in the south, west of Silver Hills homestead. The Galilee and Bowen Basin sequences are unconformably overlain by the Jurassic to Cretaceous Eromanga/Surat Basin succession. Volcanic activity was widespread in the Tertiary, and Tertiary and Quaternary superficial deposits cover large areas.

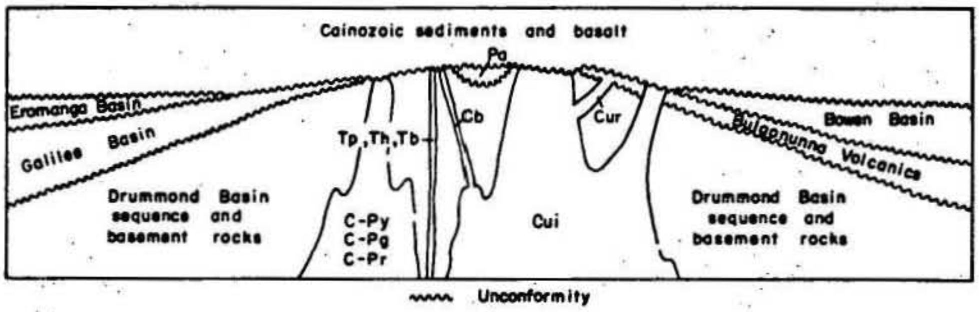
The post-Drummond rocks are described under five headings:

i) Bulgonunna Volcanics;
ii) Bowen/Galilee Basin sequence;
iii) Eromanga/Surat Basin sequence;
iv) Cainozoic sediments and basalt; and
v) Intrusives.

The relationships between these rocks are shown in Figure 32.

Bulgonunna Volcanics

The Bulgonunna Volcanics (Malone et al., 1964) unconformably overlie the Drummond Basin sequence in the northeast of the area, east of the Anakie High (Fig. 4). The unit dips on a regional scale gently to the east and forms basement to the Bowen Basin sequence.



Tp, Th, Tb — *Acid and basic intrusives*
Pa — *Blair Athol Coal Measures*
C-Py, C-Pg, C-Pr — *Granite, rhyolite*
Cb — *Basic intrusives*
Cur — *Quartz - feldspar porphyry*
Cui — *Granite*

To accompany Records 1969/19 Q/A243

Fig.32 - Diagrammatic relationships of the post-Drummond rocks.

The Bulgonunna Volcanics are mainly an acid volcanic sequence consisting of porphyritic rhyolite containing quartz and feldspar phenocrysts in a flow-banded glassy or felsitic groundmass. Welded tuff, crystal tuff, volcanic breccia and agglomerate occur also. The volcanics are intruded by small acid bodies similar in composition to the volcanics; they are probably vent fillings which can possibly be correlated with the quartz-feldspar porphyry dykes (Cur) which intrude the Drummond Basin sequence in the Sellheim River area. Several rhyolite domes occur within the Bulgonunna Volcanics. They can easily be recognized on the air-photos by their dense joint pattern; they consist of vertically flow-banded rhyolite and are surrounded by massive breccias containing blocks of flow-banded rhyolite up to 6 feet in diameter. Mount Hope, 7 miles northwest of Mount Douglas homestead, is probably an exhumed rhyolite dome intruding the Saint Anns Formation.

The Bulgonunna Volcanics are, because of their stratigraphic position, probably of Upper Carboniferous age, and are probably closely associated with the Upper Carboniferous granitic intrusions in the region.

In the north of the area are a number of isolated outcrops of acid in intermediate lavas and pyroclastics (Cuv). They are younger than the Ravenswood Granodiorite, and those at Camp Oven Mountain are younger than the Drummond Basin sequence, i.e. they are post Lower Carboniferous. The volcanics resemble the Bulgonunna Volcanics and they are probably equivalent.

Bowen/Galilee Basin sequence

The Upper Carboniferous-Permian-Triassic Bowen/Galilee Basin sequence was laid down to the east, south, and west of the uplifted Anakie High and Drummond Basin fold belt. The basins merge in the southern part of the area across the Springsure Shelf.

The greatest thickness of sediment in the Galilee Basin, about 9000 feet, was laid down in the west of the Buchanan Sheet area and the Denison Trough in the Springsure Sheet area received the greatest thickness of sediment, about 19,000 feet, in the Bowen Basin. The Springsure Shelf, the area where the depositional basin crossed the relatively stable Anakie High/Nebine Ridge axis, received about 5000 feet of sedimentary cover. The relationships between the units in the Bowen and Galilee Basins are set out in Table 3.

Sedimentation started in the Upper Carboniferous in the south of the area on the Springsure Shelf with the deposition of the glacial and fluvioglacial sediments of the Joe Joe Formation, and the deposition of equivalent sediments (C-P) in the Galilee Basin. The easterly extent of this sedimentation into the Bowen Basin is unknown. The mainly terrestrial Bulgonunna Volcanics were extruded contemporaneously in the northeast of the area.

Early in the Permian, subsidence started east of the Anakie High, and the Denison Trough, the earliest downwarp in the Bowen Basin, was formed. At first the trough subsided rapidly and at least 8700 feet of freshwater sediments, the Reids Dome Beds, were deposited in it. The freshwater sedimentation extended onto the Springsure Shelf, where 120 feet of sediment was laid down, and into the Galilee Basin (the lower Permian sediments in the Galilee Basin are included in unit C-P). Vulcanism continued in the northern Bowen Basin with the extrusion of the Lizzie Creek Volcanics unconformably over the Bulgonunna Volcanics. Marine fossiliferous tuffs near the top of the volcanics indicate that the sea invaded the northern part of the basin at that time. General subsidence throughout the Bowen Basin caused the spreading of the sea to the south into the Denison Trough, and the Tiverton Subgroup of the Back Creek Group was laid down in this enlarged basin. Sedimentation did not take place on the western part of the Collinsville Shelf, on the Springsure Shelf, or in the Galilee Basin. The Tiverton Subgroup is overlain by the Gebbie Subgroup which was laid down in a westward transgressing sea.

TABLE 3 – BOWEN – GALILEE BASIN CORRELATION CHART.

	GALILEE BASIN			BOWEN BASIN			
				SPRINGSURE SHELF	DENISON TROUGH	COLLINSVILLE SHELF	
Sheet area (see Fig. 4)	BUCHANAN GALILEE	JERICHO		TAMBO SPRINGSURE (W) EMERALD (South)	SPRINGSURE (E) EMERALD (SE)	CLERMONT	MOUNT COOLON BOWEN
Principal references	Vine et al., 1965	Vine et al., 1965		Exon et al., 1966; Mollan et al., in press; Olgers, 1968a	Mollan et al., in press; Olgers, 1968a	Olgers, 1968b	Malone et al., 1964; Malone et al., 1966
JURASSIC	Ronlow Beds	Ronlow Beds (equivalence) Hutton Sst		Precipice Sst	Precipice Sst		
TRIASSIC	Moolayember Fm	Moolayember Fm	Mimosa Group	Moolayember Fm	Moolayember Fm		Moolayember Fm
	Warang Sst (north Buchanan) (equivalence) Clematis Sst	Clematis Sst	Mimosa Group	Clematis Sst	Clematis Sst	Carborough Sst	Clematis Sst
	Warang Sst (north Buchanan) (equivalence) Dunda Beds	Dunda Beds	Mimosa Group	Dunda Beds (Tambo)	Rewan Formation	(Emergence)	Rewan Formation
	Rewan Formation	Rewan Formation	Mimosa Group	Rewan Formation	Rewan Formation	(Emergence)	Rewan Formation
UPPER PERMIAN	Pu (Galilee) Betts Creek Beds (Buchanan)	P		Blackwater Gp	Blackwater Gp	Blackwater Gp	Blackwater Gp
			Back Creek Gp. – Blenheim Sbgp	Black Alley Shale	Black Alley Shale	Undifferentiated Blenheim Subgroup	Undifferentiated Blenheim Subgroup
		?—?—?—?	Back Creek Gp. – Blenheim Sbgp	Peawaddy Fm	Peawaddy Fm		
LOWER PERMIAN		Colinlea Sst	Back Creek Gp. – Gebbie Sbgp	Colinlea Sst	Catherine Sst, Ingelara Fm, Aldebaran Sst	Gebbie Subgroup (equivalence) Blair Athol Coal M.	Collinsville Coal Measures
	(Emergence)	(Emergence)	Back Creek Gp. – Tiverton Sbgp	(Emergence)	Sirius Fm to Cattle Ck Fm interval	(Emergence)	Undifferentiated Tiverton Subgp
	C–P	C–P		Reid's Dome Beds	Reid's Dome Beds		Lizzie Creek Volcanics
UPPER CARBONIFEROUS				Joe Joe Formation			Bulgonunna Volcanics
UPPER DEVONIAN – LOWER CARBONIFEROUS	Drummond Basin sequence	Drummond Basin sequence		Drummond Basin sequence	? Drummond Basin sequence	? Drummond Basin sequence	Drummond Basin sequence

Unconformity | Equivalence | Emergence

Fig.33 - Joe Joe Formation, southern Drummond Basin.
(Neg.No.GA/1529)

Fig.34 - Unconformity between the Colinlea Sandstone (top) and Ducabrook Formation in the southern nose of the Nogoa Anticline. (Neg.No.GA/1534)

The Blair Athol Coal Measures were deposited probably at this time (Evans, 1966) to the west of this marine environment in an isolated basin on the Anakie High. Subsidence also took place on the Springsure Shelf and in the Galilee Basin where the fluvial sands of the Colinlea Sandstone were laid down with slight unconformity on the older rocks. The Blenheim Subgroup, the youngest marine unit laid down in the Bowen Basin, was deposited in a sea which transgressed still further to the west. Marine sediments were laid down on the Springsure Shelf (Peawaddy Formation), but there is no evidence that the sea also invaded the Galilee Basin, where fluvial sedimentation probably continued.

Toward the end of the Upper Permian, the Bowen Basin lost its connection with the sea and the Blackwater Group, including coal measures, was laid down in a huge basin east, south, and west of the Anakie High/Drummond Basin fold belt. Freshwater sedimentation continued in the Triassic with the deposition of the mainly fluvial deposits of the Mimosa Group.

The Bowen/Galilee Basin sedimentation came to an end toward the end of the Triassic when epeirogenesis accompanied by mild folding took place. Erosion followed until renewed subsidence in the Lower Jurassic initiated the Eromanga/Surat Basin in which Jurassic and Cretaceous freshwater and marine sediments were laid down.

Eromanga/Surat Basin sequence

The Jurassic to Cretaceous Eromanga/Surat Basin sequence unconformably overlies the Galilee and Bowen Basin rocks. The sequence, comprising the Precipice Sandstone, Boxvale Sandstone Member of the Evergreen Formation, and the Hutton Sandstone in the southwest corner of the region (Plate 1), is largely of fluvial origin and has a maximum thickness of about 1000 feet in this area. It has been fully described by Exon et al., 1966.

Cainozoic sediments and basalt

Piedmont, fluvial, and lacustrine deposits up to 200 feet thick were laid down in the Tertiary over most of the area in a huge generally flat lying sheet (T, Tf, Ts). Only some small areas projected above this surface as small hills, and the sediments dip away from these at angles up to 10°. The rocks are in most areas deeply weathered and silcrete and ferricrete are widely developed. The Tertiary sediments, which in most areas are covered by a thin layer of superficial sand or sandy soil (Qs) are actively being eroded and large tablelands, plateaux, and mesas are all that remains of this old land surface. Outcrops are confined to the margins of these, and wide swaths of alluvium (Qa) have been laid down between them in the Quaternary.

Tertiary basalts (Tb) were extruded over large areas in the Clermont District between the Anakie High in the west and the Permian sandstone of the Blenheim Subgroup in the east. The basalts, which were up to 2000 feet thick in this area, extend to the southeast into the Emerald and Springsure Sheet areas where they are interbedded with sediments. The basalts were extruded from fissures and circular vents now filled with olivine basalt or gabbroic rock, commonly with nodules of peridotitic material (Veevers et al., 1964b). The Hoy Basalt plugs of the Emerald Sheet area may be related.

Small patches of basalt occur in the northern part of the Drummond Basin west of Pyramid homestead overlying Tertiary sediments and the Saint Anns Formation, and north of the Burdekin River overlying the Star of Hope Formation.

Flat-lying magnesian limestone crops out in a low dissected plateau 8 miles southeast of Clermont. It occurs in a black soil area and probably directly overlies Tertiary basalt. The limestone may have been deposited in a shallow lake or swamp (Veevers et al., 1964a).

TABLE 4: POST MIDDLE CARBONIFEROUS INTRUSIVE ROCKS

Age	Map symbol	Rock type	Relationships	Remarks
TERTIARY	Tb	Olivine basalt, trachy-basalt, minor agglomerate	Plugs rising above the flood basalts east of Clermont. A plug 10 miles SSE of Mount McConnell homestead intruded the Saint Anns Formation	Fillings of vents through which the flood basalts were extruded.
	Th	Porphyritic olivine basalt, olivine dolerite and gabbro containing xenoliths of ultrabasic rocks	Plugs intruding Anakie Metamorphics, Retreat Granite, and Drummond Basin sequence	Source rock for precious stones, mainly sapphires, found on the Anakie gemfields. See also Figure 31.
	Tp	Alkaline trachyte and rhyolite	Plugs, domes, and minor flows. Intrusive into Permian and older rocks in Fletchers Awl area northeast of Clermont	More extensive in Peak Range southeast of Fletchers Awl (Mollan, 1965) See also Figure 31.
UPPER CARBONIFEROUS TO LOWER PERMIAN	C-Pr	Porphyritic rhyolite and micro-trondhjemite	Ring dykes intruding the Upper Carboniferous granite and volcanics (Cuv)	Intruded into ring fractures, possibly equivalent to Lower Permian high level granite stocks
	C-Pg	Granite, granodiorite, adamellite, quartz-feldspar porphyry	Intrude Ravenswood Granodiorite, Mount Windsor Volcanics, and Drummond Basin sequence	The rim of the stock 8 miles south of Mount McConnell consists of quartz-feldspar porphyry and is similar to Cuv.
	C-Py	Rhyolite and rhyolitic breccia	Mounts Cooper, Wickham and McConnell, volcanic plugs intruding the Ravenswood Granodiorite, Mount Windsor Volcanics and Drummond Basin sequence	Lithologically similar to the Bulgonunna Volcanics and Pur and probably of Upper Carboniferous age
UPPER CARBONIFEROUS	Cb	Diorite, gabbro, basalt, dolerite	Intrude the Drummond Basin sequence mainly at Saint Anns and Mount McConnell homesteads	Age uncertain. Possibly associated with the Upper Carboniferous intrusive phase, but could be younger. Basic rocks of Tertiary age are present in this northern region.
	Cui	Granite, granodiorite, trachyte, rhyolite, quartz-feldspar porphyry	Stocks and sills intruding the Ukalunda Beds and the Drummond Basin sequence	Emplaced in a narrow north to north-northeast trending belt from Twin Hills in the south to the northeast corner of the area (Plate 1). A solitary stock occurs west of Anakie
	Cur	Quartz-feldspar porphyry	Dykes emplaced in the Drummond Basin sequence and along a fault between this sequence and the Ukalunda Beds	Possibly feeder dykes to the Bulgonunna Volcanics. Equivalent porphyries included in the Bulgonunna Volcanics.

Post Middle Carboniferous intrusives

The older intrusive rocks have been described with the basement complex. The post-Drummond intrusives are summarized in Table 4.

ECONOMIC GEOLOGY

Coal is the only mineral mined economically in the whole region. Production at Blair Athol is steadily decreasing and is now less than 75,000 tons per year. The coal is suitable for steam raising and is principally mined for the Queensland Railways. The demand for this coal is continually decreasing with the increased use of diesel locomotives.

Numerous gold and copper shows and small mines occur on the Anakie High and Ravenswood Arch. Mineralization is mainly associated with granitic intrusion; three copper shows, the abandoned Copperfield mine, a copper prospect on the Burdekin River, and a copper show west of Anakie occur on important fault zones (Fig. 31), and they are controlled by these lineaments and post-tectonic intrusion. Copper was mined mainly at Copperfield southwest of Clermont between 1862 and 1877, and gold was mainly produced from the Clermont goldfield and from the Mount Coolon goldmine.

Gemstones, won from the Anakie gem fields, were also an important mineral product of the region. The stones occur in the river gravels and were probably released by the Tertiary Hoy Basalt.

The main mineral occurrences are dealt with separately and the oil prospects of the Drummond Basin sequence are discussed below.

Oil Prospects

The Drummond Basin sequence, covering an area of about 30,000 square miles in outcrop and in the subsurface west of the Anakie High, has been tested for hydrocarbons in five widely spaced exploratory wells (Table 5). They are part of a large number of wells sunk to the west and south of the Drummond Basin outcrop belt, primarily to test the Galilee, Eromanga, and Surat Basin sequences. The complete lack of exploratory wells with primary targets in the Drummond Basin sequence is a clear indication that the basin is regarded as a bad prospect for hydrocarbon accumulation.

The Drummond Basin sequence is largely made up of continental deposits. Marine conditions occurred in the Upper Devonian in the north and may have extended into the southern part of the basin west of the Anakie High. Marine incursions by a shallow epicontinental sea may have occurred early in the Lower Carboniferous; however, there is no fossil evidence to support this.

The succession is extensively folded. Deformation was probably partly contemporaneous with sedimentation, with a culmination in the Kanimblan orogenic event in the middle of the Carboniferous, which ended the Drummond Basin sedimentation. The most intense deformation occurred in the mobile eastern belt adjoining the Anakie High. The folds in the western part of the basin are probably more gentle.

The most promising area with regard to hydrocarbon accumulation is the stable western side of the basin (Fig. 27A) which has been overlapped by the Galilee Basin sequence. Traps are provided by the unconformity between the Drummond and Galilee Basin successions and by pinchouts within the Drummond Basin sequence and particularly in the Raymond and Mount Hall Formations. Similar pinchouts have been observed in outcrop along the eastern margin of the basin and they can be expected to occur along the western margin also.

TABLE 5: OIL EXPLORATION WELLS INTERSECTING THE DRUMMOND BASIN SEQUENCE

Well name (reference)	Depth to Drummond Basin sequence (feet)	Thickness of Drummond Basin sequence (feet)	Lithology	Possible correlation	Oil shows
Exoil Lake Galilee No.1 (Pemberton, 1967)	9320	9320-11175+ (1855+)	Predominantly sandstone with minor interbeds of shale and siltstone. The sandstone is grey, fine to medium-grained, generally well sorted, slightly micaceous, lithic and carbonaceous. Rare pebble zones. Interbedded and often finely interlaminated is dark grey to black shale containing poorly preserved plant fossils and siltstone. Shale, siltstone, very fine-grained sandstone. Poorly preserved plants. Cross-bedding. Scour and fill, and mud cracks.	Buckabie Formation and Mount Wyatt Formation	A drill stem test of the interval 8679-8752 feet recovered 10 feet of 43° gravity oil and a small flow of petroliferous gas from Upper Carboniferous or Lower Permian rocks.
Alliance Oil Development Jericho No.1 (Benedek, 1965)	5507	5507-9142+ (3635+)	Interbedded varicoloured shale, quartzose and lithic sandstone, conglomerate of igneous metamorphic and sedimentary origin, greenish feldspathic sandstone. Purplish-red pebbly feldspathic quartz sandstone interbedded with thin beds of mudstone. Vitric crystal tuff.	Silver Hills Volcanics in the Mt. Beaufort Anticline and the Buckabie Formation of the Adavale Basin	None
Planet Warrong No.1 (Meyers, 1964b)	2782	2782-3508 (726)	Grey to grey-green, slightly carbonaceous shale coarse-grained and conglomeratic varicoloured sandstone containing quartz, feldspar, and rock fragments in varying proportions, tuff and tuffaceous shale and sandstone; grey quartz sandstone.	Ducabrook Formation	
		3509-3579+ (70+)	Light-grey, fine-grained, well sorted quartz sandstone, and conglomerate containing mainly quartz and quartzite pebbles	Raymond/ Mount Hall Formations	None
AFO Purbrook No.1 (Minad, 1963b)	4758	4758-5049+ (291+)	Grey-green and green fine to medium-grained, hard, lithic quartz sandstone; green silicified, in part carbonaceous siltstone and green shale. Plants include <u>Leptophloeum astrale</u>	Timbury Hills Formation, equivalent to the lower part of Drummond Basin sequence	An indication of hydrocarbons in the Permian
Alliance Oil Development Penjobe No.1 (Laing, 1968)	1233	1233-1521+ (288+)	Light-grey siltstone, slightly carbonaceous and calcareous in places, grey shale, tuffaceous siltstone; tuff	Ducabrook Formation	None

Exoil Lake Galilee No. 1 was drilled in this western area; shows of gas were encountered and a drill stem test of the interval 8679'-8752' recovered 10 feet of 43° gravity oil with an associated small flow of petroliferous gas. The age of the oil-bearing sand is not known; Pemberton (1965) considered it to be of Permian age and part of the Galilee Basin sequence. The porosity of the sandstone is very low due to extensive diagenetic overgrowths on the quartz grains. The original porosity was good.

Amerada Petroleum Corporation of Australia drilled a well, Thunderbolt No. 1 (APC, 1967d), 60 miles west of Lake Galilee No. 1 in the Eromanga Basin. Shows of hydrocarbons were observed in several Permo-Carboniferous sands but no hydrocarbons were recovered from drill stem tests over prospective intervals. The well was drilled on a structural feature which had been delineated by seismic work; structure is due to drape over basement highs (APC, 1967a).

The hydrocarbons encountered in the wells may have originated in the Upper Devonian marine sequence of the northern Drummond Basin, or possibly in Middle Devonian marine rocks equivalent to the Ukalunda Beds of the northern Anakie High, and the Middle Devonian of the Adavale Basin. The Ukalunda Beds probably extend in the subsurface into this western area beneath the Drummond Basin. They are deformed and mildly metamorphosed in the Anakie High, but the metamorphism does not necessarily extend far to the west.

Only further exploratory drilling can determine the potential of the area.

Coal

Coal is the only mineral mined commercially in the area. It was discovered at Blair Athol, 10 miles northwest of Clermont in 1864, and production commenced soon after by small-scale underground mining. In 1920, the annual production was

150,000 tons. Production declined until 1936, but with the start of open-cut mining, rose steadily despite the cessation of underground mining in 1946. The greatest annual production was 390,000 tons in 1952; since then production has dropped to less than 100,000 tons per year. The organized exploration for reserves started in 1936, and in 1939 the Aerial, Geological and Geophysical Survey of Northern Australia undertook a geophysical survey which was followed by drilling. In 1958, the Commonwealth Aluminium Corporation (Comalco) took an option on the leases and, after the Bureau of Mineral Resources had conducted a gravity survey (Neumann, 1959), undertook an extensive drilling survey (Whitcher, McIver & Knight, 1960). An extensive physical and chemical study of three 4-inch drill cores through the Big Seam was undertaken by the CSIRO Division of Coal Research (CSIRO, 1960).

Operations on the field are at present restricted to the Big Seam, the greatest known thickness of which is 110 feet; the maximum depth of its base is 256 feet. Proved reserves are at least 200 million tons with an overburden to coal ratio of 1.35; of these reserves, 55 million tons occur with an overburden to coal ratio of less than 1. It has been estimated that 90% of the reserves are available for opencut operations.

The seam contains high volatile, non-coking, low-rank bituminous coal with an average calorific value of 11,810 BTU/lb; it consists mainly of durain with some vitrain bands. Soot beds are locally developed above the seam, and soot partings total 2% to 4% of the seam. An average of analyses of samples from the Big Seam is: 57.6% fixed carbon, 28.4% volatiles, 7.4% ash, 7.2% moisture at 110°C, and 0.29% sulphur. The Blair Athol coal is suitable for steam raising and power generation.

Phosphate

A small floater of black sedimentary rock containing 15% P_2O_5 was found south of Saint Anns homestead in the area where the Saint Anns Formation is exposed. Close investigation revealed two calcareous feldspathic sandstone beds 35 and 80 feet thick, containing up to 4% P_2O_5 (Doutch, 1966).

Samples collected from the Saint Anns Formation 2 miles northeast of Scartwater homestead gave moderate to strong reactions with Ammonium Molybdate but only traces of phosphate were indicated by the Shapiro test. The Saint Anns Formation crops out over a large area in the northern Drummond Basin, and the potential of the area can be evaluated only by detailed sampling.

Water

The sediments of the Drummond Basin and the rocks of the Anakie High and Ravenswood Arch have a small underground water potential. Stock and domestic supplies are drawn in these areas from earth tanks or very shallow bores or wells in creek alluvium. The rainfall in the region is sufficient to keep the tanks and shallow aquifers filled.

Numerous shallow bores have been put down in the Tertiary basalt in the southeast of the area. They produce good quantities of potable water from shallow depth (Veevers et al., 1964a & b).

The water potential of the Galilee and Eromanga Basin sequences to the west of the Drummond Basin (outside the area covered by Plate 1) has been described by Vine et al., (1965).

The Clematis and Colinlea Sandstones in the south of the area yield good supplies of potable but also brackish to saline water (Exon et al., 1966).

Gemstones

Gemstones, principally sapphires, were first recorded from the Anakie district in 1870. The field was first described by Jack (1882) and was described in detail by Dunstan (1902). The most productive period was from 1906 to 1925; since 1925 the production from the field has steadily declined because the richer deposits have been worked out.

Most of the gems have been found in the vicinity of Sapphire and Rubyvale north of Anakie; the Willows field, some 20 miles to the southwest, is a small new field which has the highest current yield.

The gemstones occur as waterworn fragments in old river gravels which form low ridges that rise above the present day alluvium. The actual wash is generally from 2 to 5 feet thick, and varies from being a surficial deposit to 40 feet deep. It is worked either in shallow open cuts or in shafts.

Other minerals found with the sapphires include zircon, pleonaste, garnet, topaz and tourmaline. Some diamonds have also been found.

Gold

Gold was first discovered in the Clermont district in 1861 near Peak Downs. The discovery triggered one of Queensland's major gold rushes, and the Peak Downs Copper Lode was discovered during the early digging for gold. It is apparent that the Clermont goldfield was one of the major producers of alluvial gold in Queensland. Later finds were at Miclere, Black Ridge, and The Springs north of Clermont. Although no records are available for the period up to 1877, it is considered from old Mining Warden reports and other sources that the peak production occurred in this period. From 1878 to 1901, the Clermont goldfield produced gold valued at £711,000, and in 1904 nearly 6,900 ounces were produced. After 1904 production declined steadily, but the discovery of new leads at Miclere in 1931 revived the field. According to files of the Geological Survey of Queensland this new find netted 40,000 oz of gold in the ensuing 25 years. Most of the shafts are now filled with water and have been abandoned. The only current production is by fossickers working the old dumps and the recent alluvium.

The gold occurs in two environments: quartz reefs in the Anakie Metamorphics and alluvial deposits of Permian, Tertiary(?) and recent age. Dunstan (1902) described over 25 reefs in the area, but reef gold production was subsidiary to that from the deep lead workings. In the period 1878 to 1901, reef gold amounted to 9,900 oz, but deep lead production was 175,500 oz. Most of the production after 1877 has come from the Permian deep leads. The gold in the deep leads was presumably derived from auriferous quartz reefs in the Anakie Metamorphics, although the quartz reefs now cropping out are mostly barren. Distribution of the gold in the leads is patchy, but appears to be controlled by small faults and quartz veins in the bedrock. These veins are barren, but because of their resistance, formed bars across the watercourses and acted as riffles. Small displacements on the faults similarly formed gutters in which gold accumulated. The shallower ground has probably been worked out at Miclere, but elsewhere many shafts could not reach the deeper Permian leads because of flooding. Gold probably remains in much of the so-called "wet ground" around The Springs lead. Water also caused considerable difficulties at the Deep Creek Lead, Wild Cat Lead, and Chinamans Flat, south of Clermont. A re-assessment of many of these diggings in the light of modern pumping equipment may prove worthwhile. Gold has been reported from the gossan of the Peak Downs Copper Lode at values from 2 to 35 dwt/ton. Details of the Clermont goldfield are given by Dunstan (1902) and Ball (1906); more recent work has been done in the Miclere area by Morton (1934) and Ridgway (1938).

Gold, copper and silver were also mined during 1914-15 from claims about 1.5 miles west-southwest of Fletchers Awl. Values were generally low, but assays of gold up to 3 oz to the ton, silver up to 10 oz to the ton, and copper up to 27% were obtained. The country rock is Anakie Metamorphics and the mineralization is probably associated with the granite intrusion.

At Mount Clifford, 4 miles southwest of Sapphire, gold was mined intermittently from 1896 to 1902 and again for a few years after 1926 but it appears that very little was produced (Dunstan, 1898; Morton, 1932). The gold occurred in hydrothermally altered slates caught up in a diorite intrusion and also in veins in the diorite. The area was first worked for silver in lodes associated with bornite, hematite, azurite, and malachite (Jack, 1882).

The Mount Coolon gold mine (Morton, 1935) produced about 197,500 oz of gold between 1914 and 1939. Approximately 60,000 oz of silver were produced after 1930; silver production before 1930 is not recorded. The gold was won from a single lode system contained in a local development of andesite. The lode consisted of siliceous rock, developed adjacent to a shear in the andesite; away from the shear the siliceous lode graded into silicified andesite. The lode averaged 7 feet in width and could be traced for half a mile. The gold was associated with pyrite mineralization and was largely confined to the siliceous lode. The source of the silicification and mineralization is thought to be a quartz diorite mass which intrudes the andesite and the Anakie Metamorphics to the west.

A geophysical survey was made in a small area southeast of the mine in 1937-38 (Oakes, Rayner and Nye, 1941), to test the possible extent of the mineralized zone under the superficial deposits, but the results were disappointing.

The Mount Wyatt goldfield in the northeast of the area was also one of the earliest known fields in Queensland (Reid, 1928). The presence of alluvial gold was known in 1868 and was reported on by Daintree (1870). The deposits are found in granite or in the metamorphosed sediments around them. Small silver and copper lodes are also known in the goldfield, but they are uneconomic. The numerous diggings and shafts in the area are not shown on Plate 1 (for location, see Paine et al., in prep.).

Rutherfords Table, 8 miles south of Mount Wyatt, is a mesa of Tertiary Suttor Formation, and goldbearing river gravels occur at the base of the formation in a depression in the granite basement. The gold occurs as small flakes and scales and as wire gold. The grains range from microscopic size up to 2mm in diameter; fragments up to half a pennyweight have been recorded. Rounding and pitting of the grains suggests they have travelled a considerable distance (Levingston, 1953). Total production during the past 10 years is about 900 oz.

A large number of small mines, all part of the Charters Towers and Ravenswood gold and mineral fields occur in the northern part of the area in the Ravenswood Arch. The mineralization occurs within the Ravenswood Granodiorite Complex or the Cape River Beds near the contact with the granodiorite. The details of many mines in the fields have been described by Maclaren (1900), Cameron (1901, 1903), Maitland (1911), and Reid (1934). (For location of mines, see Wyatt et al., in prep.).

Copper

The Peak Downs copper lode at Copperfield 4 miles southwest of Clermont was found in 1862 during the goldrush on the Peak Downs goldfield. The lode became the principal producer of copper in Queensland and was the first of significance.

The Peak Downs Copper Mining Company was formed in 1862 and until its winding up in 1837 mined from the lode 100,000 tons of ore averaging 17% copper; this ore was smelted on the site. In addition, large amounts were smelted at Swansea. Towards the end of its activities the company issued a generous but unrealistic dividend, based on ore in transit, ore at grass, and an unusually high price for copper. Before the ore reached the markets, however, the price of copper dropped; the heavy bank overdraft thus incurred and the probable working-out of the higher-grade ore crippled the company. Since 1877 a number of efforts have been made to asses reserves and re-open the mine, but with little success.

The Peak Downs Copper Lode occurs as a replacement along a major fissure or shear-line in sericitic and chloritic schists of the Anakie Metamorphics. It forms a prominent outcrop which, however, is mainly a barren siliceous ironstone; it strikes 78° and dips southwards at 35° to 60°, but at depth the dips are 30° to 45°. The lode, which is roughly bisected by the Clermont-Rubyvale road, extends for about one and a half miles in three discontinuous sections. Most of the ore production has come from the parts lying to the west of the Rubyvale road. The lode is cut by numerous dip faults, with a maximum throw of 60 feet, and at depth is displaced by strike faults. Mineralization is probably controlled by the Copperfield megashear (Fig. 31), associated secondary shear zones, and granitic intrusion.

The Peak Downs Copper Mine was developed by a number of shafts with numerous cross-cuts and winzes; the deepest shaft went to the 714-foot level along the lode (348 feet V.D.).

The initial high returns from the Peak Downs Copper Mine were due to the extensive secondary enrichment of the sulphide ore to oxidized carbonate ore. The ore is enriched to the 180-foot level (120 feet V.D.), but most of the richer ore has been removed. However, in the period of mining activity it was not economical to break stone containing less than 12% copper; consequently ore with values up to 12% copper remains in the old stopes above the 180-foot level. Very little sulphide ore has been stoped below this level. Mount Morgan Limited sampled some of the primary ores, which are iron and copper pyrites, and obtained values around 3.78% copper for a width of 2 feet 3 inches. Most of the shafts are now flooded, and have collapsed; it is recorded that during an attempt to re-open the mine in 1899, iron rails, trucks, steel ropes, and other equipment recovered from below the water level had been almost entirely converted to copper. The recovery of copper from these waterlogged diggings by the cementation process may prove worthwhile.

The copper potential of this area should be re-assessed in terms of current economic grades, and in the light of more modern mining techniques. The area may warrant development and exploratory work to estimate the reserves of lower grade secondary ore remaining, and the reserves of primary sulphide ore which has never been adequately assessed.

The most recent published work on the Peak Downs Copper Lode is by Reid (1944) and Denmead (1945).

Slight copper mineralization has been recorded from several localities between Copperfield and Anakie (Morton, 1931 a & b; Reid, 1945). All were near the contact of granite with the Anakie Metamorphics. A copper show is also present in the Silver Hills Volcanics west of Anakie.

A small copper mine operated for some years north of the Sellheim River, about 3 miles south of Mount Wyatt; it is now abandoned. The ore occurs in the Ukalunda Beds close to their contact with granite. It consists of malachite, azurite, chrysocolla, chalcopyrite, and pyrite in an epidote rich country rock. Production figures are not available.

A copper prospect is presently being investigated near the junction of the Suttor and Burdekin Rivers in the north of the region. It lies on a major fault zone and is associated with acid dykes.

Silver

Silver was first produced in 1883 in the Sellheim River area around Two-mile Creek (Jack, 1889). Several mines operated during the years 1883-1893; after 1893, most of the production came from the Sunbeam mine. Total production for the period 1883-1934 is estimated at 681,000 oz. The Sunbeam mine yielded some extremely rich ore, assaying as high as 1200 oz of silver per ton, as well as some gold, copper, and bismuth. The ore occurs as fissure lodes in the Ukalunda Beds and in intrusive dolerites.

Bismuth-Arsenic-Gold

Bismuth, arsenic and gold ores are contained in fissures in granite of the Ukalunda district. The Daisy Bismuth Mine, the Walhalla workings, and the Carrington workings are located on fissure lodes and all three were reported on by Morton (1945a, b; 1946). The Daisy Mine is 2 miles northeast of Ukalunda, and the other two are half a mile south and half a mile east of the Daisy Mine. The almost vertical Daisy fissure was worked over a length of 620 feet and contained two ore-shoots, 250 feet apart. The mine produced gold, copper, silver, and bismuth ores in 1889 and 1890. The sulphides include chalcopyrite, pyrite, and bismuthinite; quartz and siderite are the main gangue minerals. Morton (1945b) considers that sulphide ores containing high aggregate values of gold, copper, silver and bismuth remain in the ground.

Arsenic-gold ore was mined at the Salopia workings 1.5 miles southeast of Ukalunda. The auriferous arsenopyrite occurs sparingly in small quartz veins and as minor disseminations in highly altered rocks of the Ukalunda Beds close to their contact with the intrusive granite.

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APPENDIX

PLANT FOSSILS FROM THE DRUMMOND BASIN, QUEENSLAND

by

Mary E. White

Collections of plant fossils were made from 57 localities in the Drummond Basin during field seasons from 1960 to 1967. A well preserved Lepidodendron flora of Upper Devonian and Lower Carboniferous age is present. Analysis of the occurrence of different species in the formations comprising the Drummond Basin sedimentary sequence has contributed valuable information on the ranges of species.

The fossil localities are shown on the accompanying geological map (Plate 1). Table A shows the distribution of species, and Plates A to H illustrate the flora. Descriptions and discussion of the plant fossils follow.

The main facts established from the study of the collections are:

1. Psilophytites and Protolepidodendron are confined to Devonian strata.

2. Leptophloeum australe (M'Coy) is very abundant in Upper Devonian strata. It is known to persist into Lower Carboniferous horizons elsewhere in Australia. It is almost certainly the same plant as Leptophloeum rhombicum Dawson.

3. Lepidodendron mansfieldense M'Coy and Lepidodendron volkmannianum Stbg. are characteristic of Upper Devonian and lowermost Carboniferous beds. Lepidodendron mansfieldense was redescribed by Walkom as Lepidodendron osbornei.

4. Lepidodendron veltheimianum Stbg., the form-species name used to include a wide range of forms which cannot be satisfactorily separated, occurs in the Upper Devonian and throughout the Carboniferous. A variety of the species with characteristic wrinkling of the leaf base tissue appears to be confined to Carboniferous horizons and may be a distinct species.

5. Lepidodendron aculeatum Stbg. and Lepidodendron dichotomum Stbg. are confined to the Carboniferous.

6. Non-lepidodendroid plants are very rare in the assemblage, except for Equisetalean stem fragments which are of no use as index fossils.

7. There are no Upper Carboniferous plants present and the flora is essentially of Upper Devonian to Lower Carboniferous type.

Descriptions of species

Psilophytites

The form-genus Psilophytites is used to describe small stems and twigs which show Psilophyte affinity. Some have a median sulcus, lateral branches of limited growth and characteristic forking.

Protolepidodendron lineare Walkom (Pl. C, fig. 2).

The stems have leaf cushions which are arranged in distinct vertical series, and are separated from each other by straight vertical grooves. The leaf cushions are elongated vertically, and are not separated from each other by ridges but merge gradually into adjacent ones above and below. There is an ascending spiral arrangement of leaf cushions.

	Silver Hills Volcanics						St Anns Fm.			
LOCALITY AND REGISTRATION NUMBER	Em 26/5; F 22059	Em 28/8; F 22069, 22070	Em 26/10; F 22059	Em 32/1; F 22071	Em 36/2; F 22072-22077	Em 355/5; F 22066	344; F 22761-63; 22781	600; F 22839	Mc 886 F	368A; F 22769
Psilophytes										
Protolepidodendron lineare Walk.									●	
Leptophloem australe McCoy	●	●	●	●	●	●				
Lepidodendron mansfieldense McCoy										
Lepidodendron volkmannianum Stbg.								●		
Lepidodendron veltheimianum Stbg.							●	●		●
Lepidodendron aculeatum Stbg.										
Lepidodendron dichotomum Stbg.										
Stigmaria ficoides Bgt.									●	
Lepidostrobus		●								
Lepidophyllum										
Ulodendron										
Cyclostigma australe Feist.										
Indet. Lycopod stems										
Rhacopteris digitata Eth. fil.										
Rhodea sp.										
Equisetalean stems		●					●			
Cordaites australis (McCoy)										

	Mount Wyatt Formation							D/Cv	
LOCALITY AND REGISTRATION NUMBER	205; F 22927-22933	207; F 22934-22936	267; F 22949-22952	B12; B94; B1000	199; F 22918-22920	200/1; F 22923-22926	Mc81 F	GSQ 527; F 8940-8955	GSQ 508; F 8762-8764
Psilophytes	●			●				●	
Protolepidodendron lineare Walk.				●				●	
Leptophloem australe McCoy		●	●	●					
Lepidodendron mansfieldense McCoy	●					●	●	●	
Lepidodendron volkmannianum Stbg.								●	
Lepidodendron veltheimianum Stbg.					●				
Lepidodendron aculeatum Stbg.						●			
Lepidodendron dichotomum Stbg.					●		●		
Stigmaria ficoides Bgt.								●	
Lepidostrobus							●		
Lepidophyllum									
Ulodendron									
Cyclostigma australe Feist.									
Indet. Lycopod stems									
Rhacopteris digitata Eth. fil.									●
Rhodea sp.									
Equisetalean stems			●						●
Cordaites australis (McCoy)								●	

	Telemon Formation					Scartwater Formation							
LOCALITY AND REGISTRATION NUMBER	Em 24/5; F 22073	Sp 54/5; F 22089	Sp 55; F 22402	Sp 80; F 22338	943; F 22833-22838	20; F 22751-22758	256; F 22942-22948	350; F 22764-22766	351; F 22767	359; F 22768	446; F 22782-22789	GSQ 509; F 8759-8761	GSQ 529; F 8916
Psilophytes													
Protolepidodendron lineare Walk.													
Leptophloem australe McCoy													
Lepidodendron mansfieldense McCoy					●				●			●	●
Lepidodendron volkmannianum Stbg.					●						●		
Lepidodendron veltheimianum Stbg.						●	●	●				●	
Lepidodendron aculeatum Stbg.							●				●	●	
Lepidodendron dichotomum Stbg.							●						
Stigmaria ficoides Bgt.	●						●	●		●		●	
Lepidostrobus													
Lepidophyllum										●	●		
Ulodendron													
Cyclostigma australe Feist.											●		
Indet. Lycopod stems		●	●	●									
Rhacopteris digitata Eth. fil.							●				●		
Rhodea sp.					●								
Equisetalean stems													
Cordaites australis (McCoy)							●						

	Mt Hall Formation				Raymond Fm.		Star of Hope Formation						
LOCALITY AND REGISTRATION NUMBER	Sp 41; F 22332	Sp 89/1; F 22339	236/1; F 22937	925; F 22840	469; F 22778-22779	Sp 363/4; F 22391	GSQ 504; F 8723	GSQ 532; F 8939	GSQ 533; F 8938	24; F 22922	435; F 22771-22774	436; F 22775-22777	B 572 F
Psilophytes													
Protolepidodendron lineare Walk.													
Leptophloem australe McCoy													
Lepidodendron mansfieldense McCoy										●			
Lepidodendron volkmannianum Stbg.													
Lepidodendron veltheimianum Stbg.		●		●	●	●	●	●		●	●	●	●
Lepidodendron aculeatum Stbg.													
Lepidodendron dichotomum Stbg.										●			
Stigmaria ficoides Bgt.					●		●				●		
Lepidostrobus													
Lepidophyllum													
Ulodendron										●			
Cyclostigma australe Feist.													
Indet. Lycopod stems	●		●						●				
Rhacopteris digitata Eth. fil.													
Rhodea sp.													●
Equisetalean stems													
Cordaites australis (McCoy)													

	Ducabrook Formation							Mt Rankin Fm.		
LOCALITY AND REGISTRATION NUMBER	Cl 303/10	Cl 362	Em 349/5; F 22064	Em 349/10; F 22065	Sp 352/2; F 22331	Sp 354/1; F 22334	Sp 364/1; F 22392	Cl 134;	255; F 22938-22941	785; F 22841-22843
Psilophytes										
Protolepidodendron lineare Walk.										
Leptophloem australe McCoy										
Lepidodendron mansfieldense McCoy										
Lepidodendron volkmannianum Stbg.										
Lepidodendron veltheimianum Stbg.		●	●						●	●
Lepidodendron aculeatum Stbg.								●		
Lepidodendron dichotomum Stbg.										
Stigmaria ficoides Bgt.	●	●						●	●	●
Lepidostrobus								●		
Lepidophyllum								●		
Ulodendron										
Cyclostigma australe Feist.										
Indet. Lycopod stems				●			●			
Rhacopteris digitata Eth. fil.										
Rhodea sp.										
Equisetalean stems			●	●	●	●				
Cordaites australis (McCoy)										

Table A.- Plant species distribution

Leptophloeum australe (M'Coy). (Pl.A, figs 1 & 2; Pl. B, figs 1 & 2; Pl. C, fig. 1)

Plate A illustrates a range of forms which occur at localities 36/2 and 26/8 in the Silver Hills Volcanics. The characteristic rhomboidal pattern of the leaf bases is seen in Plate A, figure 1. This is the most common and widely occurring form of the species. Plate A, figure 2 and Plate B, figure 1 show interesting impressions in which leaf bases are crowded into wrinkled zones in the same way as described by Dawson (1862) in Leptophloeum rhombicum Dawson. In view of this evidence it is probable that the species are not distinct.

Plate C, figure 1 illustrates part of a cone showing sporophylls. This is probably referable to Leptophloeum australe which is the only plant species determined at the locality. There is a similar specimen in the collection of the Sydney Museum associated with Leptophloeum australe.

Plate B, figure 2 shows an interesting specimen in which leaf bases are attached in bottle-brush fashion to a stem.

Lepidodendron mansfieldense M'Coy (Pl. D, figs 1-4).

In this species the leaf bases are widely spaced, kite-shaped, and have leaf trace scars near the top. The specimens in the Drummond Basin collection have been compared with type material in the Sydney Museum. They do not appear to be distinct from "Lepidodendron osbornei Walkom" which was presumably named in ignorance of M'Coy's species which has precedence.

Associated with Lepidodendron mansfieldense at locality MC 81F is a cone which is illustrated in Plate D, figure 3. It may be the cone of the species.

Lepidodendron volkmannianum Stbg. (Pl. E, figs 3 & 4; Pl. F, fig. 1)

Young lycopod stems showing a characteristic pattern of leaf bases are referred to this species. A rhombic network is formed by the raised margins of the leaf bases. The leaf bases are heart-shaped pads enclosed by the margins, and the leaf trace scars are almost central. These specimens resemble European material identified as *Lepidodendron volkmannianum* in the Sydney Museum. The species resembles and may not be distinct from *Lepidodendron clarkei* Walkom.

Lepidodendron veltheimianum Stbg. (Pl. F, figs 1 & 4; Pl. G, fig. 1; Pl. H, figs 1 & 2)

A wide range of forms is included in this form-species. It has not been found practicable to separate varieties. In all specimens the leaf bases are roughly spindle-shaped and contiguous. Many Carboniferous examples show a characteristic wrinkling of the tissue of the leaf bases as seen in Plate G, figure 1.

An example of *Ulodendron* is illustrated in Plate G, figure 2. The leaf base pattern on the stem around the scar is of *Lepidodendron veltheimianum* type.

A young stem with attached leaves is illustrated in Plate F, figure 3 and a larger example in Plate H, figure 1.

Lepidodendron aculeatum Stbg. (Pl. C, figs 3-6)

The pattern of leaf bases in this species differs from *Lepidodendron veltheimianum* in that they are wider in proportion to their length. Sometimes the leaf bases have a median sulcus. The leaves of the species were apparently wide and ribbon-like as seen in Place C, figure 6. A cone illustrated in Plate C, figure 5, shows fine ensheathing bracts. It was associated with a large number of *Lepidodendron aculeatum* and may be the cone of that species.

Lepidodendron dichotomum Stbg. (Pl. E, fig. 1)

Stems with a pattern of leaf bases similar to Lepidodendron veltheimianum but with the leaf base margins forming an elongated diamond pattern mesh. Whether this is a valid species or just a variety of compression form of Lepidodendron veltheimianum is uncertain.

Stigmaria ficoides Bgt. (Pl. F, fig. 2)

Examples of Stigmaria ficoides occur throughout the collection. The characteristic arrangement of circular or oval scars with a central point of attachment for Stigmarian rootlets is seen in Plate F, figure 2. As all lycopod genera probably have Stigmarian root buttresses, the fossils are of no value on their own to determine age.

Cyclostigma australe Feist. (Pl. E, fig. 4)

The figure illustrates an example of a stem referred to this species. The small, oval scars on the stem are not enclosed by leaf base scars.

Rhacopteris digitata Eth. fil. (Pl. E, fig. 2)

A fragment of a frond referred tentatively to Rhacopteris digitata is illustrated in figure 2. It is not impossible that it is a fragment of Rhacophyllum diversiforme or similar leaf. Fronds of this type occur in Lower Carboniferous horizons in New South Wales in considerable numbers.

Rhodea sp.

Leaf fragments showing dichotomy are referred to Rhodea sp. They are not fully determinate and could be referred to a number of Lower Carboniferous genera on available evidence.

Cordaites australis M'Coy

Leaf fragments showing parallel venetian are referred tentatively to this species.

Reference

DAWSON, J.W., 1862 - The flora of the Devonian period in northeast America. Quart. J. geol. Soc. Lond., 18, 929-930.

Plate A

Fig. 1 - Leptophloeum australe (M'Coy). Characteristic decortication form. F22073. Locality Em 36/2.

Fig. 2 - Leptophloeum australe (M'Coy). Young stem, crowded leaf bases. Magnification X 2. F22074. Locality Em 36/2.

Plate B

Fig. 1 - Leptophloeum australe (M'Coy). Stem with zones of wrinkled crowded leaf bases. F22075. Locality Em 36/2.

Fig. 2 - Leptophloeum australe (M'Coy). Stem with 'bottle-brush' of attached leaf bases. F22076. Locality Em 36/2.

Plate C

Fig. 1 - Leptophloeum australe (M'Coy). Part of cone. F22070. Locality Em 26/8

Fig. 2 - Protolepidodendron lineare Walkom. CPC 4348. Locality Mc 886P.

Fig. 3 - Lepidodendron aculeatum Stbg. Magnification x 2. CPC 4385. Locality CL 134.

Fig. 4 - Lepidodendron aculeatum Stbg. F22782. Locality 351

Fig. 5 - Lepidodendron aculeatum Stbg. Lepidostrobus. CPC 4387 Locality CL 134

Fig. 6 - Lepidodendron aculeatum Stbg. Stem with attached leaves. Magnification x 2. CPC 4384. Locality CL 134.

Plate D

Fig. 1 - Lepidodendron mansfieldense M'Coy. Large Stem. CPC 4346 Locality Mc 81F.

Fig. 2 - Lepidodendron mansfieldense M'Coy. Young branching stem. F22767. Locality 351.

Fig. 3 - Lepidodendron mansfieldense M'Coy. Lepidostrobus. CPC 4344 Locality Mc 81F.

Fig. 4 - Lepidodendron mansfieldense M'Coy. F22754. Locality 351.

Plate E

Fig. 1 - Lepidodendron dichotomum Stbg. F22754A. Locality 24.

Fig. 2 - Rhacopteris digitata Eth. fil. F22789. Locality 446.

Fig. 3 - Lepidodendron volkmannianum Stbg. Magnification x 2. F22833 Locality 943

Fig. 4 - Lepidodendron volkmannianum Stbg. and Cyclostigma australe Feist. F22786. Locality 446.

Plate F

Fig. 1 - Lepidodendron volkmannianum Stbg. F22784. Locality 351

Fig. 2 - Stigmaria ficoides Bgt. F22771. Locality 435.

Fig. 3 - Lepidodendron veltheimianum Stbg. Young stem with leaves. F22774. Locality 435.

Fig. 4 - Lepidophyllum. F22788. Locality 351.

Plate G

Lepidodendron veltheimianum Stbg. Large stem with striated leaf bases. F22777. Locality 436.

Plate H

Fig. 1 - Lepidodendron veltheimianum Stbg. Very large stem. F22752. Locality 20.

Fig. 2 - Lepidodendron veltheimianum Stbg. Ulodendron. F22922. Locality 24.

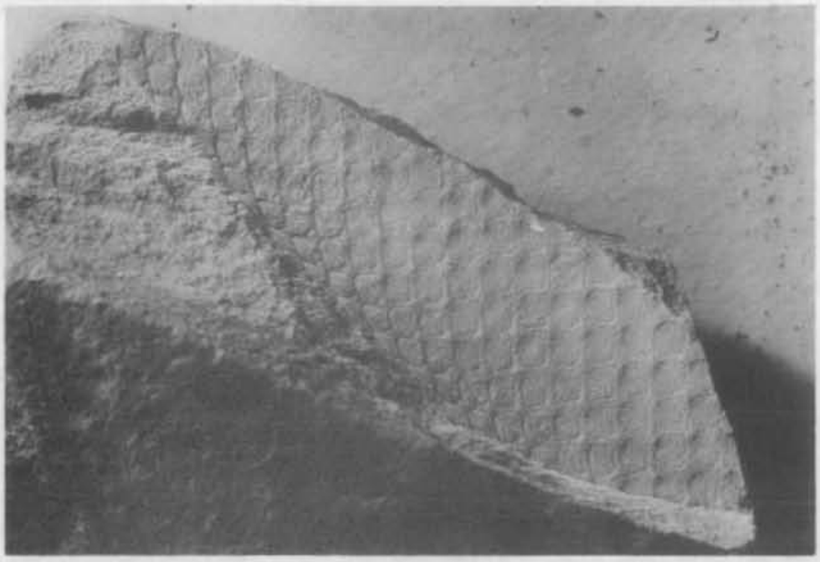


Fig. 1

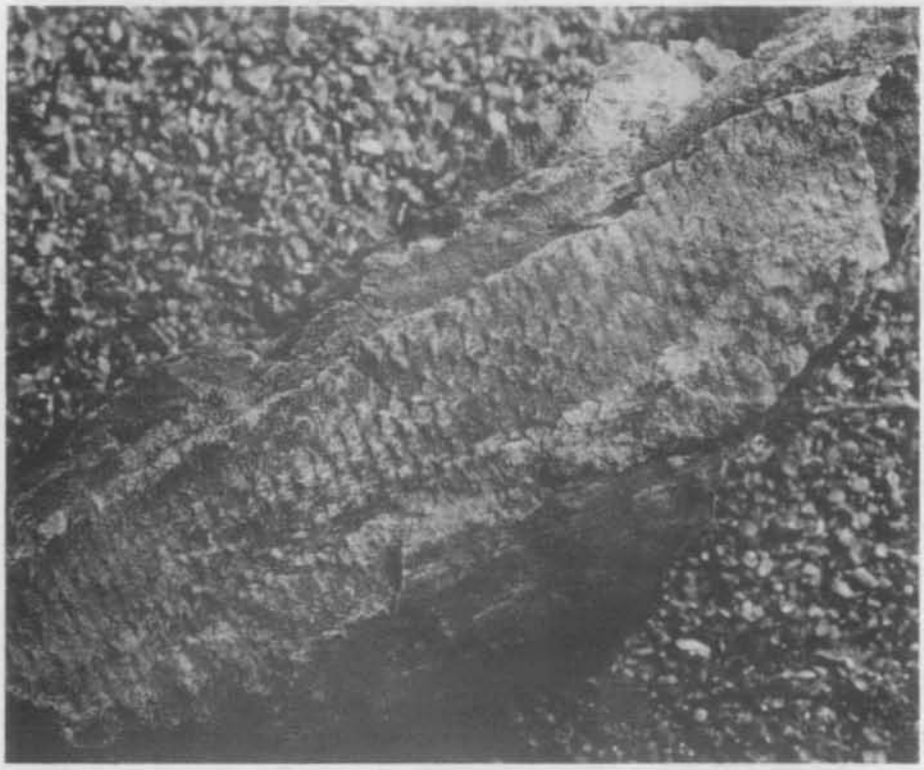


Fig.2

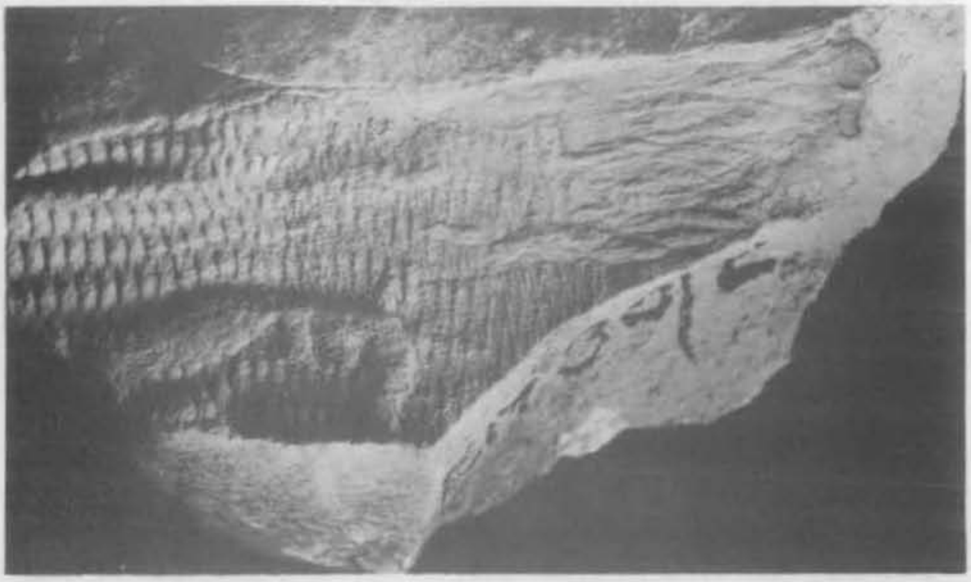


Fig. 1

Fig. 2

Fig. 1

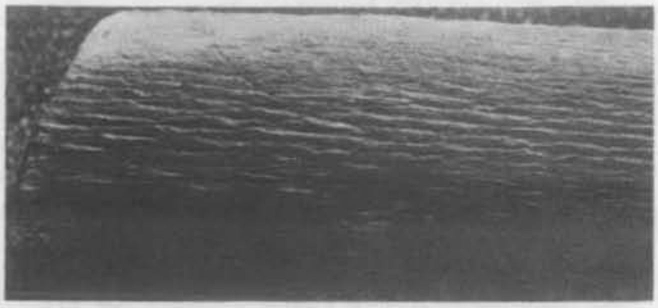


Fig. 2

Fig. 4

Fig. 3

Fig. 6

Fig. 5

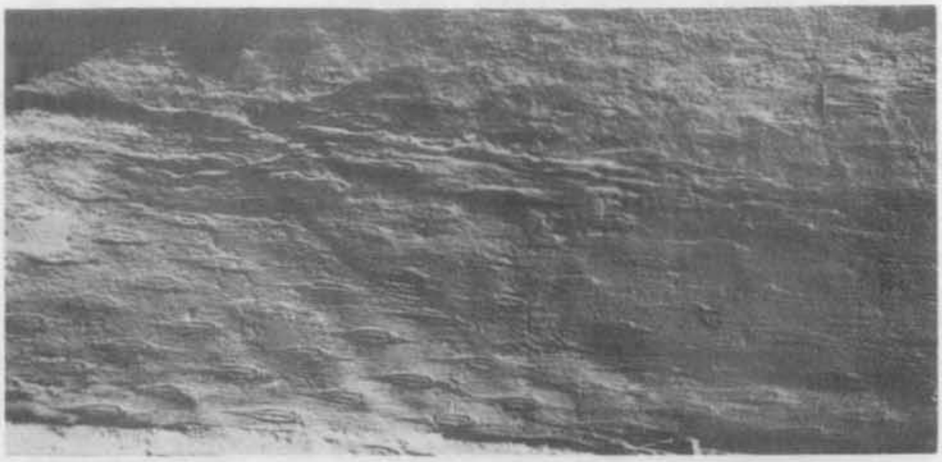


Fig. 1

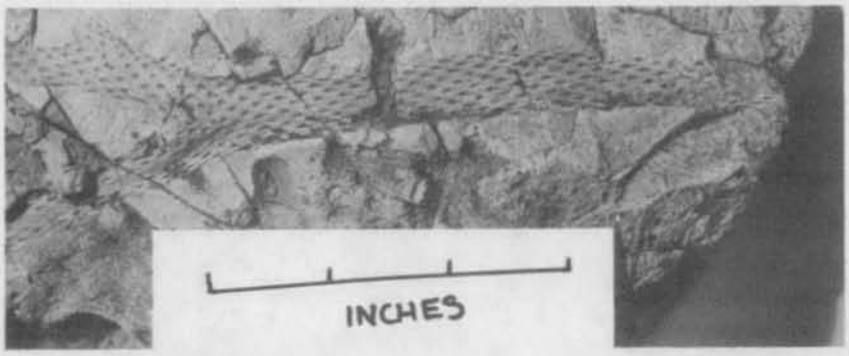


Fig. 2

Fig. 3

Fig.4

PLATE E

Fig. 1

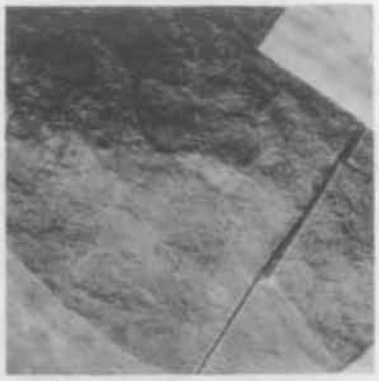


Fig. 2

Fig.3

Fig.4

Fig. 1

Fig. 2

Fig. 3

Fig. 4

Fig. 1

Fig. 1

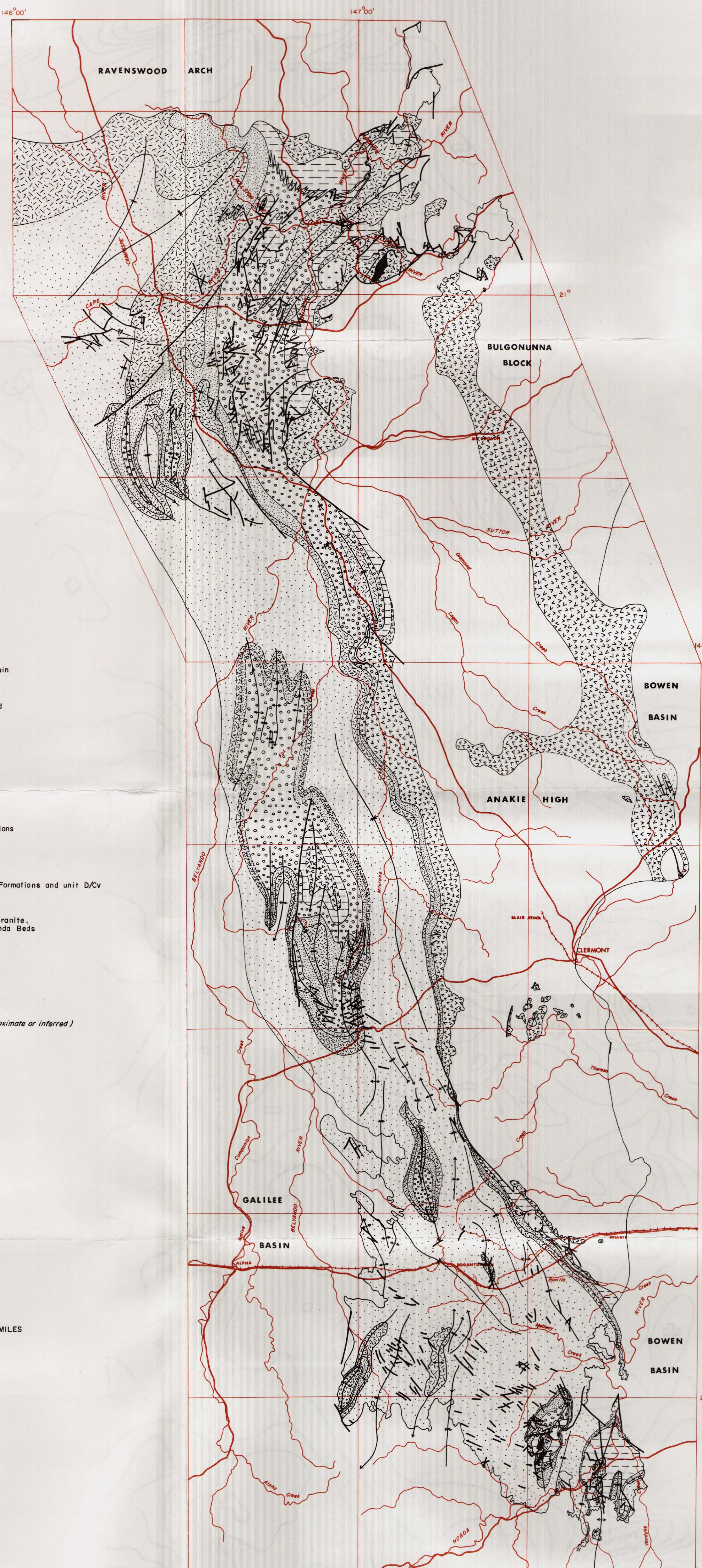
Fig. 2

PLATE 1


PRELIMINARY EDITION, 1969
SUBJECT TO AMENDMENT
NO PART OF THIS MAP IS TO BE REPRODUCED FOR PUBLICATION WITHOUT THE WRITTEN PERMISSION OF THE DIRECTOR OF THE BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS, DEPARTMENT OF NATIONAL DEVELOPMENT, CANBERRA, A.C.T.
DRUMMOND BASIN
QUEENSLAND
Scale 1 : 500,000
10 0 10 20 MILES
10 0 10 20 30 KILOMETRES
Geology Drummond Basin 1960-1967, by: F. Olgers, H.F. Doutch, R.G. Mollan, E.J. Malone, J.J. Veevers and J.G. Binnekamp (B.M.R.); A.G. Kirkegaard, D.E. Clarke and D.E. Wyatt (G.S.Q.); J. Eftekharnezhad (Geol. Survey of Iran)
Compiled by: F. Olgers and J.G.A. Den Hertog
Cartography by: Geological Branch B.M.R.
Drawn by: J.G.A. Den Hertog
Compiled by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development. Issued under the authority of the Hon. David Fairbairn, Minister for National Development.
Base map compiled by the Bureau of Mineral Resources from air photographs, and information supplied by the Division of National Mapping, Department of National Development. Commonwealth aerial photography; complete vertical coverage at 1: 48,000 and 1: 85,000 scales
Transverse Mercator Projection
BUREAU OF MINERAL RESOURCES · GEOLOGY AND GEOPHYSICS · DEPARTMENT OF NATIONAL DEVELOPMENT · AUSTRALIA
TECTONIC SETTING
RAVENSWOOD ARCH
GALILEE BASIN
BOWEN BASIN
147°00'
148°00'
Reference
CAINOZOIC
QUATERNARY
Qa Alluvium
Qs Sand, sandy soil
UNDIFFERENTIATED
Cz Soil, alluvium
Czg Gravel and sand
Czm Magnesian limestone
TERTIARY
Tf Ferricrete
T Argillaceous and feldspathic sandstone and conglomerate, generally lateritized
Suttor Formation Ts Quartz sandstone, siltstone, conglomerate
Peak Range Volcanics Tp Trachyte and rhyolite plugs, domes and flows
Hoy Basalt Th Plugs of porphyritic olivine basalt
Tb Basalt flows, rare plugs
MESOZOIC
LOWER JURASSIC
Hutton Sandstone Jlh Feldspathic quartz sandstone
Evergreen Formation Boxvale Sandstone Member Jlb Quartz sandstone, sandstone, minor coal
Precipice Sandstone Jlp Cross-bedded quartz sandstone
TRIASSIC
Moolayember Formation Rm Lithic sandstone, siltstone, shale
Warang Sandstone Rlw Kaolinitic quartz sandstone, siltstone, mudstone
Clematis Sandstone Re Cross-bedded pebbly quartz sandstone, siltstone
Dunda Beds Rld Lithic sandstone, quartz sandstone, siltstone, mudstone
Rewan Formation Rlr Mudstone, lithic quartz sandstone
PALAEOZOIC
PERMIAN
Undifferentiated P Lithic and quartz sandstone, siltstone, mudstone, carbonaceous shale, coal, conglomerate
Blair Athol Coal Measures Pa Sandstone, shale, mudstone, conglomerate, coal
UPPER PERMIAN Blackwater Group Puw Lithic sandstone, mudstone, carbonaceous shale, coal, tuff
LOWER TO UPPER PERMIAN
Back Creek Group
Undifferentiated Pb Quartz sandstone, pebbly quartz sandstone, feldspathic sandstone, mudstone, coal
Blenheim Subgroup Pue Quartz sandstone, lithic quartz sandstone, conglomeratic siltstone, micaceous and carbonaceous mudstone
Black Alley Shale Puc Black shale, soft clay, tuff
Peawaddy Formation Pup Lithic quartz sandstone, carbonaceous siltstone
LOWER PERMIAN
Gebbie Subgroup Colinlea Sandstone Plo Quartz sandstone, pebbly quartz sandstone, conglomerate
Reids Dome Beds Plj Sandstone, siltstone, shale, coal
UPPER CARBONIFEROUS TO LOWER PERMIAN
Joe Joe Formation C-Pj Tillitic conglomerate, lithic quartz sandstone siltstone
C-Pr Porphyritic rhyolite and microtrondhjemite
C-Pg Adamellite, granodiorite, granite
C-Py Flow-banded rhyolite and rhyolite breccia
UPPER CARBONIFEROUS
Cb Diorite, gabbro, monzonite, dolerite, meladiorite
Cui Granite and granodiorite with aplite and other fine grained acid components
Bulgonunna Volcanics Cub Rhyolite, dacitic flows, tuff, agglomerate
Cuv Rhyolite, dacitic breccia, andesite, coarse pyroclastics
Cur Intrusive rhyolite and quartz-feldspar porphyry
LOWER CARBONIFEROUS
Natal Formation Cln Feldspathic quartz sandstone, olive siltstone
Bulliwallah Formation Clb Feldspathic quartz sandstone, minor olive mudstone, acid volcanics, conglomerate
Ducabrook Formation Clu Feldspathic lithic sandstone, mudstone, shale, limestone, tuff
Mount Rankin Formation Cla Conglomerate, feldspathic-lithic sandstone, siltstone
Star of Hope Formation Cls Sandstone, conglomerate, mudstone, chert, tuff
Raymond Formation Clr Flaggy quartz sandstone, olive mudstone, minor limestone
Mount Hall Formation Clh Quartz sandstone, pebbly quartz sandstone, conglomerate
Scartwater Formation Clc Feldspathic sandstone, mudstone, algal and sandy limestone, minor tuff
Telemon Formation Clt Lithic conglomerate, sandstone, siltstone, algal limestone, tuff
UPPER DEVONIAN TO LOWER CARBONIFEROUS
Silver Hills Volcanics D/Cs Rhyolite, welded tuff, minor sediments
Llanarth Volcanic Member D/Cl Acid tuff, minor flows; conglomerate
Saint Anns Formation D/Ca Conglomerate, lithic sandstone, acid and intermediate flows, and tuff, phosphatic sandstone, algal and oolitic limestone
D/Cv Quartz-feldspar porphyry, agglomerate, tuff, tuffaceous sandstone
D/Ci Granodiorite, porphyry
UPPER DEVONIAN
Mount Wyatt Formation Dum Lithic sandstone, siltstone, conglomerate, silicified fossiliferous limestone
Retreat Granite Dgr Granodiorite, adamellite
MIDDLE DEVONIAN
Ukalunda Beds Dk Lithic sandstone, shale, phyllite, fossiliferous limestone, conglomerate
Dunstable Volcanics Dmn Green andesite lavas and pyroclastics, shale, coralline limestone
Dmg Limestone, rhyolite, tuff, sandstone, shale
Dn Andesitic flows, pyroclastics with limestone lenses
Theresa Creek Volcanics Dt Andesite, basalt, basic crystal tuff
Douglas Creek Limestone Dmd Fossiliferous limestone, micaceous siltstone
SILURIAN TO LOWER DEVONIAN
Ravenswood Granodiorite Complex
S-Da Biotite granite and adamellite, microgranite, biotite, pegmatite and aplite
S-Do Olivine gabbro, leucogabbro
S-Dr Hornblende and biotite granodiorite and quartz diorite; adamellite; minor gabbro
EARLY PALAEOZOIC
Anakie Metamorphics Pza Schist, slate, fine grained sandstone, shale
Cape River Beds Pzc Schist, quartzite, phyllite, metavolcanics; mudstone, arenite, minor tuff, marble and calc-silicate rocks
Mount Windsor Volcanics Pzw Acid volcanics, hornfels, schist, minor quartzite, labile sediments and basic volcanics
Geological boundary
Anticline
Syncline
Monocline
Overturned anticline
Plunge of fold axes
Fault
Where location of boundaries, folds and faults is approximate, line is broken; where inferred, queried; where concealed, boundaries and folds are dotted, faults are shown by short dashes
Strike and dip of strata
Dip < 15°
Dip 15-45°
Trend lines
Lineament
air-photo interpretation
Plant fossil locality
Cl 362 Fossil locality number
Abandoned dry oil exploration well
Abandoned mine
Quarry
Alluvial workings for gemstones
Au Gold
Ag Silver
As Arsenic
Bi Bismuth
C Coal
Cu Copper
Road
Railway
DIAGRAMMATIC RELATIONSHIP OF ROCK UNITS
NORTHERN DRUMMOND BASIN
Cainozoic sediments
Granite, low grade metasediments, volcanics
SOUTHERN BRUMMOND BASIN
Cainozoic sediments and basalt
Bowen Basin sequence
Granite, low grade metasediments
POST DRUMMOND ROCKS
Cainozoic sediments
Drummond Basin sequence and basement rocks
BASEMENT ROCKS
Cainozoic sediments or Drummond Basin sequence
Unconformity
Equivalence
Sections
(Cainozoic sediments omitted)
CAPE RIVER
DRUMMOND RANGE
PEAK RANGE
SUTTOR RIVER
BELYANDO RIVER
Clermont
Blair Athol
Alpha
Jericho 25 M
Tambo 55 M
Collinsville 50 M
Charters Towers 12 M
Charters Towers 15 M
DRUMMOND BASIN
QUEENSLAND
Complimentary

SOLID GEOLOGY

DRUMMOND BASIN QUEENSLAND



	Granite intrusives within the basin
DRUMMOND BASIN SEQUENCE — LOWER CARBONIFEROUS	Ducabrook, Bulliwallah, Natal, and Mount Rankin Formations
	Star of Hope Formation
	Raymond Formation
	Mount Hall Formation
	Telemon and Scartwater Formations
UPPER DEVONIAN TO LOWER CARBONIFEROUS	Silver Hills Volcanics
	Mount Wyatt and Saint Anns Formations and unit D/Cv
UPPER DEVONIAN AND OLDER	Basement inliers of Retreat Granite, Dunstable Volcanics and Ukalunda Beds

Geological boundary (dashed where very approximate or inferred)

Anticline
Syncline
Monocline
Overturned anticline
} *For names see Plate 1*

Plunge of fold axes

Fault

Isogal
"High" anomaly
"Low" anomaly
} *On back of map*

SCALE 1:1,000,000

10 0 10 20 30 MILES