THE GEOLOGY OF THE BURRUM SYNCLINE, MARYBOROUGH BASIN, SOUTHEAST QUEENSLAND

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(with 9 Text-figures, 7 Tables, and 4 Plates)

ABSTRACT. A thick sequence of Lower Cretaceous sediments outcrops in the Burrum Syncline, near Maryborough, southeast Queensland. The Aptian Maryborough Formation (*ca* 2 000 m, mostly marine), and the Albian Burrum Coal Measures (*ca* 2 400 m, mostly fluviatile and lacustrine), form the broad, asymmetrical, north-west-plunging Burrum Syncline. These units are compositionally alike, consisting of lithic greywacke, subgreywacke, arkosic sandstone, mudstone, and silty shale. The Burrum Coal Measures also contain carbonaceous shale and coal seams.

The Lower Cretaceous sediments were folded during the Late Cretaceous, with associated movement along the Electra Fault. These strata have subsequently undergone a complex alteration history, involving pedogenic silicification, followed by lateritization. The overlying Early Tertiary Takura Beds, a talus deposit of oligomictic breccia derived from the Maryborough Formation, and the Elliott Formation (fluviatile orthoquartzite) were extensively lateritized before extrusion of the first olivine basalt flow at Dundowran. Lateritization ceased before extrusion of the second flow. Geochemically these basalts belong to an alkali province, exhibiting some transitional characters. Geomorphological evidence indicates a Miocene age for the basalts, which has been confirmed by whole-rock K-Ar ages of 18.4 m.y. (minimum age, lower altered flow), and 12 m.y. (upper fresh flow).

Specifically identifiable fossils are limited to the Lower Cretaceous units of the sequence. The Maryborough Formation contains abundant marine bivalves of Aptian age. The Burrum Coal Measures contain a microflora of limited diversity, which is dominated by fern spores of presumed gleicheniaceous and schizaeaceous affinity. This assemblage is typical of a coal-forming paludal environment. Biostratigraphically, the Burrum Coal Measures microflora belongs to the lower part of the *Coptospora paradoxa* Zone of Dettmann & Playford (1969), of early to middle Albian age.

INTRODUCTION

The Burrum Syncline is located northeast of Maryborough, southeast Queensland, and covers 300 km^2, centred on 25° 25′S Lat. and 152° 40′E Long. (Text-fig. 1). The syncline lies within the eastern section of the onshore (western) part of the Maryborough Basin, which is regarded by Day, Cranfield, & Schwarzböck (1974) as a Jurassic-Cretaceous and Tertiary depositional

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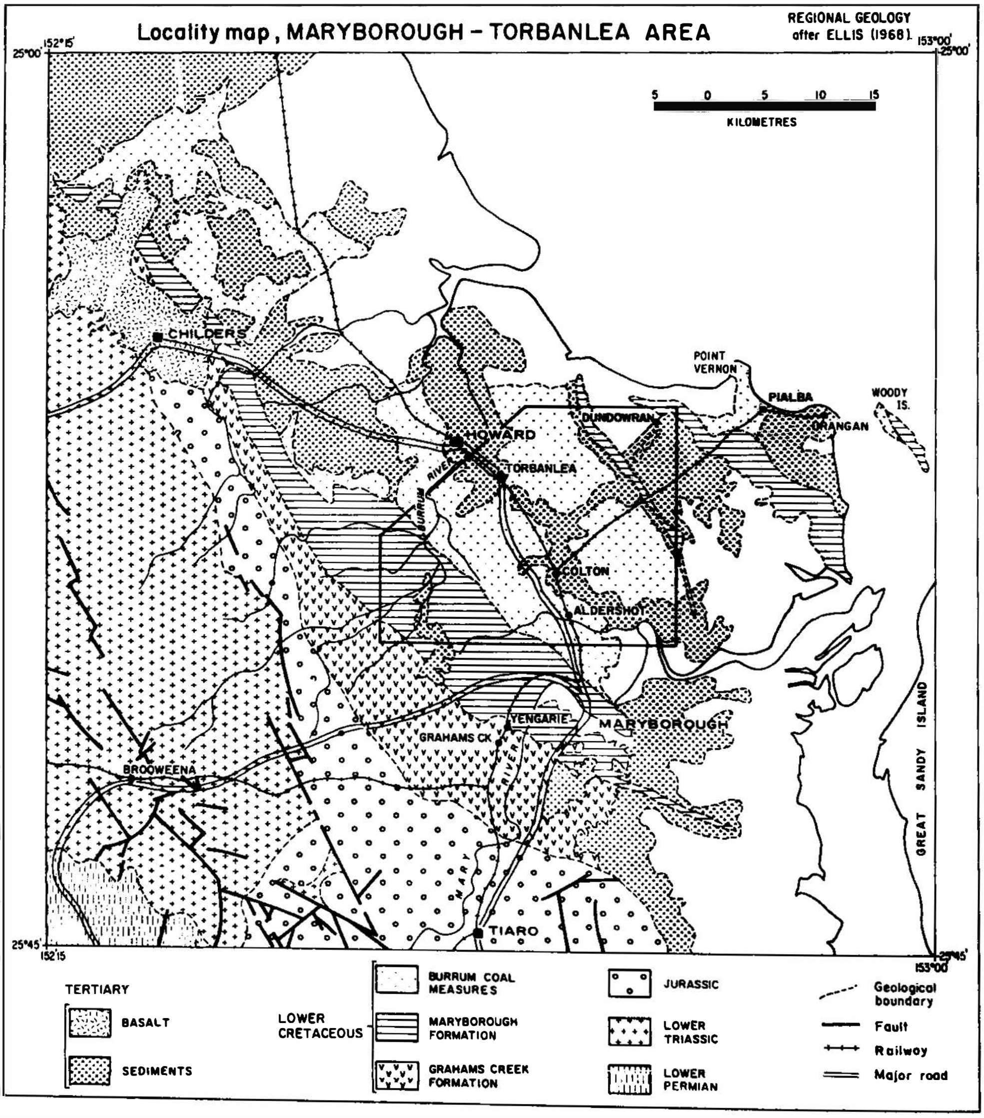
TEXT-FIG. 1


Locality map, MARYBOROUGH - TORBANLEA AREA
REGIONAL GEOLOGY after ELLIS (1968)
152°15'
25°00'
153°00'
25°00'
5 0 5 10 15
KILOMETRES
CHILDERS
POINT VERNON
PIALBA
WOODY IS.
URANGAN
DUNDOWRAN
HOWARD
TORBANLEA
BURRUM RIVER
COLTON
ALDERSHOT
YENGARIE
MARYBOROUGH
GRAHAMS CK
BROOWEENA
MARY RIVER
TIARO
GREAT SANDY ISLAND
25°45'
152°15
25°45'
153°00
TERTIARY
BASALT
SEDIMENTS
LOWER CRETACEOUS
BURRUM COAL MEASURES
MARYBOROUGH FORMATION
GRAHAMS CREEK FORMATION
JURASSIC
LOWER TRIASSIC
LOWER PERMIAN
Geological boundary
Fault
Railway
Major road

feature (not including the surficial onshore Tertiary section). The onshore Maryborough Basin sequence (Table 1) comprises *ca* 5 000 m of post-Triassic sediments. The basin's boundaries are formed by the rocks of the Permo-Triassic Gympie Basin in the west and north, and those of the Triassic-Jurassic Nambour Basin to the south. Geophysical evidence (Ellis, 1968) indicates that the basin extends as far offshore as the Bunker Ridge.

Day *et al.* (1974) considered the sequence in the onshore Maryborough Basin to have terminated during the Late Cretaceous folding of the Mesozoic sediments, which deformed the sequence into a series of six northwest-trending fold structures: Urangan Syncline, Susan Anticline, Gregory Anticline, Burrum Syncline, Cherwell Anticline, and Pig Creek Syncline (from east to west).

The Burrum Syncline is a broad, asymmetrical, northwest-plunging synclinal structure of 40 km maximum width and 80 km axial outcrop length. Three Cretaceous units comprise the bulk of the rocks in the syncline: Graham's Creek Formation (not exposed in the area mapped), Maryborough Formation, and Burrum Coal Measures (in ascending stratigraphic order). These are overlain in places by a superficial cover of Tertiary fluviatile sediments, Tertiary basalts, and Quaternary unconsolidated sediments.

Daintree (1872) discussed the geology of the Maryborough Basin, but the first detailed geological investigations in the Burrum Syncline were conducted by Gregory (1879) who reported on coal mining activities in the Burrum Coal Measures. Most early geological reports focussed on coal mining, viz. Tenison-Woods (1883), Ball (1902), Dunstan & Cameron (1910), and Dunstan (1911, 1912). Rands (1886) made the first detailed investigation of the Burrum Syncline sequence. He recorded a bivalve fauna of Cretaceous age from the 'Maryborough Marine Beds', which he considered to overlie the Burrum Coal Measures. He identified plant fossils from the Burrum Coal Measures as Triassic forms.

Jack (in Jack & Etheridge 1892) placed the Burrum Coal Measures in the Jurassic, and considered them to lie stratigraphically beneath the 'Maryborough Beds'. He regarded the boundary between the units as faulted. Etheridge (in Jack & Etheridge *loc. cit.*) described elements of a marine bivalve fauna from the 'Maryborough Beds', which he considered to be of Late Cretaceous age.

Dunstan (1912) studied the stratigraphic sequence in the Burrum Syncline, and demonstrated the conformable relationship between the 'Maryborough Marine Beds' and the overlying Burrum Coal Measures. He correlated the 'Maryborough Beds' with the 'Rolling Downs Formation' of the Great Artesian Basin, on the basis of common occurrence of the ammonite genus *Crioceras*. Walkom (1918, 1919) described floras from the marine Maryborough Formation and the Burrum Coal Measures. He ascribed an Early Cretaceous age to both units as a result of this comprehensive work. Whitehouse (1926a, b) regarded the occurrence of the ammonite genus *Australiceras* in the Maryborough Formation as indicating an Aptian age for the unit. Day (1974) has supported this Aptian dating. Skwarko (1963) and Fleming (1966, 1970) described species (chiefly of bivalves) from the Maryborough Formation. Day (1969) and Fleming (1970) regarded bivalves from the lowest part of the Maryborough Formation as suggesting a

TABLE 1

STRATIGRAPHIC SEQUENCE, MARYBOROUGH 1:250,000 SHEET AREA

after ELLIS 1968

ERA	AGE	ROCK UNIT	DISTRIBUTION	LITHOLOGY	THICKNESS (m)	RELATIONSHIPS	DEPN. ENVIRONT.	FOSSILS/AGE	REFERENCES
CAINOZOIC	Quaternary	Alluvium Qa	Restricted to present stream areas	Alluvium	0 to 45	Superficial	Narrow Flood plains	Recent	
		coast dunes	Narrow coast strip N.E. of Basin	dune sands, strand deposits	not known	Superficial	Aeolian/ coastal	Recent	
		sand Qs	Coast and Estuary areas	fine sand and mud	not known	Superficial	Estuarine	Recent	
	Tertiary	Basalt Tb	Scattered-Childers and Hervey Bay	olivine basalt	0 to 75	Unconform. on Mesozoic rocks	Extruded on land surface	Tertiary	Ellis, 1968
		Elliott Fm Te	Scattered in Maryborough Basin	sandstone, conglomerate	50	Unconform. on Cretaceous	Mainly fluviatile	Tertiary	Ridley, 1957
		Takura Beds Tt	Adjacent to top Maryborough Fm	oligomictic conglomerate	40	Unconform. on Klb and Klm	Talus deposit	Tertiary	Ellis, 1968
MESOZOIC	Cretaceous Albian	Burrum Coal Measures Klb	24Km wide coast belt, Maryborough Basin	sandstone, siltstone, shale, mudstone, coal	1650 to 3000	Conformably overlies Klm	Lacustrine, paludal in part	Early Cret. flora (spores) Albian	Walkom, 1919 Hawthorne, 1960
	Cretaceous Early Aptian	Maryborough Formation Klm	Onshore Maryborough Basin, eastern part	mudstone, sandstone siltstone, shale	540 to 2400	Disconform. overlies Klg	Shallow marine, early volcanism	Aptian bivalve fauna	Hawthorne, 1960 Fleming, 1970
	Cretaceous Neocom.	Graham's Creek Fm Klg	8Km wide belt western part Maryborough Basin	trachytic and andesititc flows & pyroclastics	420 to 1200	Conformably overlies Jt	Continental, partly lacustrine	K/Ar min. age, lava 135 ± 3 m.y.	Everden & Richards, 1962
	Jurassic Mid-Late	Tiaro Coal Measures Jt	2-12 Km wide belt, Isis River to Gunalda	Shale, sandstone mudstone siltstone, coal	1350 to 1500	Conformable on Jm	Lacustrine, periodic paludal	Jurassic flora	Hawthorne, 1960
	Jurassic Early	Myrtle Creek Sandstone Jm	Narrow belt Isis River - south Maryborough Basin	orthoqtzite., quartzose sandstone	60 to 600	Unconform. on Rlb	Fluviatile	?Jurassic	Hawthorne, 1960
	Triassic Early	Ooramera volcanics Rlo	Covers 95Km^2, 32Km S.E. of Biggenden	acid - interm. flows & pyroclastics	1050	?equivalent to lower Rlb	Lacustrine early; then subaerial	?Early Triassic	Ellis, 1968
		Brooweena Formation Rlb	88Km long N.W. trending belt, west Gympie B.	sandst., siltst., mudstone, shale congl., tuff	1000 to 3300	Unconform. on Plb	Lacustrine, one marine incursion	Early-Mid Triassic flora&fauna	Hawthorne, 1960
PALAEO-ZOIC	Permian Early	Biggenden Beds Plb	690Km discontinuous exposure, west of Gympie B	greywacke siltstone, shale, spilite chert	2000 to 6000	?unconform. on Lower Palaeozoic	Eugeosynclinal early, later shallow marine	Early Permian Marine faunas	Denmead, 1960 Brown, 1964

?Neocomian age for this part of the unit.

Detailed local geological reports on the Burrum Syncline were presented by Hawthorne (1954-1963) and Chiu Chong (1965) as a result of renewed search for economic seams in the Burrum Coal Measures. Hawthorne (1960) provided a geological map of the Burrum Syncline. In a report accompanying the Maryborough 1:250 000 preliminary geological map, Ellis (1968) presented a broad coverage of the Cretaceous stratigraphy of the Burrum Syncline in the context of the Maryborough Basin's regional geology.

Dettmann & Playford (1969), in a review of Australian Cretaceous palynology, placed the Burrum Coal Measures in their *Coptospora paradoxa* Zone, which they regarded as Albian from foraminiferal and ammonite correlation in the zone's reference section in Santos Oodnadatta No. 1 well, South Australia.

Field work in the Burrum Syncline resulted in the geological map reproduced as Text-fig. 2. Grid references cited herein refer to that of the Pialba sheet (Number AHQ/ARMY/5672(P) Edition I-AAS) of the 1:63 360 Australian Military Series R731. Figured fossil specimens are housed in the Department of Geology and Mineralogy, University of Queensland. Fossil specimen numbers are prefixed by the letters 'F' (bivalves and Foraminifera), and 'Y' (spores/pollen), rock specimen numbers 'UQR'. Co-ordinates cited in explanations of Plates 2–4 are mechanical stage readings ex Zeiss RA binocular microscope Mx3576 of the above Department.

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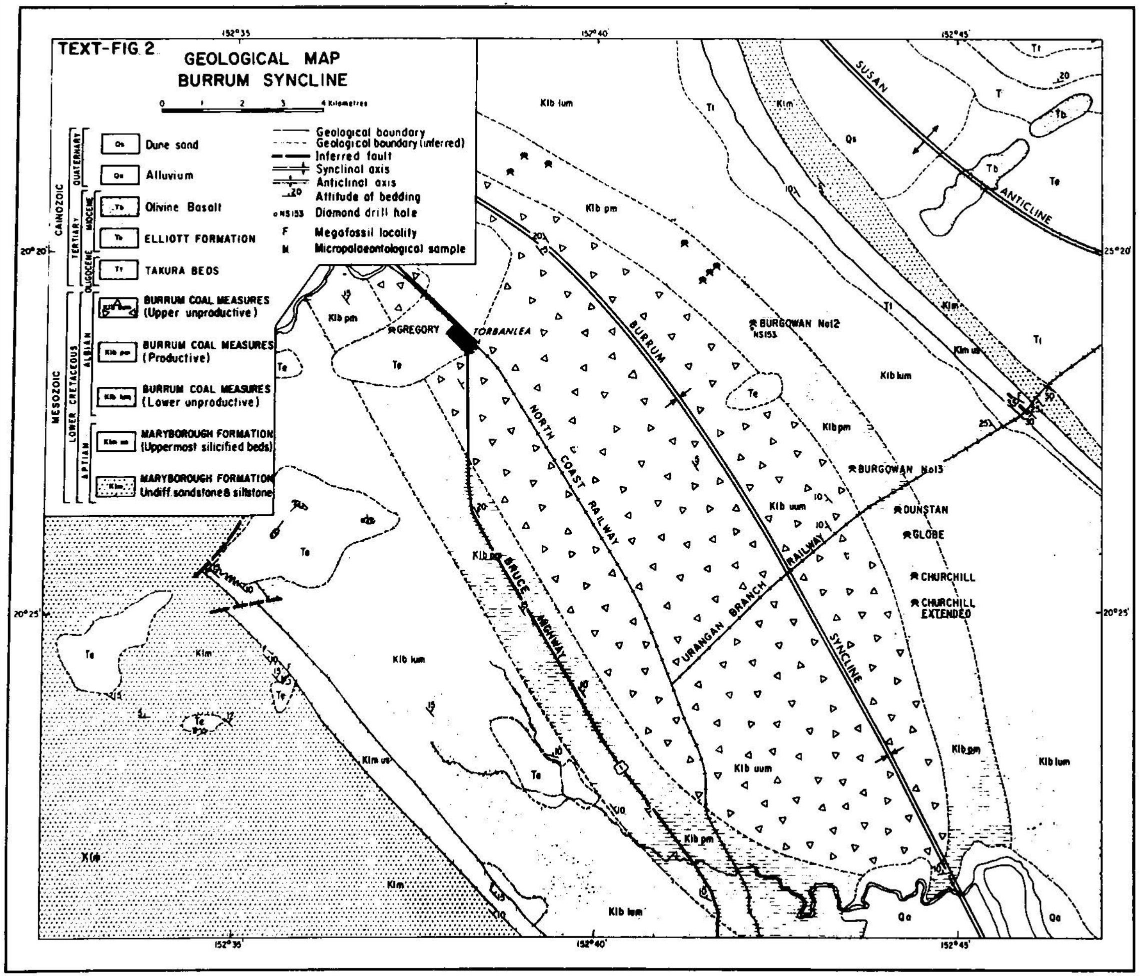
STRATIGRAPHY

Maryborough Formation

Nomenclature and distribution. The Maryborough Formation was defined by



TEXT-FIG. 2 GEOLOGICAL MAP BURRUM SYNCLINE

Hawthorne (1960, p. 6) as 'the formation lying conformably between the Graham's Creek Formation below and the Burrum Coal Measures above.' He estimated the total thickness at *ca* 1 800 m. Hawthorne did not designate a type section for the Maryborough Formation as no complete section of the formation had been measured due to paucity of outcrop in the middle part of the sequence. However, he referred to the most complete section of the unit exposed on the road from Maryborough to Yengarie (12 km west of Maryborough). The upper half of the middle part of the formation does not outcrop in this section.

The Maryborough Formation occurs over an area of *ca* 440 km^2. The best exposures are on the western flank of the Burrum Syncline. Exposures of the upper part of the formation occur on the eastern flank of the Burrum Syncline, on the crest and limbs of the Susan Anticline, and on Woody Island in the Urangan Syncline. Much of the section in the Burrum Syncline is concealed by a veneer of soil, superficial Tertiary Elliott Formation and Holocene sediments (both alluvium and coastal deposits). In the Hervey Bay area, the silicified youngest beds of the Maryborough Formation are rimmed by the scree deposits of Tertiary Takura Beds. Two faulted outliers of fine grained marine sediments assigned to the Maryborough Formation outcrop in the Gundiah Embayment, 40 km southwest of Maryborough.

Lithology. The sequence in outcrop is dominated by silicified mudstone, which comprises the uppermost part of the formation. The silicification is a pedogenic feature, which does not persist at depth. Unsilicified glauconitic sandstone is also important (30% of outcrop) but is confined to the western flank of the Burrum Syncline, near the top of the formation. On the eastern flank, silicified mudstone is the only lithology, typically occurring as an elevated dip slope.

The silicified mudstone is very fine grained, and texturally uniform. Inhomogeneities in colour are due to variations in secondary migration of limonite and hematite. It consists of extremely fine clay minerals, cemented by cryptocrystalline silica; minor angular, silt-sized quartz; and spherules of hematite. The mudstone beds are generally thick (up to 1 m) and are separated by thin (5 cm) interbeds of siltstone or fine sandstone.

The most common sandstone of the formation is green and brown in colour, medium-grained, and glauconitic (subgreywacke of Pettijohn 1956). This sandstone consists of dominant angular quartz (50%), volcanic rock fragments, fresh angular feldspar (plagioclase and microcline), and rounded glauconite grains. A fine matrix of clay minerals and limonite binds the grains, but siliceous cement is not developed. The texture is compact, but markedly variable, as the sandstone contains abundant thin interbeds and lenses of shale and mudstone. Sorting is compositionally and texturally poor. Thin bedding lamina and micro cross-bedding are developed.

White and brown silicified sandstone of the Maryborough Formation (protoquartzite of Pettijohn 1956) is hard, and of uniform, compact texture. The mineralogy is dominated by angular quartz; chert, extensively altered sedimentary rock fragments (now clay), and plagioclase comprise the remainder. A fine matrix of clay minerals and iron oxide (chiefly limonite) binds the grains. The sandstone is cemented by cryptocrystalline silica of probable secondary origin.

Siltstone and shale are subordinate to silicified mudstone and sandstone in the Maryborough Formation. White to brown silicified siltstone is interbedded with silicified mudstone at the top of the formation, and exhibits a similar mineralogy to the latter. Green and brown unsilicified siltstone and shale occur as thin (0.5 cm) lenticular interbeds within mineralogically similar glauconitic sandstone.

Coquinite outcrops at a single locality (710387) on the western side of the Burrum Syncline. The rock consists of disarticulated, algal-bored, and abraded valves of *Maccoyella* and other molluscs in a dark sulphurous matrix of angular quartz, feldspar (plagioclase and potassium feldspar), iron-stained clay minerals, and glauconite. The shells in the rock have all assumed a uniform orientation, concave down, reflecting the original bedding of the host sediment.

Provenance. Abundant fragments of quartz and feldspar, together with diverse lithic fragments (sedimentary, igneous, and metamorphic) representative of most earlier units in the Maryborough and Gympie Basins, occur in the rocks of the Maryborough Formation. Ellis (1968) considered that the Maryborough Formation's well-sorted quartzose sediment had its origins in the Lower Triassic Brooweena Formation. This is quite feasible as the mineralogy of the two formations is closely comparable.

Current directional measurements, on small-scale cross-bedding in the glauconitic sandstone outcropping in the area mapped, suggest currents from the west and northwest. This supports Ellis's observations from the Pine Creek area, near Cordalba (100 km northwest of Maryborough). Ellis regarded the orientation of crossbeds in the Ghost Hill area, near Urangan, as indicating possible transport of material from an emergent high in the east, but no evidence exists in the Burrum Syncline area for an eastern source of detritus. All available information points to a source in the Lower Mesozoic sediments of the Gympie Basin, and the Palaeozoic metamorphic and igneous basement of the Biggenden Block.

Depositional environment. In the Burrum Syncline the Maryborough Formation consists of quartzose, non-graded, medium to fine-grained sediments, which contain molluscan species indicative of deposition under shallow water conditions. Glauconite occurs in some sandstone of the upper part of the section studied. Folk (1965) considered glauconite to be very diagnostic of marine beds, especially those deposited under mildly reducing to mildly oxidising conditions on the continental shelf. Reineck & Singh (1973) stated that glauconite is restricted to areas of turbulence, low sedimentation rate, and free organic matter.

Stratigraphic relationships. The relationship between the Maryborough Formation and the underlying Graham's Creek Formation (not exposed in the area mapped) is disconformable, as evidenced by the occurrence of conglomerate at the base of the Maryborough Formation, containing clasts derived from the Graham's Creek Formation (Ellis 1968).

The Maryborough Formation in the area mapped is overlain by the Burrum Coal Measures with apparent conformity; however, the boundary between the units does not outcrop clearly.

Age. Palaeontological evidence (see BIOSTRATIGRAPHY, Maryborough Formation) indicates an Aptian age for the upper part of the formation exposed in the Burrum Syncline. Previous work has indicated that this Aptian age applies to most of the formation. Day (1969) proposed a ?Neocomian age for outliers of the formation exposed near Gundiah, 40 km southwest of Maryborough.

Burrum Coal Measures

Nomenclature and distribution. The Burrum Coal Measures have been variously named ('Burrum Beds', 'Burrum Formation') by several authors since Tenison-Woods's (1883) reference to the 'Burrum Coal Beds'. Dunstan (1919) proposed a three-fold subdivision of the Burrum Coal Measures or 'Burrum Beds' on the basis of economic potential and lithology: Lower Unproductive Measures, Productive Measures, and Upper Unproductive Measures.

Due to paucity of outcrop, no complete section of Burrum Coal Measures is known from surface exposures. Hawthorne (1960) designated the Burrum Coalfield as the type locality of the unit, but Ellis (1968) considered only a small part of the section to be present in that area. Ellis chose Pine Creek (100 km northwest of Maryborough) as the type locality for the Lower Unproductive Measures, and retained the Burrum Coalfield as the type locality for the Productive Measures. He regarded the outcrop of the Upper Unproductive Measures as insufficient for the proposal of a type locality. Ellis's stratigraphic concept has been followed in the present study.

Hawthorne (1960) estimated the maximum thickness of the Burrum Coal Measures to be *ca* 1 700 m. Ellis (1968) quoted a maximum thickness of *ca* 3 000 m from outcrops in the Pine Creek area, and an average of *ca* 2 000 m from boreholes in the Torbanlea area.

Outcrops of Burrum Coal Measures are restricted to a coastal belt 80 km long and 25 km wide. Exposure is limited, due to extensive coverage by lateritized sediments of the Tertiary Elliott Formation, and Holocene sediments (both alluvium and coastal deposits). Scattered exposures of the Lower Unproductive Measures occur in northwest-trending belts on both flanks of the Burrum Syncline. The Productive Measures outcrop in a 2 km-wide band, adjacent to, and stratigraphically above, the Lower Unproductive Measures. This band follows the trend of the Burrum Syncline and forms a closed oval to the immediate north and south of the area mapped (see Text-fig. 2; Dunstan 1919; Hawthorne 1960). The Upper Unproductive Measures occur in the axis of the Burrum Syncline, but they are almost completely covered by thin lateritized Tertiary sediments and soil.

Lithology. The Burrum Coal Measures are lithologically diverse, containing fine- to medium-grained subgreywacke and sandstone, argillaceous and quartzose siltstone, shale (argillaceous and carbonaceous), mudstone, and coal. Lithologies of the Lower Unproductive Measures and Upper Unproductive Measures are closely comparable; however, the Unproductive Measures and the Productive Measures differ in relative proportions of several major rock types. A characteristic of all lithologies in the Burrum Coal Measures is lenticularity of the beds, which inhibits lateral correlation within the unit.

The mineralogy of all rock types in the three subdivisions of the Burrum Coal Measures is remarkably constant. Burrum Coal Measures sandstone (lithic greywacke of Pettijohn 1956) typically consists of angular quartz grains (30%), fragments of strongly weathered fine-grained igneous rock (30%), subordinate angular plagioclase (5%), and scattered muscovite flakes, bound by a very fine grained quartzo-feldspathic and clay matrix. Some sandstone is secondarily cemented by iron oxide or silica mobilized by lateritization. Siltstone and shale of the Burrum Coal Measures usually possess a comparable mineralogy to sandstone, but differ in mode and grain size of constituent minerals.

The principal lithology of the Lower Unproductive Measures is medium- to fine-grained sandstone; mudstone of significant thickness is rare, and carbonaceous shale is absent. Few fossils occur in the Lower Unproductive Measures excepting occasional petrified wood fragments. The sandstone is mottled yellow brown, or uniform white or brown, as a result of lateritization. Interbedded siltstone or mudstone consists of brown limonitic material, with interspersed angular quartz. Interfaces between mudstone interbeds and overlying sandstone exhibit many features (e.g. flame structures, and sedimentary dykes of sandstone intruding mudstone), which can be attributed to compaction in a plastic state. Depositional sedimentary structures (macro and micro cross-bedding) occur in the sandstone.

The Productive Measures consist mainly of siltstone, carbonaceous shale, and coal seams; sandstone and mudstone are subordinate. Fine lithic greywacke occurs in the Productive Measures, especially towards the lower part.

Carbonaceous shale and siltstone outcrops are strongly lateritized, the only fossils present being brown plant fragment impressions in a light brown rock, which originally contained up to 30% carbonaceous matter. Carbonaceous shale exhibits complex bedding caused by slumping and sliding of the sediment contemporaneous with deposition. Siltstone comprises a significant proportion of the Productive Measures in the area mapped, and overlies coal seams in many mines. Siltstone is brown to green when fresh (chloritic matrix), but when weathered assumes a dirty white to brown colour (due to iron migration).

Coal seams are present in the middle 500 m of the Burrum Coal Measures. These seams may be observed in two producing mines in the area mapped (Burgowan Nos 12, 13), but former exposures on the banks of the Burrum River have been mined out. Coal seams consist predominantly of bright coal, with minor thin dull coal bands. In polished sections, the bright coal consists of two distinct types; these may be directly related to the sample position within the seam. Coal from upper and lower seam margins contains homogeneous vitrinite as the major microlithotype (without fusinite or exinite), interbedded with clay layers containing fusinite lenses and bands. Excepting for clay, this coal has a very small silicate mineral content. Towards the centre of the seams, the clay content is reduced. The major microlithotype is again vitrinite, but contains in addition disseminated fusinite and exinite blebs. Silicate content of the central part of the seam is up to 10%; occuring as thin diagenetic quartz veins infilling compaction cracks. The seams generally enclose lenticular siltstone and ironstone bands. Ironstone is dark brown to black, fine-grained siderite, containing calcite replacements of plant stems. Narrow, rhythmically bedded sandstones and siltstones, with individual beds approximately 1 mm thick, frequently form seam roofs.

The Upper Unproductive Measures, although poorly represented in outcrop, appear similar in lithology to the Lower Unproductive Measures comprising predominantly medium-grained sandstone and subordinate siltstone; mudstone and shale are rare. The Upper Unproductive Measures sandstones are generally coarser than those of the Lower Unproductive Measures, and often contain up to 20% quartz.

Provenance. The variable content of quartz grains, basic igneous rock fragments, feldspar, and muscovite indicates a diverse provenance for the Burrum Coal Measures. Quartz grains possibly had their origin in the quartzose Lower Triassic Brooweena Formation. Feldspar, igneous rock fragments, and mica flakes could have been supplied by immature sediments and volcanics of the Lower Permian Biggenden Beds. The material for coal and carbonaceous shale is apparently autochthonous, derived from paludal swamps developed in parts of the basin.

No conclusive evidence for a source direction of sediment for the Burrum Coal Measures was obtained from measurements of crossbeds in the area mapped. Ellis (1968) deduced a possible transport direction from the east as a result of micro cross-bedding measurements in the Pine Creek and Point Vernon areas, but he regarded these results as inconclusive.

Depositional environment. The Burrum Coal Measures arenites in the Burrum Syncline are moderately sorted, have subrounded clasts and lack graded bedding, suggesting steady accumulation in a shallow depositional area. Coal seams and carbonaceous shales of the Productive Measures indicate a lacustrine, periodically swampy environment. Micro- and medium-scale cross-bedding is present in the Lower Unproductive Measures and Productive Measures, and lenticular beds are common in the unit. These features suggest the presence of periodic traction currents in parts of the depositional area. The absence of conglomerate and coarse arenite suggests that these currents were not strong.

Although beds in the unit are lenticular, coal seams worked on the western limb of the Burrum Syncline can be correlated with those worked on the eastern limb (Chiu Chong 1965). Thus paludal conditions were possibly quite extensive laterally, but Ellis (1968) considered such conditions to have been unlikely in the north where deeper water sediments were deposited.

Ellis (1968) noted glauconite in Upper Unproductive Measures sandstones near Pine Creek and Stephens (1971) reported glauconite, together with trace fossils resembling marine worm burrows, in Upper Unproductive

Measures sandstone on Point Vernon Headland; both suggest a marine environment of deposition. No glauconite was found in any of the Burrum Coal Measures examined during the present study.

Stratigraphic relationships. The Burrum Coal Measures appear to conformably overlie the Maryborough Formation, although outcrop near the boundary between the units is sparse. The Burrum Coal Measures are uncomformably overlain in some places by superficial deposits of Tertiary Elliott Formation, and in others by Holocene unconsolidated sediment.

Age. Palaeontological evidence (see BIOSTRATIGRAPHY, Burrum Coal Measures), indicates an early to middle Albian age for the Productive Burrum Coal Measures, which are assigned to the *Coptospora paradoxa* Zone of Dettmann & Playford (1969).

Takura Beds

Nomenclature and distribution. This Tertiary conglomerate in the Maryborough area was first recorded and named by Ellis (1968). He proposed an exposure on the Torbanlea-Pialba road, 8 km from Torbanlea, as the type locality. Most exposures of Takura Beds are restricted to between 20 m and 30 m above sea level, on both sides of 'Takura Heights', a resistant elongate ridge composed of the silicified uppermost 60 m of the Maryborough Formation. The unit has a maximum thickness of 7 m, and thins rapidly away from the silicified ridge. Occasional exposures of the Takura Beds occur in the Pialba area, but they are usually represented only by residual gravels, forming a broken double chain up to 1 km wide either side of the ridge of Maryborough Formation. Subsidiary outcrops of Takura Beds occur on the eastern limb of the Susan Anticline, in the Hervey Bay area, where ridges of silicified mudstone outcrop.

Lithology. The Takura Beds consist of very poorly sorted coarse oligomictic conglomerate and rubble breccia, in which all clasts are silicified mudstone derived from the Maryborough Formation. Most clasts are pebble sized (average diameter 30 mm), but cobble sized clasts up to 40 cm occur occasionally. All cobbles and pebbles greater than 10 mm are rounded; smaller fragments are subangular to angular.

At the type locality, clasts are set in a secondarily cemented matrix of very fine grained silica. In some places rudites of the Takura Beds are cemented by more ferruginous material, resembling those of the Elliott Formation, but lacking the characteristic rounded quartz (2 mm diameter) of the latter. Ellis (1968) observed that the Takura Beds have a depositional dip of more than 5°.

Provenance. Oligomictic conglomerate comprising the Takura Beds was wholly derived from the silicified uppermost mudstone of the Maryborough Formation, which formed a continuous ridge above the Tertiary peneplain, to a much greater height than the present 75 m.

Depositional environment. The depositional dip, stratigraphic relations, and lithology of the Takura Beds indicate that the rubble, released from the uppermost Maryborough Formation, accumulated by the process of mass movement on the lower slopes of the silicified ridge. Ellis (1968) suggested that this locality was the margin of a developing Tertiary lake, in which the Elliott Formation was deposited.

The degree of rounding of rubble during gravity transport is related to size of fragments; coarse material reaches a high degree of rounding and sphericity, while small fragments (10 mm or less) are not abraded to such an extent. The matrix binding these clasts was formed by fine-grained siliceous material, abraded from the clasts during consolidation. This matrix was silicified by lateritization, subsequent to deposition and exposure of the younger Elliott Formation.

Age. The age of the Takura Beds is not precisely established, as no autochthonous fossils have been recovered. The unit postdates the Cretaceous (post-Albian) movements which affected the Upper Mesozoic rocks in the Maryborough Basin. Ellis (1968) considered that the Takura Beds immediately predated deposition of the Elliott Formation, which Ridley (1957) tentatively dated as late Oligocene to early Miocene.

Elliott Formation

Nomenclature and distribution. Ridley (1957) defined the Elliott Formation as 'a formation of quasihorizontal freshwater sediments 20-40 ft thick . . . in the Maryborough-Bundaberg area'. He noted that 'a complete type section in any one locality is not to be found, but most of the formation's characteristics may be seen along the banks of the Elliott River'.

The formation is almost wholly confined to a coastal strip 64 km wide, from Tiaro in the south to Gin Gin in the north (a distance of 90 km), and covers 900 km^2. It is best exposed between the Elliott River and Oakey Creek, in the north of the basin. In the area mapped, the unit is represented by thin, weathered, discontinuous outliers, separated by coastal streams in the axial region of the Burrum Syncline.

Lithology. Elliott Formation outcrops in the area studied are predominantly either sandstone or rudite. Exposures immediately adjacent to the silicified uppermost Maryborough Formation are rudites, which typically consist of large angular fragments (1-50 cm) of Maryborough Formation silicified mudstone, and smaller clasts (0.7-1 mm) of subangular to rounded quartz, plagioclase, and chert. Rudites are cemented by fine hematite.

Coarse breccias are frequently overlain by finer breccias or coarse sandstones, which lack large angular clasts of silicified mudstone. Fragments in the coarse sandstone are predominantly subangular to subrounded quartz, small angular fragments of Maryborough Formation silicified mudstone, and chert fragments, bound by hematitic cement. Coarse sandstones appear texturally poorly sorted, but compositionally well sorted (dominantly quartz).

Coarse sandstones grade upwards to grey, medium-grained sandstones, which are the formation's commonest lithologies. Typically they consist of subangular, low sphericity quartz, and subordinate euhedral plagioclase laths, bound by a very fine argillaceous and siliceous matrix, which has been secondarily silicified by lateritization. Microscopically, the rock is compositionally well sorted, but texturally poorly sorted, and the framework of grains is open (much matrix between grains).

Provenance. Mature sandstone of the Triassic Brooweena Formation in the northwest of the Maryborough Basin could have contributed abundant quartz to the Elliott Formation via east and southeast flowing streams. The Early Permian Biggenden Beds, and the Gympie Basin Mesozoic succession could have provided chert, other rock fragments, and fine siliceous sediment. Feldspar content in the unit is small, suggesting negligible igneous contributions.

Ellis (1968) observed only isolated Maryborough Formation clasts in basal Elliott Formation near Takura Heights, and concluded that the uppermost Maryborough Formation, and flanking Takura Beds, did not supply detritus for the Elliott Formation in that area. In the west of the Burrum Syncline, Elliott Formation breccias, containing large angular blocks of Maryborough Formation silicified mudstone, are exposed near outcrops of the latter unit. Thus for initial Elliott deposition in the western part of the area, the Maryborough Formation was a source of detritus. As deposition proceeded, contributions of silicified mudstone decreased rapidly, indicating that the uppermost Maryborough Formation was quickly denuded.

Coarse crossbedded sandstone and interbedded conglomerate in the north of the basin indicated strong traction currents (Ellis 1968). In the area studied, large proportions of fine detritus suggest lower energy conditions. The formation was considered by Ellis to be deposited on a peneplained land surface which formed during an appreciable erosion period, following Cretaceous deformation of the Upper Mesozoic sequence in the basin.

Age. No diagnostic fossils have been recorded from the Elliott Formation. Ridley (1957) presented criteria for a tentative late Oligocene to early Miocene age. The unit unconformably overlies the Early Cretaceous Burrum Coal Measures, it possibly postdates a late Oligocene orogeny proposed by Bryan & Jones (1945), and the entire formation is lateritized.

BASALT: PETROLOGY AND GEOCHEMISTRY

Basalt at Dundowran (15 km north of Maryborough), was first noted and mapped by Dunstan (1918). Ellis (1968) referred to 'a small flow 6 miles southwest of Point Vernon'. Stephens (1971) informally used the name 'Dundowran Basalt' for this unit, and regarded a 15 m section in the basalt quarry at Dundowran (936542) as the type locality. Ellis (*loc. cit.*) estimated the maximum thickness of basalt at 45 m. At Dundowran, Tertiary basalt covers *ca* 3 km^2, in the form of two elongate outliers arranged end on end (total length 5 km), individually 0.4-0.6 km wide. The outliers are elevated 20-25 m above the surroundings, and have a base level of 15 m above sea level.

Petrography

The basalts at Dundowran are fine-grained olivine basalts, in which microphenocrysts of olivine, magnetite, and clinopyroxene are set in a holocrystalline groundmass of plagioclase, olivine, pyroxene, and opaques. Two texturally distinct types of basalt occur at Dundowran, which represent two separate flows.

Type 1 is uniformly very fine grained, and very altered. It consists of serpentinized olivine microphenocrysts (20%, average size 0.3 mm), and equidimensional iron oxide microphenocrysts (possibly magnetite), in a groundmass of 0.1 mm labradorite laths (50%), serpentinized augite, olivine, and iron oxides (10%) of both equidimensional (magnetite) and acicular (ilmenite) form. Type 1 basalt exhibits either closely spaced (5 cm) laminar jointing, or apparently no jointing (merely spheroidal weathering).

Type 2 is uniformly fine grained, and relatively unaltered. It consists of olivine microphenocrysts (20%, average size 0.7 mm), in a holocrystalline matrix of zoned bytownite laths (40%, average size 0.2 mm), augite (20%, average size 0.4 mm), and olivine. Groundmass iron oxides comprise 5% of the rock; both acicular grains (ilmenite), and small equidimensional grains (possibly magnetite) occur. Glomeroporphyritic olivines (2 mm diameter) are present. Vescicles are infilled by two phases of unidentified fibrous zeolites. Type 2 basalt exhibits widely separated laminar jointing (average spacing 50 cm). Stratigraphically, Type 2 basalt overlies Type 1.

Geochemistry

Seven samples of basalt from Dundowran (including both petrographic types) were analysed by X-ray fluorescence spectroscopy for their oxide and trace element contents (see Tables 2, 3). Comparison of the Dundowran samples with world average basalt analyses for oxides (Manson 1967) and trace elements (Prinz 1967), reveal that they are transitional between world-wide average alkali basalts and tholeiites. This is evidenced by the transitional SiO_2, K_2O, P_2O_5, Ba, and Zn values.

The Dundowran basalts can be plotted in the normative Ne-Di-Ol-Hy-Qz system (Text-fig. 3). Type 1 plots in the saturated field (no normative nepheline or quartz), while the upper flow (Type 2) is undersaturated (normative nepheline present). Using the classification scheme of Coombs & Wilkinson (1969) based on the normative mineralogy, and assuming 1.5% Fe_2O_3 (Coombs 1963), the Dundowran basalts are predominantly hawaiites (4 analyses), and basanites (2 analyses); one sample being classified as alkali olivine basalt.

On the $Na_2O + K_2O$ vs SiO_2 diagram (Text-fig. 4), analyses plot in a narrow horizontal field extending from 46% SiO_2 to 50% SiO_2 (except for the altered sample). This field lies entirely within the alkali basalt fields of MacDonald & Katsura (1964) and Kuno (1968). In an AFM diagram, the Dundowran basalts plot in a small field, showing no trend towards enrichment in either iron or alkalis, the latter reflecting absence of differentiates more siliceous than hawaiite. Compared with primitive tholeiites (e.g. Scottish

	UQR 36097	UQR 36099	UQR 36100	UQR 36101	UQR 36102	UQR 36103	UQR 36104	AVERAGE
SiO_2	49.46	46.5	48.21	46.85	48.42	47.87	47.82	47.90
TiO_2	1.38	1.52	1.28	1.50	1.51	1.49	1.45	1.45
Al_2O_3	14.34	14.61	14.69	14.03	13.58	13.98	13.95	14.17
+ Fe_2O_3	11.88	12.22	11.33	11.87	12.42	12.01	11.72	
* Fe_2O_3	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
#FeO	9.34	9.65	8.84	9.33	9.83	9.46	9.20	9.38
MnO	0.15	0.16	0.14	0.15	0.20	0.15	0.16	0.16
MgO	9.01	8.86	8.31	9.03	8.43	10.18	9.55	9.05
CaO	7.49	8.10	7.40	8.50	8.41	8.78	8.17	8.12
Na_2O	3.83	3.60	2.89	3.99	3.96	3.76	4.2	3.75
K_2O	0.81	1.07	0.77	1.05	1.11	0.96	1.02	0.97
P_2O_5	0.27	0.33	0.26	0.31	0.43	0.30	0.31	0.32
LOI	1.66	1.17	3.26	1.05	0.96	1.35	0.98	
TOTAL	100.28	98.18	98.53	98.32	99.42	100.29	99.33	

+ Value of Fe_2O_3 determined by analysis

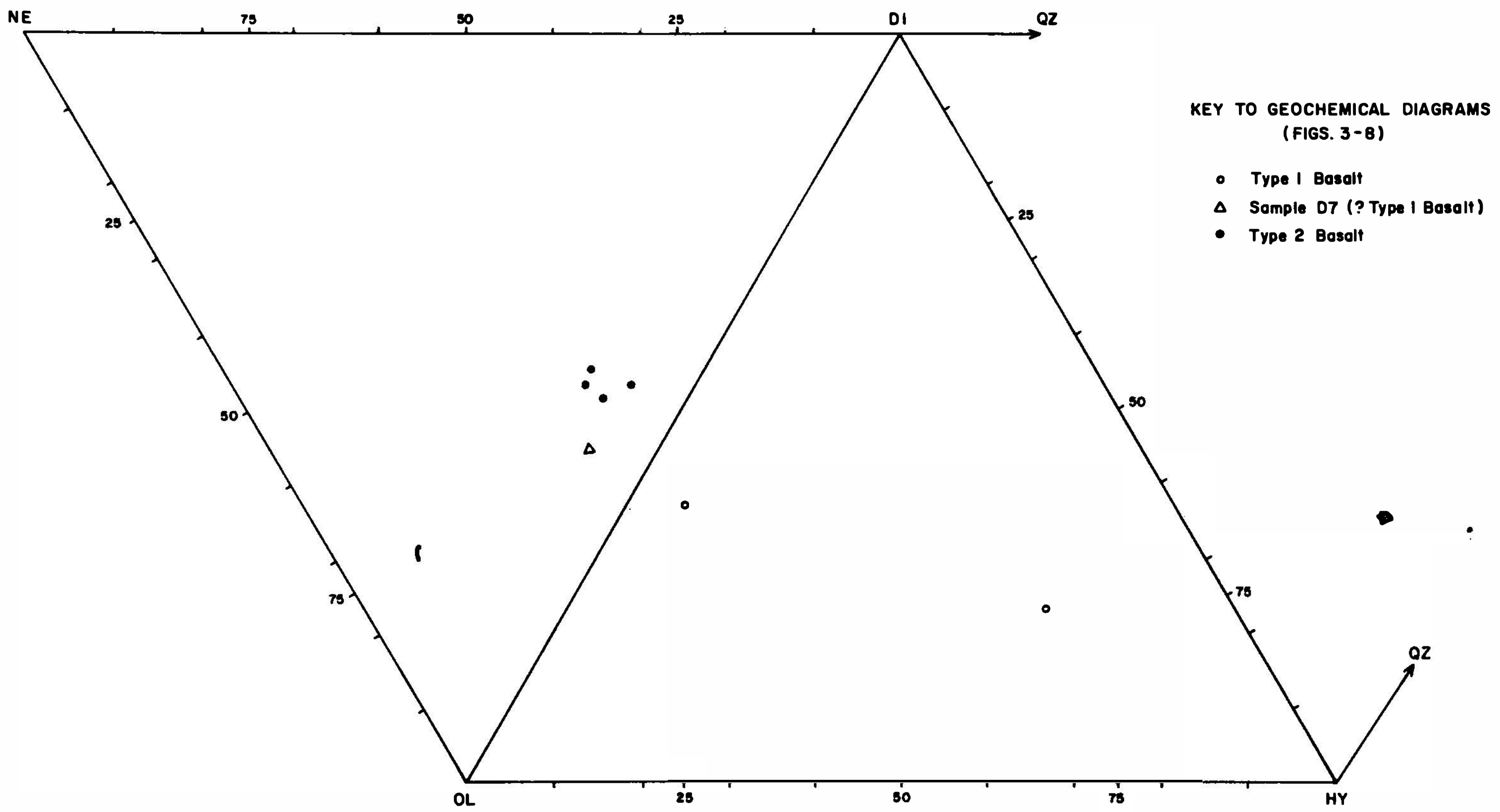
* Assumed true Fe_2O_3 value, all samples = 1.5% (Coombs 1963).

Calculated value FeO content assuming Fe_2O_3 = 1.5%

Table 2. X-ray Fluorescence analyses of Dundowran basalt samples oxides (%)

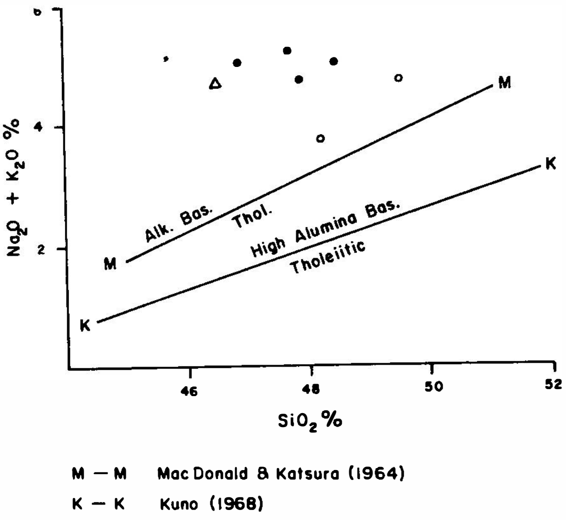
	UQR 36097	UQR 36099	UQR 36100	UQR 36101	UQR 36102	UQR 36103	UQR 36104	AVERAGE
Ba	236	285	234	314	308	247	253	268
Cr	385	333	320	393	284	388	411	403
Rb	17	19	12	21	22	19	19	18
Sr	533	448	336	393	544	449	397	367
V	163	141	145	159	148	158	152	152
Y	21	19	19	22	23	21	20	21
Zr	104	129	100	120	134	121	120	118
Zn	104	110	109	105	106	106	106	107

Table 3. X-ray Fluorescence analyses of Dundowran basalt samples, trace elements (ppm)



TEXT FIG 3 NORMATIVE NE – DI – OL – HY – QZ SYSTEM

(Fe_2O_3 assumed = 1·5%)



TEXT-FIG. 4 $Na_2O + K_2O$ - SILICA DIAGRAM

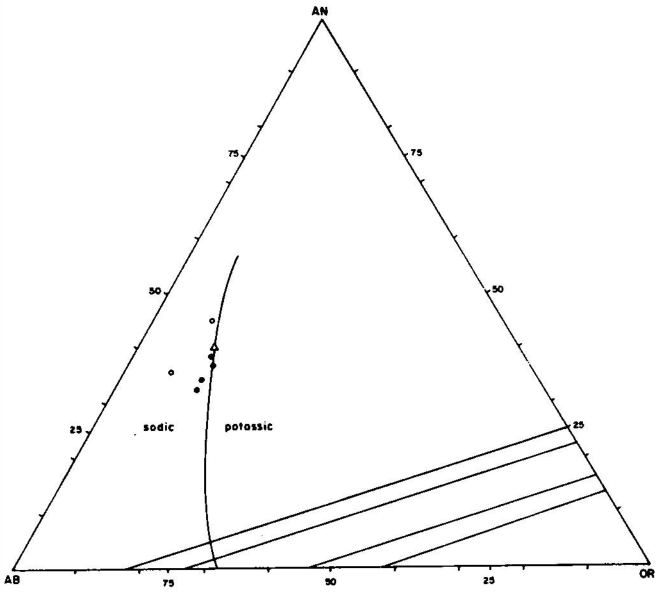
Tertiary Province of Kuno 1968), the Dundowran basalt is deficient in iron.

Whole rock analyses plotted in the normative An-Ab-Or system (Text-fig. 5) fall into two general groups. Most of the analyses (Type 2 basalt) plot in a linear field close to the sodic-potassic feldspar boundary (on the sodic side). The remaining two analyses (Type 1 basalt) plot in widely separated positions, closer to the An-Ab side of the diagram, than the field formed by the Type 2 analyses. K-Rb ratios of the Dundowran basalts (Table 4) are higher than the world average of all basalt types (Manson 1967), due to relatively low Rb values.

Sample	K/Rb
UQR36097	476
UQR36099	564
UQR36100	640
UQR36101	500
UQR36102	505
UQR36103	505
UQR36104	537
(Average, excluding UQR36100)	514

Table 4. K/Rb ratios, Dundowran basalt

No evidence can be advanced for plagioclase fractionation in the Dundowran basalt, as all analyses plot in the system Al_2O_3 vs CaO as a very small,



TEXT-FIG 5 NORMATIVE AN-AB-OR SYSTEM DUNDOWRAN BASALT

equidimensional field. No phenocrystic plagioclase was observed in the rock. The high Cr content (400 ppm average) of the Dundowran basalts probably implies that magnetite fractionation was, at best, of minor importance in their petrogenesis.

Thus available geochemical evidence indicates an alkali province, although exhibiting some transitional characteristics; and that the two flows, distinguished by field and petrographic characteristics, also differ geochemically.

Radiometric age

Isotopic age measurements by the potassium-argon method, were undertaken on two whole-rock samples of basalt from Dundowran. Techniques of measurement followed those described by Green & Webb (1974); potassium was determined by atomic absorption, and argon by isotope dilution. The results of these isotopic age measurements are given in Table 5.

As the determinations are based on whole rock samples, they should be treated with caution, as the alteration, devitrification, or recrystallization of any potassium bearing phase in the rock will result in a loss of radiogenic argon and a measured age that is too low (Green, pers. comm.) The Type 2 sample (relatively unaltered) gave a date of 12.0 m.y., with a radiogenic argon yield of 62.6%, indicating that this is probably close to the true crystallization age of the basalt. Type 1 sample (strongly altered) gave a date of 18.6 m.y., and yielded only 43.2% radiogenic argon, which suggested that the date should be regarded as a minimum age, though probably close to actual.

Sample No.	Sample	K (wt %)	$\frac{\text{Rad Ar40}}{\text{Tot Ar40}}\%$	Calculated Age (m.y.)	Locality
UQR 36098 (QA 161)	whole rock basalt	1.205	62.6	12.0my ±3%	Upper flow at 924535
UQR 36100 (QA 162)	whole rock basalt	0.64	43.2	18.4my ±3%	Lower flow at 924535

$e = 0.585 \times 10^{-10} yr^{-1}$ $B = 4.72 \times 10^{-10} yr^{-1}$ $^{40}K/K = 0.000119$

Table 5. Potassium/argon ages of basalts, Dundowran, near Hervey Bay, southeast Queensland

The 6 m.y. gap between the ages of Type 1 and Type 2 basalt confirms that these basalts represent two discrete flows, which was suggested by the great difference in their respective weathering intensities. Such a large time gap between the flows, and their close geographical relationship, necessitates their origin from separate vents, possibly closely associated near the present exposures.

Previous K-Ar ages of whole-rock Tertiary extrusives in southeast Queensland range from early Eocene to early Miocene. Webb, Stevens, & McDougall (1967) noted that the majority of K-Ar ages cluster around 25 to 22 m.y. When compared with these, the Dundowran basalts are markedly younger. The date of 12 m.y. (middle Miocene) obtained from the fresh upper flow, represents one of the youngest Tertiary basalt ages recorded in southeast Queensland.

Conclusions on origin and age

The origin and age of the basalt at Dundowran had been uncertain for some time. Basalt overlies strongly lateritized Elliott Formation, and the lower flow only is affected by lateritization. Ellis (1968) had considered all basalt on the Maryborough Block to be post-Elliott Formation, and pre-lateritization. Stephens (1971) correlated the Dundowran basalt with that at Childers, on the basis of similar stratigraphic relationships and mineralogy. The Childers basalt, at a higher topographic level, is much more strongly lateritized (altered to depth of 60 m), and is thus presumably older.

The apparent absence of source vents for basalt flows at Dundowran has led previous workers to regard them as distant outliers of the Childers basalt (e.g. Stephens 1971). The distance from the basalt at Dundowran to the nearest Childers basalt outcrop is, however, in excess of 50 km, and no intervening basalt outcrops occur. Thus, a local origin for the Dundowran basalt cannot be discounted. Evidence exists for at least some small-scale basaltic intrusive activity in the Point Vernon area, Hervey Bay. Stephens (1971) has noted two strongly weathered basalt dykes (1 m wide) intruded along fold axes in the Burrum Coal Measures, and parallel to small-scale faults. Individually these features are probably too small to have been source vents for the Dundowran basalt. Additionally, the direction of elongation of the two axially aligned basalt outliers parallels the trends of minor faults in the Burrum Syncline Cretaceous sequence. All the above evidence suggested that these flows do not belong to the Childers basalt. Rather they are local, and probably Late Tertiary extrusions in the Hervey Bay area.

BIOSTRATIGRAPHY

Maryborough Formation

The silicified uppermost mudstone of the Maryborough Formation contains abundant well preserved moulds of bivalve shells. A large collection of these fossils was assembled from several localities in the Burrum Syncline. Although the Maryborough Formation comprises up to 2 000 m of sediment, most well preserved fossils have been collected from these silicified beds. Fossils obtained from other lithologies (e.g. glauconitic sandstone) in the upper part of the formation are usually too poorly preserved for specific identification.

Samples of fresh Maryborough Formation at 712384 (fine glauconitic sandstone) and at 710387 (coquinite) were processed for Foraminifera by standard methods. The coquinite was barren; however, the fine glauconitic sandstone from 712384 yielded well preserved Foraminifera.

Composition of fauna. A fauna of bivalves collected from silicified uppermost mudstones at several localities includes: *Phaenodesmia elongata* (Etheridge Snr 1872), *Phaenodesmia randsi* (Etheridge Jnr 1892),*'Tellina' mariaeburiensis* Etheridge Snr 1872, *Leionucula quadrata* (Etheridge Snr 1872), *Thracia primula* Hudleston 1890 *Maccoyella alata* (Etheridge Snr 1872), *Panopea maccoyi* (Moore 1870), *Opisthotrigonia nasuta* (Etheridge Snr 1872), *Meleagrinella* sp., *Rotularia* sp., and *Peratobelus* sp. The sample of fine glauconitic sandstone outcropping at 712384 yielded several well-preserved specimens of the foraminiferid *Bigenerina loeblichae* Crespin 1953, together with a single fragmented specimen of *Hyperammina* sp. Examples of the fauna are illustrated on Plate 1.

Age of fauna. Several bivalve species collected from the Maryborough Formation of the area mapped are of stratigraphic importance. Fleming (1970) recorded *P. elongata, P. randsi, 'T'. mariaeburiensis, M. alata, P. maccoyi,* and *L. quadrata,* together with the ammonoid *Australiceras jacki* (Etheridge Jnr 1880), in uppermost Maryborough Formation on Woody Island, Hervey Bay. Fleming regarded *A. jacki* as indicating an Aptian age for this part of the unit. Day (1969) indicated that the ranges of most bivalve species noted in the Maryborough Formation by Fleming (*loc. cit.*) do not extend above the Aptian.

Belemnites of the genus *Peratobelus* were collected from the uppermost silicified beds of the Maryborough Formation in the Burrum Syncline. In the Great Artesian Basin, *Peratobelus* is considered an Aptian genus (Day 1964, 1969; Woods 1961; Ludbrook 1966; Skwarko 1966). The bivalve species

Opisthotrigonia nasuta (Etheridge 1872) was collected from a coquinite bed (at 710387), 200 m below the top of the formation. Fleming (1970) considered this species to be a reliable Aptian index.

Previous foraminiferal investigations have provided only inconclusive evidence for the exact age of the formation. Foraminifera extracted from oil exploration well cuttings from the Maryborough Formation yielded ages as follows: L.S.D. (Susan River) No. 2, Lower Cretaceous (Crespin 1955); Shell (Gregory River) No. 1, Lower Cretaceous, probably Aptian (see Ellis 1968). *Bigenerina loeblichae* has previously been recorded from near the top of the Maryborough Formation in the L.S.D. Cherwell No. 1 well by Crespin (1955). Ludbrook (1966) regarded the species as of Aptian age in its Great Artesian Basin occurrences. These occurrences were considered by Scheibnerová (1971) to be of Aptian to Cenomanian age. The work of D.W. Haig (pers. comm.), however, indicates an Aptian to earliest Albian range for *B. loeblichae.*

Thus all available palaeontological evidence indicates an Aptian age for the upper Maryborough Formation in the study area. Previous palaeontological work implies an Aptian age for most of the formation, except for a ?Neocomian age of the lowest beds in the unit (Day 1969; Fleming 1970).

Palaeoecology. Most outcrops of Maryborough Formation in the area mapped consist of silicified mudstone or glauconitic sandstone. The faunal diversity of glauconitic sandstones is limited, and epifaunal bivalves exceed infaunal ones in both number and variety. Abundance of thick-shelled types (e.g. *Fissilunula clarkei*) and strongly ornamented ones (e.g. *Opisthotrigonia nasuta*) imply shallow water.

In silicified mudstone forming the uppermost parts of the formation, fossil shells are rarely broken. Commonly, bivalve shells occur articulated, and they are seldom concentrated or oriented, suggesting that no strong current or wave influence operated. Locally (at 710387), a bed of coquinite containing transported, disarticulated, abraded, oriented shells in enormous quantity, but limited variety, indicates strong local transport and depositional currents. The most common forms contained in the coquinite are epifaunal *Maccoyella alata* and infaunal *Opisthotrigonia nasuta,* but the allochthonous origin of the shells precludes palaeoecological interpretation based on species.

Features of faunas in silicified mudstone and sandstone suggest rapidity of sedimentation. Epifaunal shells are buried without abrasion of fine ornament, and no overgrowth of sessile or encrusting benthos on shells is observed. Commonly, plant debris is abundantly associated with marine fossils. Infaunal species (e.g. *Panopea maccoyi*) are preserved in a position of life, with valves in opposition, in an orientation crossing the sediment bedding planes, and siphonal gape pointing upward.

The taxonomic diversity of the Maryborough Formation fauna is very low (13 bivalve genera recorded in the present study; 21 bivalve genera recorded by Fleming 1970). Fleming referred to the work of Stehli, McAlester, & Helsey (1967), which indicated that such faunas of low taxonomic diversity indicated a cold water province. He noted, however, that several thick, large, strongly ornamented bivalve species (e.g. *Maccoyella* spp.) suggested mild temperatures, following the opinion of Nicol (1967).

Possibly relative isolation of the basin during the Aptian inhibited development of a diverse invertebrate fauna. The rarity of cephalopods in the Maryborough Formation supports this theory; however, Day (1969) argued that at least limited connection between the Maryborough and Great Artesian Basins was established for part of the Aptian, based on similarities between *Meleagrinella* species of the basins.

Thus the fauna of the uppermost part of the Maryborough Formation is interpreted as having lived in a shallow, calm sea, of mild water temperatures, undergoing rapid sedimentation, and possibly nearly isolated by land barriers. Day (1969) has suggested that some restricted east-west sea connection existed with the Surat Basin.

Burrum Coal Measures

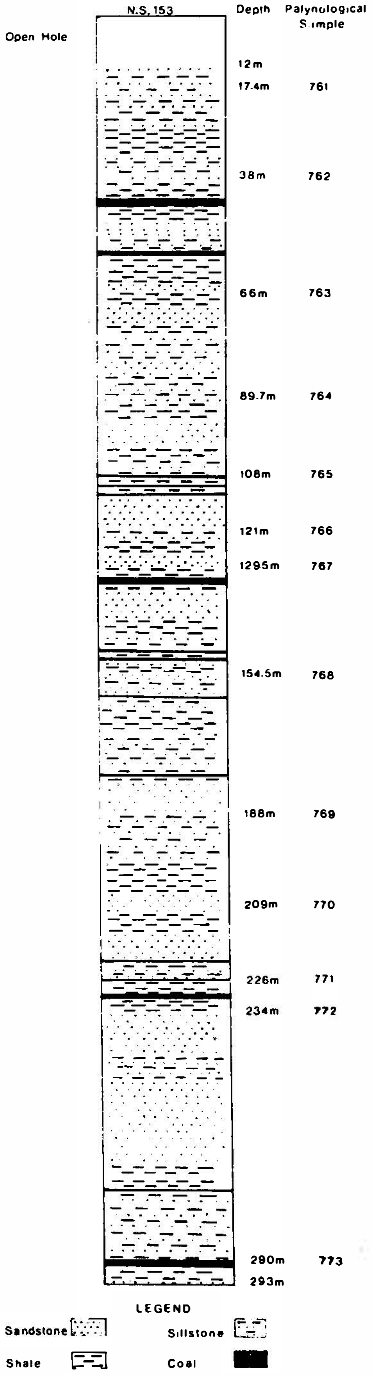
Shale and siltstone of the middle Burrum Coal Measures (Productive Measures) are richly carbonaceous, containing frequent coal seams, abundant fragmented leaf and stem impressions, and slightly carbonized, but specifically identifiable spores and pollen. Burrum Coal Measures surface exposures are too strongly lateritized to yield useful palynological material, but Queensland Department of Mines coal exploration diamond drill cores from holes in the area afford scope for spore-pollen investigations.

Diamond drill hole N.S.153 (at 844451), continuously cored through 280 m of the Productive Measures, was selected for palynological examination. Thirteen samples from unevenly spaced levels in the borehole (Text-fig. 6), over its entire depth, were processed for palynomorphs, with a positive result in each case.

Rock samples were prepared for miospores according to laboratory techniques described by Dettmann (1963). Megaspores were picked from the unoxidised residues, subjected individually to controlled oxidation, and mounted separately in glycerine jelly. Specimens of megaspores and miospores were selected and mounted for study under the 'Stereoscan' Scanning Electron Microscope (S.E.M.). Selected miospores were picked from residues dried in absolute ethyl alcohol using a micromanipulator.

Composition and age of microflora. A microflora of 40 species of spores and pollen was identified from N.S.153. Relative abundances (by visual observation) of the various species in the 13 samples are shown on Table 6. Examples of species in the microflora are illustrated on Plates 2-4.

Of the identified species, 7 were considered by Dettmann & Playford (1969) to be of stratigraphic significance. The occurrence together of the following species is important: *Pilosisporites notensis* Cookson & Dettmann 1958, *Cicatricosisporites australiensis* (Cookson) Potonié 1956, *Balmeisporites holodictyus* Cookson & Dettmann 1958, *Arcellites reticulatus* (Cookson & Dettmann) Potter 1963, *Kraeuselisporites majus* (Cookson & Dettmann) Dettmann 1963, *Crybelosporites striatus* (Cookson & Dettmann) Dettmann 1963, and *Foraminisporis asymmetricus* (Cookson & Dettmann) Dettmann 1963. Collectively these species indicate that the part of the Productive

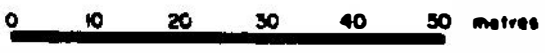


TEXT FIG 6

STRATIGRAPHIC SECTION

QUEENSLAND MINES DEPT. DIAMOND DRILLHOLE NS 153

SHOWING DEPTHS OF PALYNOLOGICAL SAMPLES



Measures examined lies in the *Coptospora paradoxa* Zone of Dettmann & Playford (1969); however, the nominate species *C. paradoxa* (Cookson & Dettmann) Dettmann 1963 was not found in any of the samples examined.

P. notensis ends its range in the lowest part of the *Coptospora paradoxa* Zone (Dettmann & Playford 1969, Table 9.4); the range of *K. majus* begins in the lowest part of this zone. Thus, the Productive Measures is assignable to the lowest part of the *Coptospora paradoxa* Zone. The seven species indicated, together with *Microfoveolatosporis canaliculatus* Dettmann 1963, limit the stratigraphic interval represented by N.S.153, to the K2a spore unit of Evans (1966) which Burger (1973) regarded as approximately equivalent to Dettmann & Playford's *Coptospora paradoxa* Zone.

No tricolpate angiospermous pollen grains were observed in the material examined, suggesting that the unit predates the appearance of the earliest angiosperms (base of spore unit K2b of Burger 1973; base of *Phimopollenites pannosus* Zone of Dettmann & Playford 1969). The presence of *Appendicisporites* sp. in some N.S.153 samples is unusual. Dettmann & Playford (1969) observed synchronous appearance of angiosperms and *Appendicisporites* in Victoria and South Australia. Burger (1973) noted that in the Eromanga Basin the earliest specimens of this genus do not occur before spore unit K2b, and coincide with the first appearance of tricolpate angiosperms (Burger 1968). Burger (1973), however, recorded specimens of *Appendicisporites* spp. together with forms characteristic of his spore unit Kld, from samples of the Wallumbilla Formation in Mid-Eastern Burketown 1 well, Carpentaria Basin. He considered the early appearance of the genus in the north to be perhaps connected with a warmer climate at lower latitudes.

Dettmann & Playford (1969) considered the range of their *Coptospora paradoxa* Zone to be lower Albian to upper Albian on the basis of Foraminifera and ammonites identified by Ludbrook (1966) from the reference section of the zone: South Australia, Santos Oodnadatta No. 1 well, 62.5-176 m (Bulldog Shale, upper part and Oodnadatta Formation). Burger (1973) regarded the age of his approximately equivalent K2a spore unit as Albian. In the Eromanga and Surat Basins, he considered the unit to extend from the upper part of the middle Albian to the middle part of the upper Albian. In the southern Carpentaria Basin, he regarded the range of the combined Kld-K2a units as lower Albian to middle upper Albian.

Thus from evidence obtained from N.S.153 samples, the Productive Burrum Coal Measures are placed in the *Coptospora paradoxa* Zone (spore unit K2a), of Albian age, probably the early part (from the occurrence of *P. notensis*), and before the middle-late Albian when tricolpate angiospermous pollen grains were introduced (see Dettmann 1973).

Palaeoecology. The dispersed spore and pollen species identified from N.S.153 samples are tabulated, together with relative abundances (estimated from visual examination) of the forms in each sample (Table 6). The tabulation is arranged in order of presumed botanical affinities of the spores and pollen.

Dominant species of the N.S.153 microflora are gleicheniaceous fern spores, *Gleicheniidites* cf. *G. cercinidites* (Cookson) Dettmann 1963, *G. senonicus* Ross emend. Skarby 1964; and schizaeaceous fern spores, *Micro-*

Table 6 . Check list of identified spore species, N.S.153 borehole; showing their relative abundances (estimated by visual observation) in the identified microflora, and the assumed natural affinities of the species)

Provisional Natural Taxon		Lithology (see Tab. for key) Species Sample No.	761	762	763	764	765	766	767	768	769	770	771	772	773	Overall
BRYOPHYTES	Hepaticae	*Cingutriletes clavus*				C			C			C	A	C	R	C
		Foraminisporis asymmetricus					R				R					R
		Aequitriradites verrucosus	R													R
		Aequitriradites spinulosus	R									R				R
		Triporoletes reticulatus	R	R			R	R				R	R			R
LYCOPSIDS		*Leptolepidites verrucosus*					C					C	C			R
		Neoraistrickia truncata	R				R	R				R	R	R	R	R
		Ceratosporites equalis	C	C		R	C					C	C	C	R	C
		Foveosporites canalis	C	C		A	C			R	C	A	C	C	C	C
		Retitriletes austroclavatidites	C	R	R	C	C		C	R	C	C	C	C	C	C
		Krauselisporites majus					R						R			R
PTEROPSIDS	Gleichen-aceae	*Gleicheniidites cercinidites*	VA	VA	A	C	A	C	A	VA	A	A	VA	A	A	VA
		Gleicheniidites senonicus	VA	VA	VA	C	VA	C		A	A	A	A	A	A	VA
	Osmund-aceae	*Osmundacidites wellmanii*		A	C	C	VA	VA	C	R	C	C	C	C	C	A
		Baculatisporites comaumensis	R	C	VA	R	C	VA	C	C		C	C	C		A
	Schizaeaceae	*Cicatricosisporites australiensis*		VA	C		C	C	C		C	R	R	C	R	C
		Cicatricosisporites hughesi		R	R		C	C		C	C			C		C
		Appendicisporites sp.										R		VA		R
		Trilobosporites purvulentus		R	R		C		C	R				C	R	R
		Microfoveolatosporis canaliculatus	C	A	VA	C	VA	A	A	VA	VA	VA	C	A	A	VA
		Contignisporites fornicatus				C	R	R		C		R	R	C		R
	Dick-inson eaceae	*Trilites tuberculiformis*											R	R		R
	Hydropter-idales	*Crybelosporites striatus*				R	R	C	C	R		R	R	R	C	k
		Arcellites reticulatus	R		C				C							R
		Arcellites nudus			R				C							R
		Arcellites disciformis			R											R
	Cyath-eaceae	*Cyathidites australis*			R	R	R									R
		Cyathidites minor		C	C	C	C	C	C			R	C	C	C	C
		Cyathidites asper			R											R
GYMNOSPERMS	Coniferales	*Alisporites grandis*	R			C	C	C	C						C	C
		Alisporites similis			C	C	C	R	C			R	R	C	C	C
		Podocarpidites ellipticus		R	R	C	R		C	C			R	C	C	C
		Podocarpidites multesimus				C		R	C	R		R	C	R	A	C
		Microcachryidites antarcticus	C		C	C	C	R	VA	A	A	C	C	C	C	A
		Trisaccites microsaccatus									C				VA	R
		Classopollis classoides				C	R									R
	Cyca-dales	*Cycadopites follicularis*		R	R	R	C				R		R		R	R
Incertae sedis		*Pilosisporites grandis*		R		R					R		R	R		R
		Balmeisporites holodictyus			R				C				C			R
		Balmeisporites tridictyus			R		R						R			R

(VA = very abundant 20%; A = abundant 10%; C = common 1 - 10%; R = rare 1%)

Lithology			▒	▤	▬	▬	▬	▬	▬	▒	▬	▒	▬	▬	■	
Natural Taxon		No.	761	762	763	764	765	766	767	768	769	770	771	772	773	Overall
		No. of Species														
Bryophyta	Hepaticae	5	R	R		C	R	R	C			C	A	C	R	C
lycopsids		6	C	R	R	C	C	R	R	R	R	A	C	C	R	C
pteropsids	Gleichen-iaceae	2	VA	VA	VA	C	VA	C	A	VA	A	A	VA	A	A	VA
	Osmund-aceae	2	R	C	A	R	A	VA	C	R	R	C	C	C	R	A
	Schiz-aceae	6	R	A	A	R	A	A	C	A	A	C	R	A	R	A
	Dick-inson-eaceae	1											R	R		R
	Hydar-optar-idales	4	R		R	R	R	R	C	R		R	R	R	R	R
	Cyath-aceae	3		R	R	R	R		R	R		R	R	R	R	R
Gymnospermaphyta	Coniferales	7	R	R	R	C	C	R	A	C	C	R	R	C	A	C
	Cycadales	1		R	R	R	C				R		R		R	R
Incertae	sedis	3		R	R	R	R		R		R		R	R		R
Total Species		40														

▒ Siltstone ▤ Shale ▬ Carb. Shale ■ Coal

Table 7. Distribution of assumed natural plant taxa, as represented by the microflora of borehole N.S.153.

(VA = very abundant, 20%; A = abundant, 10%; C = common, 1-10%; R = rare, 1%)

foveolatosporis canaliculatus. Other important constituents of the microflora are *Osmundacidites wellmanii* Couper 1953, and *Baculatisporites comaumensis* (Cookson) Potonié 1956 (osmundaceous fern spores); and *Microcachryidites antarcticus* Cookson 1947 (conifer pollen). In a few samples, the distinctive schizaeaceous fern spores *Cicatricosisporites australiensis* and *Appendicisporites* sp. are important.

The number of form species assigned to various major natural taxonomic groups, and relative abundances of these groups in each sample are set out in Table 7. Pteropsids (ferns) are dominant types in the N.S.153 microflora (18 species), other important groups are Coniferales (7 species), lycopsids (6 species), and bryophytes (5 species). This agrees with data on the composition of the megaflora of the Burrum Coal Measures presented by Walkom (1919). The spore-pollen composition of the eastern Australian Albian in general, and the Burrum Coal Measures in particular, is similar to contemporaneous floras of U.S.S.R. (Bolkhovitina 1961), Canada (Singh 1964, 1971), and England (Kemp 1971). In each case the gleicheniaceous fern spores are dominant; cicatricose trilete spores, associated with the Schizaeaceae, and gymnospermous (conifer) pollen are common.

Dominance of fern spores is expected in coal measures, as they represent *in situ* coal-forming swamp vegetation. This has been observed in the coal-bearing, non-marine Wealden (Lower Cretaceous of England) by Chaloner & Muir (1968). The common component of conifer pollen possibly has an origin external to the coal forming area, being derived from the hinterland vegetation.

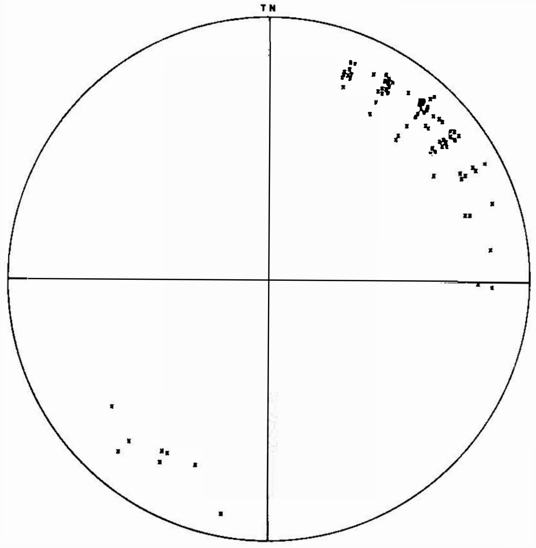
The Burrum Coal Measures microflora lacks dinoflagellates and acritarchs, which are characteristic of contemporaneous microfloras in the Great Artesian Basin (e.g. Burger 1973). This reflects the non-marine nature of Burrum Coal Measures deposition as opposed to marine depositional conditions prevailing in the Great Artesian Basin. Apart from this distinction, the microfloras of the Burrum Coal Measures are very similar in spore and pollen composition to contemporaneous microfloras of the Great Artesian Basin, and to many extra-Australian Cretaceous microfloras.

STRUCTURE

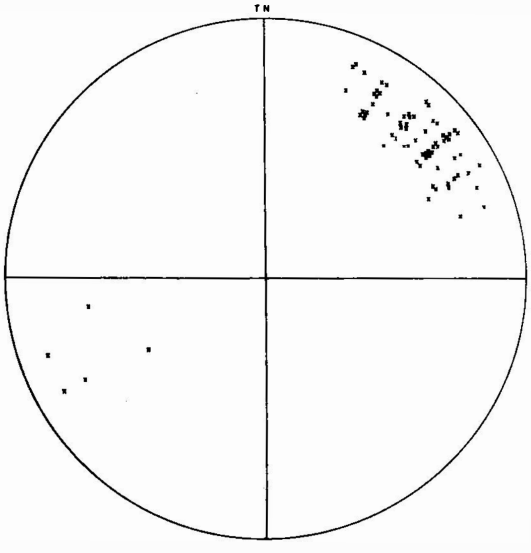
Folds

The Burrum Syncline is a northwest plunging asymmetrical fold; beds dip at 10-15° on the broad western limb, and at 20-25° on the eastern limb. Stereographic plots of dip and dip azimuth measurements taken from Maryborough Formation outcrops (94 observations, Text-fig. 7), and Burrum Coal Measures outcrops (75 observations, Text-fig. 8) in the syncline show consistency between the two units on each flank of the syncline. These plots do not 'girdle' in the manner expected for a parallel fold with a northwest trending axial surface trace (as indicated by distribution of rock units in the Burrum Syncline). The spread in azimuth exhibited by the plots suggests more complexity than simple parallel folding, perhaps involving secondary (parasitic) folds on the major structure (Burrum Syncline).

Minor folds in sandstone and siltstone of the Burrum Coal Measures



TEXT-FIG 7 STEREOGRAPHIC PLOT, MARYBOROUGH FORMATION
DIPS AND DIP AZIMUTHS (94 observations)



TEXT-FIG 8 STEREOGRAPHIC PLOT, BURRUM COAL MEASURES
DIPS AND DIP AZIMUTHS (75 observations)

are exposed in road cuttings in the area mapped. Near such structures, dips increase to 50°. These folds, which plunge very shallowly eastward, are usually asymmetrical, open and parallel, with an 060 axial surface trace. One overturned tight asymmetrical anticline occurs at 810348. Fine sandstone and siltstone forming these structures exhibit fractures along fold hinges, indicating folding primarily of material in a brittle state. Some small scale slump and compaction fold structures suggest deformation of plastic sediments.

Faults

Only one fault was demonstrated from outcrop in the area studied but this may be due to lack of exposure, as study of aerial photographs of the area reveals several major lineations, resembling faults. They are expressed (at 695420 and 698403) by the formation of northeast-trending, linear channels by otherwise mature, meandering rivers, and associated with right lateral displacement of the marker formed by the uppermost silicified mudstones of the Maryborough Formation.

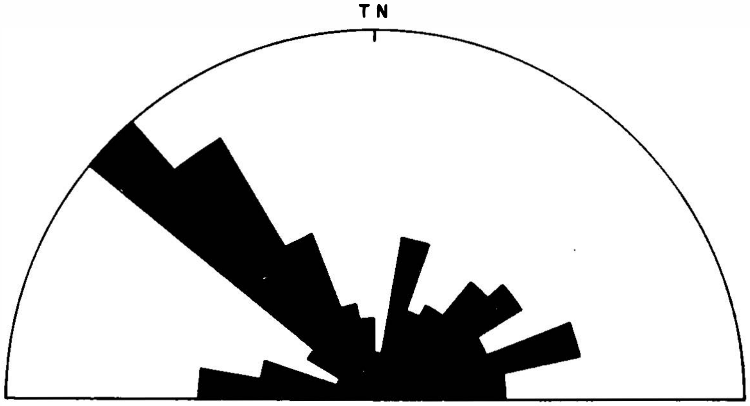
The fault observed in outcrop (in a quarry face at 916458) is a minor structure, striking 130° and resulting in 0.5 m vertical reverse separation. Slickensiding is visible on joint surfaces near this fault. In general, faulting of the Burrum Syncline sediments is much less intense than that recorded by Ellis (1968) in the Urangan Syncline on the coast, but the strike direction of faults in the two synclines is similar.

Joints

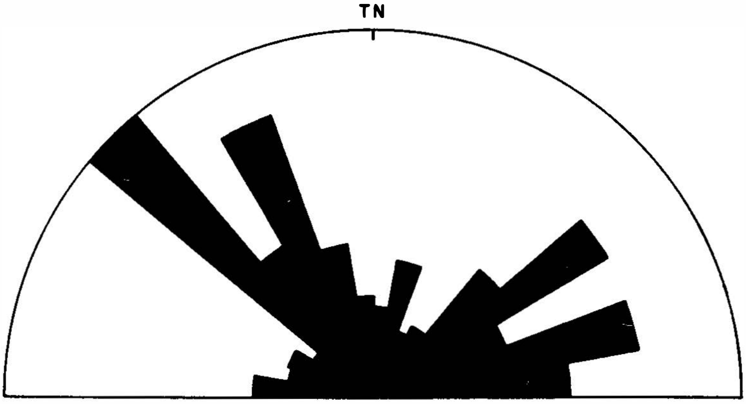
The overwhelming majority of joints observed in the area mapped are vertical (minimum dip 80°). Rose diagrams (Text-fig. 9) of joint trends in the Maryborough Formation (235 observations) and the Burrum Coal Measures (176 observations) are comparable to the rose diagram of aerial photographic linear trends (150 observations) from the Pialba 4 900 m series aerial photographs. All three plots show a consistent dominant direction of 130-140°, which is parallel to the axial direction of the Burrum Syncline. Subsidiary prominent directions of joints and airphoto linears were observed as 070-080 and 270-275. Stephens (1971) interpreted comparable jointing patterns in the Burrum Coal Measures at Point Vernon as being predominantly due to shear. In the area mapped, however, 'feathering' marks occur on most joint surfaces, indicating predominantly tensional jointing.

Structural interpretation

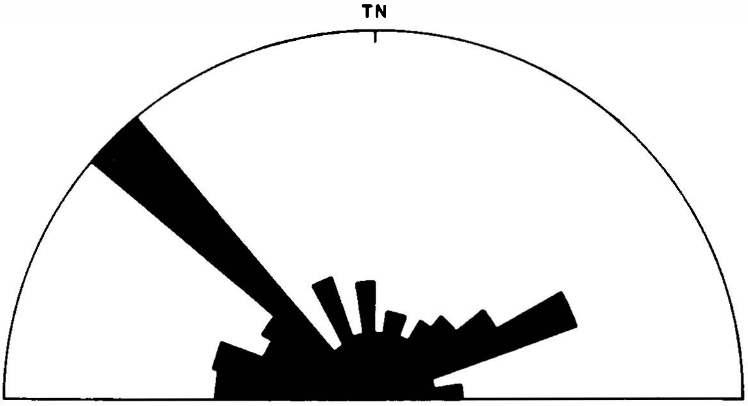
The Burrum Syncline is an open fold with few minor intense or overfolded parasitic folds. The style of folding is concentric (parallel), suggesting a flexural slip mechanism, as opposed to slip (shear) folding. Minor folds are usually of asymmetrical form, and show shallow or no plunge. Some variation in vergence and plunge occurs along the fold axes. Stephens (1971) regarded the change in plunge of folds observed in the Burrum Coal Measures at Point Vernon as reflecting disharmonic folding. Axial normal faults and joints (no



TEXT FIG 9a "ROSE" DIAGRAM OF TRENDS IN VERTICAL JOINTS MARYBOROUGH FORMATION (235 observations)



TEXT FIG 9b "ROSE" DIAGRAM OF TRENDS IN VERTICAL JOINTS BURRUM COAL MEASURES (175 observations)



TEXT FIG 9c "ROSE" DIAGRAM OF AIRPHOTO LINEAR TRENDS TORBANLEA AREA (150 observations) displacement) in fold hinges, no drag folding on reverse faults, and no changes in bed thickness over minor folds, suggest that deformation occurred (at least in the final stages) of material in a brittle state.

Stephens (1971) considered that jointing patterns in the Point Vernon area, exhibiting prominent orientations similar to those of the area studied (130, 090, and 060), were consistent with compression from a direction 60° E of N. Although this dynamic interpretation is plausible also in the Burrum Syncline, it is possible that the folding dynamics are more complex than simple compression. Ellis (1968) considered that the forces were related to basement faulting with normal downthrow to the east. He suggested Saxonian (germanotype) fold structures (i.e. not simple compression). Day *et al.* (1974) considered that all Mesozoic deformation of southeast Queensland was of Saxonian type and occurred in an environment of regional tension. They regarded the contrast between strong folding and faulting of Jurassic-Cretaceous sequences in parts of the Maryborough Basin, and the mild deformation of other basins, as one of degree of intensity rather than style of deformation.

The generally broad, open, parallel folds of the Burrum Syncline exhibit only minor disharmony and overfolding. Joint structures are mostly tensional, and faulting is not widespread, with reverse faulting being very rare and of small scale. Thus the evidence available from field observations in the Burrum Syncline supports the interpretation of Ellis (1966) and Day *et al.* (1974), that deformation of the Maryborough Basin occurred in an environment of tension, which they related to basement faulting, with downthrow to the east.

GEOLOGICAL HISTORY

The evolution of the Cretaceous-Tertiary sequence of the Burrum Syncline began at the close of the Jurassic, when volcanism became active on the eastern margin of the Maryborough Basin and continued through the Neocomian (Ellis 1968). Rapid accumulation of trachyandesitic pyroclastics of the Graham's Creek Formation (exposed to the immediate west of the Burrum Syncline) covered freshwater sediments of the Jurassic Tiaro Coal Measures.

Towards the end of the Neocomian, the Gundiah Embayment (20 km southeast of Maryborough) was flooded by an arm of the sea, which deposited tuffaceous sediments and supported a molluscan fauna. In the Maryborough Basin proper, the beginning of the Aptian was marked by waning volcanism, followed by a short period of stability, during which the volcanic terrain was eroded. Subsequent submergence led to the development of marine conditions and the deposition of the Maryborough Formation, the initial unit of the sequence exposed in the Burrum Syncline.

The Maryborough Formation contains a shallow-water, predominantly molluscan (bivalve) fauna. The unit, as represented in the Burrum Syncline, was deposited partly under shallow-water marine, high-energy conditions (depositing medium-grained glauconitic sandstones). The basin reverted to very quiet, shallow-water conditions late in the depositional history of the unit (depositing very fine argillaceous sediments, containing shallow water bivalves).

The source of sediment for this unit (from directional measurements on cross-beds in the area) is partly the pre-Jurassic terrain to the west. A possible additional sediment source was from a postulated high in the east (Ellis 1968).

Late in the Aptian, the sea withdrew from the basin, leaving a shallow-water lacustrine environment, which probably prevailed through most of the Albian. Ellis regarded this environmental change as being very abrupt, but Stephens (1971) considered that marine conditions periodically existed in the Point Vernon area, during the dominantly lacustrine deposition of the Burrum Coal Measures. These marine episodes resulted in the deposition of glauconitic sediments at Point Vernon. Paludal conditions became widespread in the basin in middle Albian times, when carbonaceous shale and coal seams of the Productive Burrum Coal Measures were deposited.

Following the Albian lacustrine deposition, relative subsidence in the Maryborough Basin ceased, due to readjustment along the Perry Fault. Such basement movement ultimately produced the Late Cretaceous folding developed in the Jurassic-Cretaceous sequence.

In the earliest Tertiary, the area was emergent, and exhibited much relief, due to the presence of elevated ridges of silicified Maryborough Formation mudstone on its flanks. Oligocene subsidence, in areas adjacent to these silicified ridges, accumulated thin, localized oligomictic conglomerates. These conglomerates consist entirely of Maryborough Formation material deposited by subaerial mass wasting processes. Continuation of subsidence through the Oligocene and Miocene accumulated the Elliott Formation of arenaceous and rudaceous quartzose sediments, under fluviatile conditions in the western part of the basin.

The Tertiary of the Burrum Syncline area was characterized by the operation of lateritic processes on Mesozoic and Tertiary sediments. Ridley (1957) dated the lateritization as Miocene, but Ellis (1968) considered that lateritization occurred from the Miocene until the Pleistocene.

Local olivine basalt extrusions occurred at Dundowran, where two flows can be distinguished. The lower flow was extruded on to Tertiary and Cretaceous lateritized sediments in the early middle Miocene (K-Ar minimum age 18.4 m.y.). A lengthy period of subaerial weathering followed, during which the basalt was extensively altered. In the late middle Miocene the second, fine-grained, unweathered basalt flow (K-Ar age 12 m.y.) was extruded on to the first.

On flood plains of mature streams, estuaries, and coastal areas respectively, fluviatile alluvium, coastal muds, and sand dunes were and are being deposited in Holocene time.

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PLATE EXPLANATIONS

Plate 1

(All specimens from Maryborough Formation, uppermost silicified beds. All figures xl unless otherwise stated.)

Figs. 1-3	*Phaenodesmia elongata* (Etheridge Snr 1872). 1, F66999, external mould of both valves. 2, F67002, external mould of right valve. 3, F66996, external mould of right valve.
Figs. 4, 5	*Opisthotrigonia nasuta* (Etheridge Snr 1872). 4, F67006, left valve. 5, F67007, right valve.
Figs. 6, 9	'*Tellina*' *mariaeburiensis* Etheridge Snr 1872. 6 F67003, external mould of distorted left valve. 9, F67004, external mould of left valve.
Figs. 7, 8	*Phaenodesmia randsi* (Etheridge Snr 1892). 7, F66995, internal mould of left valve. 8, F66991, internal mould of left valve.
Figs. 10, 13	*Thracia primula* Hudleston 1890. 10, F67010, external mould, right valve of juvenile specimen. 13, F67008, external mould, left valve of mature specimen.
Fig. 11	*Leionucula quadrata* (Etheridge Snr 1872). F66989, internal mould, left valve of thin-shelled compressed specimen.
Figs. 12, 14, 15	*Bigenerina loeblichae* Crespin 1953, x64. 12, F67098. 14, F67097. 15, F67012.

Plate 2

(All figures x500 unless otherwise stated, bright field illumination.)

Fig. 1	*Retitriletes austroclavatidites* (Cookson) Döring, Krutzsch, Mai, & Schulz 1963. Proximal focus. N.S.153 borehole at 38 m; 762/1, 21.5 x 95.9 (Y1918).
Fig. 2	*Leptolepidites verrucatus* Couper 1953. Distal focus. N.S.153 borehole at 209 m; 770/3, 18.6 x 103.1 (Y1911).
Fig. 3	*Foraminisporis assymetricus* (Cookson & Dettmann) Dettmann 1963. Distal focus. N.S.153 borehole at 188 m; 769/2, 18.5 x 97.1 (Y1919).
Fig. 4	*Gleicheniidites* cf. *G. cercinidites* (Cookson) Dettmann 1963. Proximal focus. N.S.153 borehole at 108 m; 765/2, 14.7 x 95.7 (Y1914).
Fig. 5	*Gleicheniidites senonicus* Ross emend. Skarby 1964. Proximal focus, N.S.153 borehole at 108 m; 765/2, 19.7 x 106.7 (Y1915).

Fig. 6 *Crybelosporites striatus* (Cookson & Dettmann) Dettmann 1963. High focus of specimen in off-polar aspect. N.S.153 borehole at 108 m; 765/2, 3.9 x 83.1 (Y1930).

Fig. 7 *Cicatricosisporites australiensis* (Cookson) Potonié 1956. Proximal focus. N.S.153 borehole at 38 m; 762/1, 3.4 x 105.9 (Y1931).

Fig. 8 *Cicatricosisporites australiensis* (Cookson) Potonié 1956. Lateral view. N.S. 153 borehole at 129.5 m; 767/1, 7.4 x 100.5 (Y1932).

Fig. 9 *Baculatisporites comaumensis* (Cookson) Potonié 1956. Proximal focus. N.S.153 borehole at 154.5 m; 768/2, 6.6 x 96.7 (Y1912).

Fig. 10 *Cingutriletes clavus* (Balme) Dettmann 1963. Proximal focus. N.S.153 borehole at 226 m; 771/3, 3.5 x 98.2 (Y1933).

Fig. 11 *Aequitriradites spinulosus* (Cookson & Dettmann) Cookson & Dettmann 1961. Proximal focus. N.S.153 borehole at 17.4 m; 761/4, 8.8 x 92.9 (Y1936).

Fig. 12 *Trilites* cf. *T. tuberculiformis* Cookson 1947. Distal focus. N.S.153 borehole at 38 m; 762/1, 21.3 x 85.1 (Y1917).

Fig. 13 *Foveosporites canalis* Balme 1957. Proximal focus. N.S.153 borehole at 108 m; 765/2, 20.0 x 97.5 (Y1916).

Fig. 14 *Kraeuselisporites majus* (Cookson & Dettmann) Dettmann 1963. Oblique proximal view, corroded specimen. N.S.153 borehole at 234 m; 772/1, 18.5 x 104.5 (Y1923).

Fig. 15 *Cicatricosisporites hughesi* Dettmann 1963. Distal focus. N.S.153 borehole at 154.4 m; 768/2, 10.0 x 114.1 (Y1938).

Fig. 16 *Cicatricosisporites hughesi* Dettmann 1963. High focus of specimen situated in off-polar aspect. N.S.153 borehole at 234 m; 772/1, 15.2 x 95.3 (Y1939).

Fig. 17 *Contignisporites fornicatus* Dettmann 1963. Low focus of specimen in off-polar aspect. N.S.153 borehole at 89.7 m; 764/2, 7.1 x 90.6 (Y1934).

Fig. 18 *Pilosisporites notensis* Cookson & Dettmann 1958. Distal focus. N.S.153 borehole at 38 m; 762/1, 7.7 x 98.3 (Y1928).

Fig. 19 *Trilobosporites purverulentus* (Verbitskaya) Dettmann 1963. Proximal focus, torn specimen. N.S.153 borehole at 290 m; 773/1, 22.4 x 107.3 (Y1929).

Plate 3

(All figures x500 unless otherwise stated, bright field illumination.)

Fig. 1 *Kraeuselisporites majus* (Cookson & Dettmann) Dettmann 1963. Oblique lateral view. N.S.153 borehole at 108 m; 765/2, 5.5 x 96.5 (Y1921).

Fig. 2 *Osmundacidites wellmanii* Couper 1953. Proximal focus. N.S.153 borehole at 108 m; 765/2, 6.9 x 100.9 (Y1924).

Fig. 3 *Trisaccites microsaccatus* (Couper) Couper 1960. Distal focus. N.S.153 borehole at 290 m; 773/1, 19.6 x 84.6 (Y1945).

Fig. 4 *Neoraistrickia truncata* (Cookson) Potonie 1956. Distal focus, torn specimen. N.S.153 borehole at 121 m; 766/3, 9.2 x 109.1 (Y1913).

Fig. 5 *Microfoveolatosporis canaliculatus* Dettmann 1963. Lateral view. N.S.153 borehole at 38 m; 762/1, 12.5 x 103.3 (Y1946).

Fig. 6 *Osmundacidites wellmanii* Couper 1953. Proximal focus. N.S.153 borehole at 66 m; 763/1, 6.1 x 114.6 (Y1925).

Fig. 7 *Cyathidites asper* (Bolkhovitina) Dettmann 1963. Proximal focus, distorted specimen. N.S.153 borehole at 66 m; 763/1, 19.2 x 108.3 (Y1926).

Fig. 8 *Microcachryidites antarcticus* Balme 1957. Lateral view. N.S.153 borehole at 129.5 m; 767/1, 20.8 x 97.8 (Y1944).

Fig. 9 *Appendicisporites* sp. Distal focus, showing two elongate narrow appendages at each amb angle. N.S.153 borehole at 284 m; 772/1, 18.9 x 96.9 (Y1942).

Fig. 10 *Aequitriradites verrucosus* (Cookson & Dettmann) Cookson & Dettmann 1961. Distal focus. N.S.153 borehole at 17.4 m; 761/5, 20.2 x 109.5 (Y1935).

Fig. 11 *Cyathidites australis* Couper 1953. Proximal focus. N.S.153 borehole at 108 m; 765/2, 16.0 x 99.4 (Y1927).

Fig. 12 *Appendicisporites* sp. Proximal focus of specimen in off-polar aspect. N.S.153 borehole at 234 m; 772/1, 6.2 x 111.1 (Y1941).

Fig. 13. *Appendicisporites* sp. Distal focus, showing thickened radial appendages. N.S.153 borehole at 234 m; 772/1, 15.8 x 115.0 (Y1940).

Plate 4

(All specimens from Queensland Department of Mines borehole N.S.153 at 66 m. All figures scanning electron micrographs.)

Fig. 1 *Arcellites reticulatus* (Cookson & Dettmann) Potter 1963. Lateral aspect, x120. 763 SM/8, 10.6 x 96.7 (Y1968).

Fig. 2 *Cicatricosisporites australiensis* (Cookson) Potonié 1956. Lateral aspect of slightly folded specimen, x700. 763/2, 10.5 x 95.6 (Y1960).

Fig. 3 *Osmundacidites wellmanii* Couper 1953. Distal aspect of slightly folded specimen, x900. 763/2 SEM, 9.5 x 95.9 (Y1954).

Fig. 4 *Arcellites nudus* (Cookson & Dettmann) Potter 1963. Lateral aspect, x120. 763 SM/9, 10.5 x 95.0 (Y1969).

Fig. 5 *Trilobosporites purverulentus* (Verbitskaya) Dettmann 1963. Proximal aspect, x450. 763/2 SEM, 11.9 x 96.3 (Y1959).

Fig. 6 *Trisaccites microsaccatus* (Couper) Couper 1960. Distal aspect, x1000, 763/2 SEM, 11.2 x 95.7 (Y1965).

Fig. 7 *Foveosporites canalis* Balme 1957. Proximal aspect, x670. 763/2 SEM, 10.4 x 96.0 (Y1953).

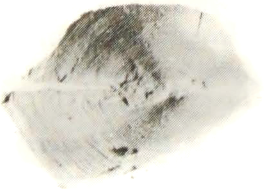
Fig. 8 *Baculatisporites comaumensis* (Cookson) Potonié 1956. Distal aspect, x650. 763/2 SEM, 11.5 x 95.8 (Y1955).

Fig. 9 *Cicatricosisporites hughesi* Dettmann 1963. Equatorial aspect, x700. 763/2 SEM, 9.4 x 95.3 (Y1964).

Fig. 10 *Trilobosporites purverulentus* (Verbitskaya) Dettmann 1963. Proximal aspect of slightly distorted specimen, x450. 763/2 SEM, 9.1 x 95.3 (Y1958).

Fig. 11 *Appendicisporites* sp. Equatorial aspect, down on amb angle, x300. 763/2 SEM, 10.9 x 95.6 (Y1962).

Fig. 12 *Ceratosporites equalis* Cookson & Dettmann 1958. Proximo-equatorial aspect, x670. 763/2 SEM, 10.7 x 96.0 (Y1952).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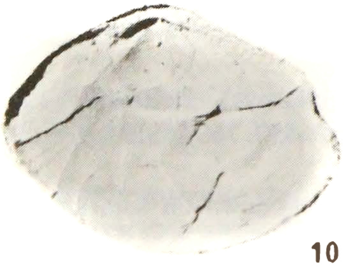
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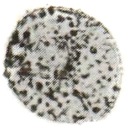
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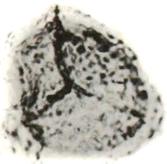
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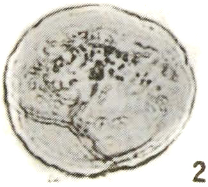
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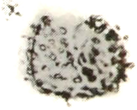
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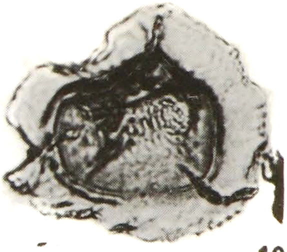
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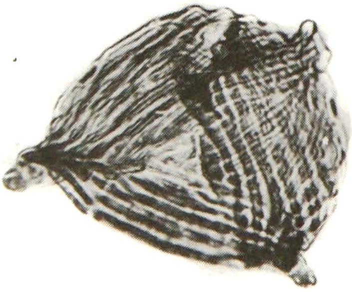
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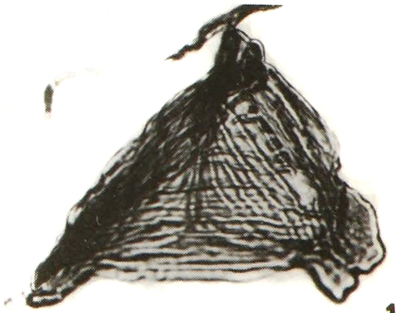
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PLATE 3


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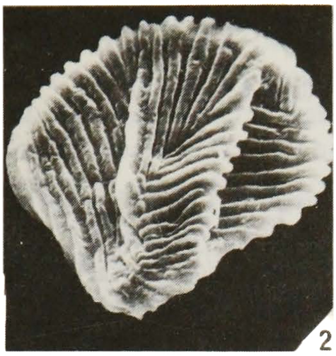
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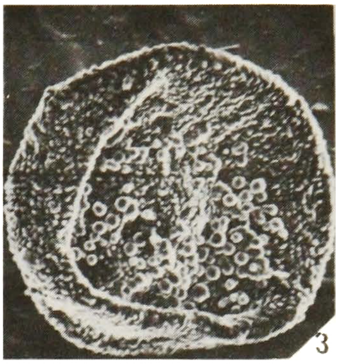
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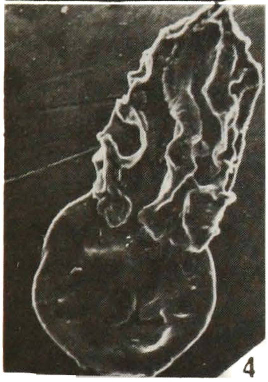
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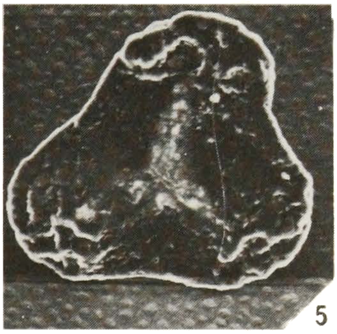
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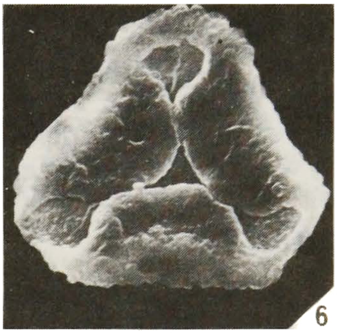
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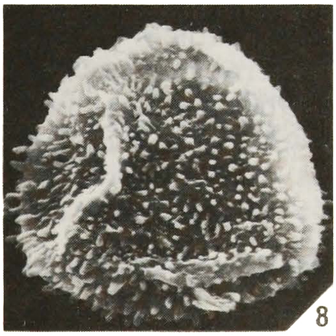
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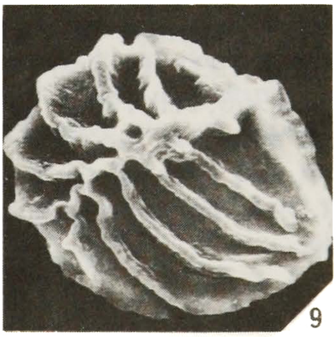
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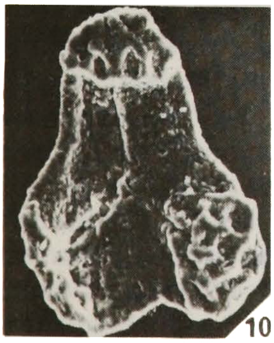
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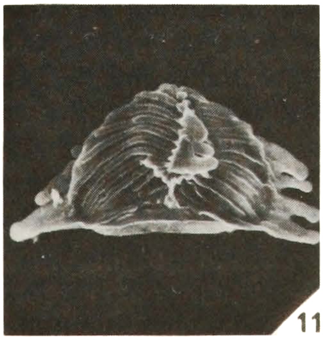
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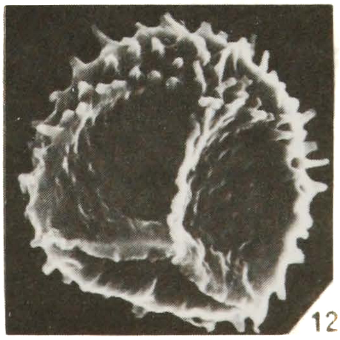
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PLATE 4