DEPARTMENT OF
MINERALS AND ENERGY

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Record 1974/106

MESOZOIC AND CAINOZOIC GEOLOGY OF THE LAWN HILL, WESTMORELAND, MORNINGTON, AND CAPE VAN DIEMEN 1:250 000 SHEET AREAS, QUEENSLAND

by

K.G. Grimes*

* Geological Survey of Queensland

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SUMMARY

This report describes the geology of part of the southwestern Carpentaria Basin and the adjacent 'Northern Territory Shelf'. The boundary between basin and 'shelf' is taken as the zone of non-deposition separating the basal Mesozoic sandstone sequences in the two areas.

The Precambrian and Palaeozoic basement rocks are not discussed.

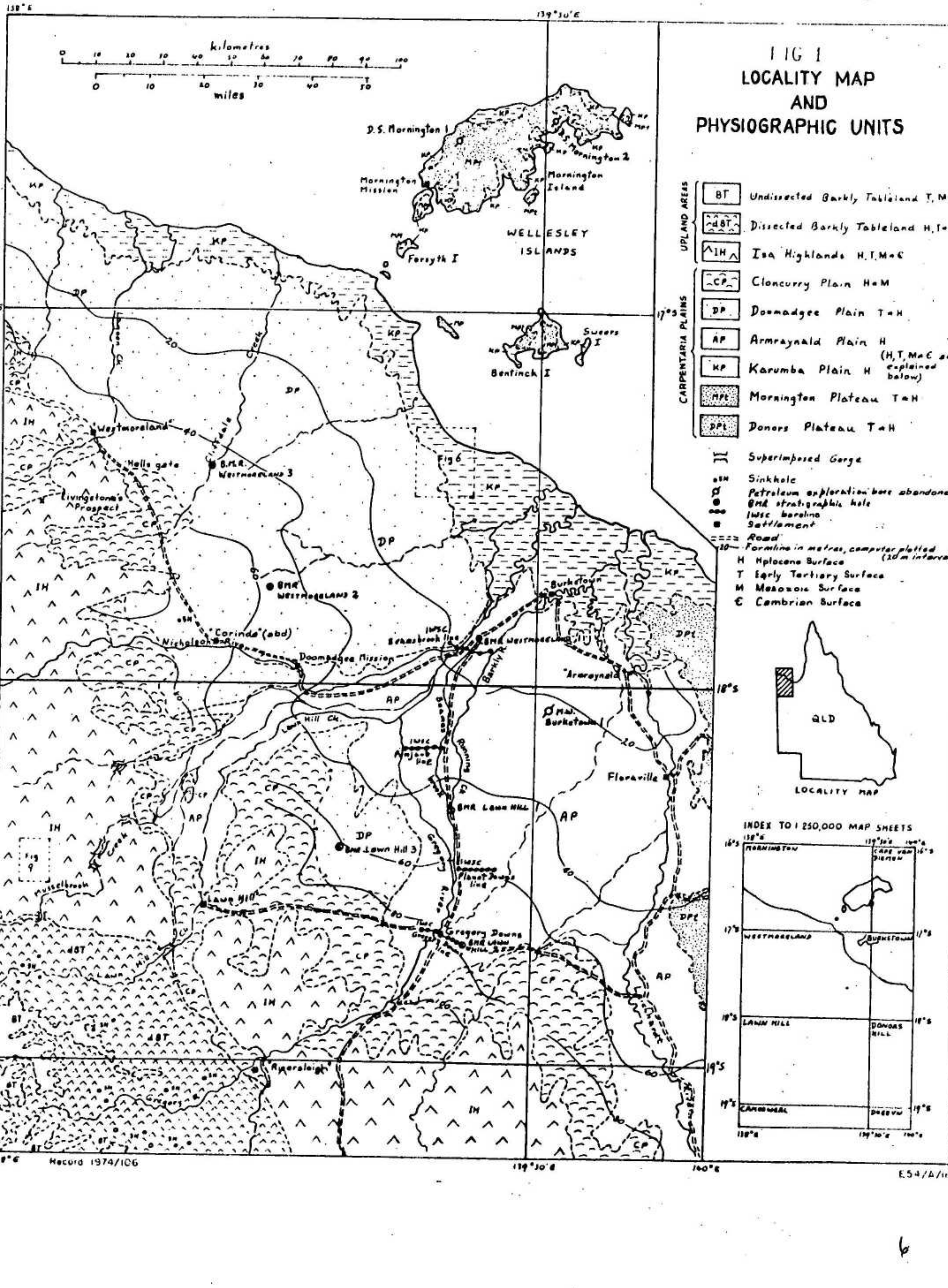
Erosion of the area in early Mesozoic times produced an irregular surface which was buried beneath later Mesozoic deposits. This Early Mesozoic Surface has since been exhumed in parts of the Isa Highlands. The basinal sequence commenced with Jurassic and Early Cretaceous sandstones, which were overlapped in Aptian and early Albian times by transgressive marine mudstones of the Wilgunya Subgroup. A regression in late Albian times was followed by the deposition of the paralic labile sandstones of the Normanton Formation. On the shelf a similar sequence of events occurred but the shelf deposits are much thinner than those of the subsiding basin.

Erosion in Late Cretaceous and early Tertiary times was accompanied by deposition of continental Floraville Formation. Further erosion culminated in the planar Tertiary Surface, which was subjected to deep weathering with the ultimate production of a standard laterite profile. Isolated Oligocene-Miocene limestone deposits in the southeast of the area may have followed on a later period of erosion.

The Isa Highlands were uplifted in the Pliocene and subjected to erosion. The Pleistocene Armraynald Beds represent some of the detritus produced by this erosion.

A variety of Quaternary deposits have been distinguished in the area and they fall into three groups: colluvial, alluvial, and coastal deposits.

Water supplies are obtained from the basal Mesozoic sandstones, and from porous basement rocks. The Cainozoic deposits have not yielded any sizable supplies to date. There do not appear to be any mineral deposits of economic value in the Mesozoic-Cainozoic sedimentary sequence.



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INTRODUCTION

The Mesozoic and Cainozoic units of the LAWN HILL*, WESTMORELAND, MORNINGTON, AND CAPE VAN DIEMEN 1:250 000 Sheet areas were mapped by a joint field party of the Bureau of Mineral Resources (BMR) and the Geological Survey of Queensland (GSQ) as part of a program of regional mapping in the Carpentaria Basin (cf Doutch et al., 1970, 1972).

The second edition maps and explanatory Notes for LAWN HILL and WESTMORELAND will not be compiled until current mapping of the Precambrian rocks is completed. This Record, therefore, presents the preliminary information of the Carpentaria Basin mapping.

The area lies on the western margin of the Carpentaria Basin in northwest Queensland (Fig. 1). Non-contoured topographic maps at a scale of 1:250 000 produced by the Division of National Mapping were used as bases for the accompanying preliminary edition geological maps. There is a complete air-photo coverage of the area at 1:85 000-scale, flown in 1966 (mainland) and 1971 (Wellesley Islands). There is also a 1:50 000-scale coverage of the mainland area flown between 1966 and 1968, and 1:25 000-scale colour photographs were flown in 1972 over the Hedleys Creek, Bowthorn, Musselbrook (north half), and Lawn Hill 1:100 000 Sheet areas. Older air-photos, generally of poorer quality, are also available.

The average annual rainfall of the area decreases from about 760 mm on the coast to 450 mm on the northern edge of the Barkly Tableland. Most of the rain falls in summer as heavy thunderstorms of the northwest monsoon. During winter, most streams dry up or are reduced to a chain of waterholes; however, the spring-fed Gregory River flows throughout the year.

PREVIOUS WORK

Most of the early geologists who visited the area concentrated on the study of the older rocks and made only passing reference to the Mesozoic and Cainozoic sediments. References to these earlier studies are given in the first edition explanatory notes for WESTMORELAND and

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* Throughout this Record the names of 1:250 000 Sheet areas are printed in capital letters to distinguish them from place names.

LAWN HILL (Carter, 1959; Carter & Öpik, 1961). The Mesozoic Mullaman Beds were described by Skwarko (1966). The Tertiary limestone at Riversleigh has been studied in detail by Whitehouse (1940) and Tedford (1967).

Petroleum exploration companies have had an intermittent interest in the area since 1954. Frome-Broken Hill Co. carried out geological surveys on the mainland and on Morington Island (Reed, 1954; Dixon, 1956, 1957). Delhi Australian Petroleum Ltd carried out geological surveys and stratigraphic drilling on Mornington Island and the adjacent mainland (Warner, 1960a, b), and then drilled two deep exploration wells (Delhi Santos Mornington 1 and 2) on Mornington Island (Harrison et al., 1961; Terpstra & Evans, 1962). An aeromagnetic survey was flown (Hartman, 1962), and the southern part of Delhi's A. to P. was then relinquished (Delhi, 1963). Mid-Wood Exploration Pty Ltd carried out aeromagnetic, seismic, and geological surveys immediately to the east of the report area (Hartman, 1963; Boutakoff, 1963; Warner, 1963; Rade, 1963a, b), and drilled Mid-Wood Burketown 1 (Perriman, 1964). More recently Australian Aquitaine Petroleum Co. Ltd has prospected the oil-shale deposits of the area (Swarbrick, 1974), but most exploration to date has been restricted to regions farthur southeast. Doutch (1973) has compiled a bibliography of work performed in the Carpentaria Basin up till 1972.

Stewart (1954) studied the geomorphology of the area, and Twidale (1966) the adjacent area to the east. The offshore sediments of the Gulf were examined by Phipps (1970). A terrain analysis of the area was made by CSIRO but only the sheets to the east have been published to date (Grant, 1968). The Irrigation & Water Supply Commission (IWSC) carried out shallow drilling along the Gregory River to assess the groundwater potential of the Cainozoic deposits (Cox, 1973).

A soils map at 1:2 million scale is available for the area (Isbell et al., 1968). CSIRO land research surveys of the area are described by Christian et al., (1954) and Perry et al., (1964).

During the current mapping project, several shallow stratigraphic holes were drilled in the area (Needham et al., 1971; Gibson et al., 1973). Explanatory notes for the map Sheets to the east of the area have recently been prepared (Ingram, 1972, 1973; Smart, 1973), and notes for other adjacent sheets were published earlier (Smith, 1963; Yates, 1963; Roberts et al., 1963; Smith & Roberts, 1963; Öpik et al., 1973).

PHYSIOGRAPHY

The physiographic units which I recognize are shown in Figure 1. A description of each of these units, and a discussion of the development of the old land surfaces, is given below.

An earlier description of the geomorphology of the region is given by Stewart (1954); the whole of this area falls within his Gulf Fall Division. Stewart adopted a genetic approach to the classification of his landforms, whereas the physiographic units used here are based on the more descriptive system of Twidale (1956, 1966) in the Leichhardt-Gilbert area, immediately to the east. A number of Twidale's units can be traced into the area described in this Record. Additional units were defined by Carter & Opik (1961) and Doutch et al., (1970) along the lines of Twidale's system, and are adopted here. Two new units are recognized: the Doomadgee Plain and the Mornington Plateau. The relations between Stewart's geomorphological units and the physiographic units used here are indicated in Table 1.

The physiographic units fall into two natural groups: the Upland Areas, and the Carpentaria Plains.

THE UPLAND AREAS

(1) Undissected Barkly Tableland

This is a black-soil* plain lying between 200 to 300 m elevation in the far southwest of LAWN HILL, and is only part of a more extensive unit farthur south and west. It consists of flat to gently rolling. treeless plains patterned with large-diameter gilgaies. The black soil overlies Cambrian dolomite. The surface drainage pattern consists of widely spaced streams that have a drainage density of 0.7 per km ** and are separated by expanses of black-soil downs without drainage channels; there are few tributaries. Stewart (1954) explains the absence of a close drainage net as being due 'to the extremely low relief, the intermediate to low rainfall (450 mm p.a.); and the cracked black soils that are very permeable when dry'.

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*"Black soil" is used here in the sense of Carter & Opik (1961) for the deep, grey-brown, cracking clays of Isbell (1968).

** Drainage densities were estimated from the 1:86 000-scale aerial-photographs. At this scale, first-order streamlets might not be recognizable, so that the densities quoted here might be less than the true density.

TABLE 1. RELATION BETWEEN STEWART'S (1954) GEOMORPHOLOGICAL UNITS AND THE PHYSIOGRAPHIC UNITS IN THIS RECORD

Stewart (1954)	This Record
Tertiary Swamp	Undissected Barkly Tableland[3]
Dissected Gulf Fall without lateritic remnants	Dissected Barkly Tableland[3]
As above with lateritic remnants	Isa Highlands[1]
Low-level Tertiary lateritic plain	Cloncurry Plain[1]
Post-Miocene Coastal Alluvia	Doomadgee Plain[3]
	Armraynald Plain[2]
	Karumba Plain[1]
	Mornington Plateau[3]
	Donors Plateau[1] (in Fig.1 only)

Footnotes

1. Term originated by Twidale (1956)
2. " " " Doutch et al., (1970)
3. " " in this paper

Mass erosion appears to be the dominant erosional process acting in the area, though sheetwash could play a part. Mass movement is evidenced by the presence of convex slopes right down to the stream beds, the nature of the gilgai patterns (which radiate away from high points), and the general absence of gulleys except near the major streams. Swelling and shrinking of the black soils would promote soil creep.

At the margins of the area, adjacent to the dissected country, there is a zone of flat timbered country in which the black soils are thin or absent (see below).

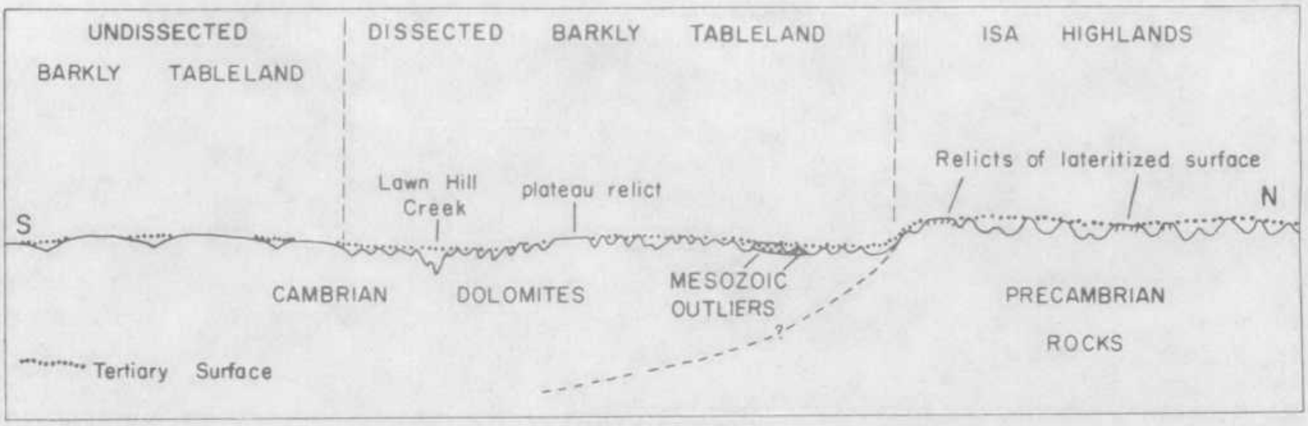

Fig. 2 Diagrammatic section across three physiographic units in the southwest of the LAWN HILL Sheet area. Not to scale.

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Fig. 3 Present wave-cut platform and cliff, above which is an older high-level platform. Beach rock remnants occur on the higher platform. Gee Wee Point, Mornington Island. (Neg No. GA 9291)

(2) Dissected Barkly Tableland

This is an area in southwestern LAWN HILL where the Gulf drainage is actively dissecting the Cambrian dolomite of the Barkley Tableland. It is equivalent to the canyon country of Opik et al., (1973). The elevation rises from 150 to 300 m above sea level. There is a dense dendritic drainage network (drainage densities of 3-5 per km), and the streams flow in narrow valleys separated by lobate interfluves. In a few places the drainage is less intense: where there are either Mesozoic rocks or sandy soils derived from an original Mesozoic cover, and where the tableland surface has been slightly modified by removal of the protective black-soil cover. These areas are mainly along the southwest margin of the unit, and in an outlying area north of the western part of Lawn Hill Creek.

There is a fairly marked summit concordance or gipfelflur which seems to be a continuation of the surface of the Undissected Barkly Tableland (Fig. 2); it probably corresponds to an old plateau surface. This gipfelflur lies below the one formed on the Precambrian rocks to the north and east; it undulates and has low points along the drainage axes of Lawn Hill Creek and the Gregory River. Lawn Hill Creek is at present sunk into the dolomite and has incised meanders; it leaves the area through a narrow gorge cut through the rim of Precambrian rocks which bound the area to the east (see Fig. 1 and the geological map). This indicates a superimposed drainage, and suggests that the creek owes its location to the nature of the old tableland before dissection commenced. These surfaces are discussed later in a separate section.

(3) Isa Highlands

This unit, named by Twidale (1956), can be extrapolated into the area described in this Record, and applied to the main area of hills and ranges underlain by Precambrian rocks (Fig. 1). Elevations range from 400 m above sea level, to 100 m where the unit merges with the Cloncurry Plain. Photo-interpretation shows that the relief varies, though quantitative estimates cannot be made in the absence of contour maps. It is large in such rock bodies as the Constance Sandstone and the Westmoreland and Conglomerate, but is relatively subdued in others, e.g. the Lawn Hill Formation the Cliffdale Volcanics, and parts of the Mullera Formation.

The drainage densities are diverse, but are generally between 2 and 4 per km. The stream patterns are generally strongly controlled by structural elements such as bedding trends, joints, and faults. In some of the less resistant lithologies a uniform dendritic pattern is developed. Dip

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slopes are common, especially in WESTMORELAND. A particularly well developed dip slope is present on the Westmoreland Conglomerate near Livingstones Prospect, south of Lagoon Creek (area reference 6479y - WESTMORELAND).

The landforms are 'youthful' to 'early mature' in appearance. Many of the streams are not graded and their profiles vary between low gradients with alluvial deposits where they cross the less resistant lithologies, and steep gradients with waterfalls where they have cut narrow gorges through the more resistant strata (e.g. Musselbrook Creek). The narrow gorges suggest a superimposed drainage pattern derived from an earlier land surface.

Several old land surfaces are preserved in the area, or can be interpolated from summit concordances (see Figs 8, 9, 10, 11). The nature and development of these surfaces are discussed later. They are an early Mesozoic surface, which was preserved beneath the Mesozoic deposits, a Tertiary planation surface, which is generally preserved as flat-topped hills and plateau remnants, and isolated remnants of an early Cambrian surface.

THE CARPENTARIA PLAINS

(1) Cloncurry Plain

This unit of Twidale's (op. cit.) is transitional between the uplands and the flat sedimentary plains (Fig. 1). It rises from 100 to 250 m above sea level, and consists of flat to gently sloping fluvial and colluvial plains and pediments with discontinuous low hills of Precambrian rocks which become higher and more numerous towards the upland margin. The hills are either surrounded by pediments, in places with a sharp piedmont angle (for example, the Hells Gate area, WESTMORELAND), or they rise out of alluvial flats (e.g. the Precambrian inliers along Lawn Hill Creek near Lawn Hill homestead).

The area has an overall drainage density of about 1-5 per km. The major streams are commonly braided, and are incised into a narrow flood plain. The subsidiary streams form a close dendritic drainage within the hilly areas of the interfluves, but combine to form wider-spaced channels, which cross the pediment slopes and enter the valleys of the major streams that flow through the area.

(2) Mornington Plateau

This partly dissected plateau covers much of Mornington Island and the other Wellesley Islands. The surface is developed on deeply weathered (lateritized) Normanton Formation and is composed of gently undulating, low, flat-topped or rounded ridges separated by broad shallow valleys. The plateau lies between 5 and 20 m above sea level and appears to have a general slope to the southeast; but this is not pronounced. Drainage is by a dendritic pattern of small streams, which adopt a meandering habit and widen in a short distance to form mangrove-fringed inlets in the tidal zone.

The lower parts of the eroded plateau surface are buried by coastal deposits or dune fields. The higher parts are terminated abruptly by sea cliffs, beyond which wave-cut platforms extend in places for a considerable distance (Fig. 3). The cliffs are highest and most continuous on the northwestern side of Mornington Island and have well developed laterite profiles. The wave-cut platforms are widest on the southeast coast, where the cliffs are lower and less common. Along the north-western coast there are raised beach ridges and coral reefs exposed just above the present high-tide level (Figs 4, 5), and old wave-cut platforms with remnants of beach rock up to 5 m above the present high-water mark (Fig. 3). The beach ridges and raised reef could be explained by eustatic changes in sea level, but upwarping of the Wellesley Islands is also possible. Upwarping is supported by the presence of numerous small-scale faults and folds, some of which affect the laterite profile but not the wave-cut platforms (see Structural Geology). The laterite profile lies at a higher level on the northeastern coast than it does in the southeast; this may indicate tilting of the laterite surface, though the slope might be that of the surface before it was lateritized.

The greatest uplift appears to have been on Sweers Island, where Ingram (1973) reports an old, consolidated beach ridge which rises to 31 m above sea level and rests on a laterite platform 10 m above sea level.

The sea cliffs and wave-cut platforms are peculiar to the islands, and contrast with the present mainland coast of the area which is entirely depositional in its forms; however, there are some old sea cliffs and platforms preserved behind younger coastal sediments several kilometres inland north of Magowra homestead in BURKETOWN (Doutch, pers. comm.). This difference in form may be due in part to the recent upwarping of the islands, which would promote erosion, and, more importantly, to the presence on the mainland coast of major rivers which deliver large amounts of sediment to the coast and allow it to prograde rapidly.

(3) Doomadgee Plain

The name Doomadgee Plain is applied to the large, sandy plain which extends over most of the lowland area of WESTMORELAND and MORNINGTON, and a few isolated areas on LAWN HILL; it corresponds with much of the unit Cz on the geological maps (see Fig. 1). It rises from an elevation of about 10 m near the coast to 120 m above sea level at its inland junction with the Cloncurry Plain. The coastal plain of ROBERTSON RIVER (Yates, 1963) and other sheet areas in The Northern Territory is in part an extension of the Doomadgee Plain.

The Doomadgee Plain is gently and broadly undulating and has a few flood plains along the larger water courses. The surface is of loose sand overlying a laterite profile and it is covered with low Eucalypt and Paperbark scrub. It is crossed in places by low, winding ridges of sand, mapped as Qas. These probably represent abandoned stream channels and levees. The drainage has densities of 0.1 to 0.3 per km, is widely spaced, and, in the central area of the plain, is directed radially away from the point where Cliffdale Creek emerges from the highlands. This radial form of the stream patterns and the Qas depositional areas may represent an old alluvial 'fan' similar to the Gilbert and Mitchell Fans of the eastern part of the Gulf (Doutch et al., 1972). It could also be a response to slight upwarping of the coast adjacent to the Wellesley Islands. The streams are braided or closely meandering. The Nicholson River and some of the streams of the eastern part of the plain have been incised, possibly as a result of the Holocene drop in sea level (see later). This erosion has exposed the ferricrete horizon of the laterite profile.

The ferricrete horizon appears to lie at only a shallow depth below the sandy surface of much of the plain, and it follows the local rise and fall of the ground. This suggests that the lateritization is a fairly recent (Pleistocene?) event, and antedates only the Holocene incision of the streams and the deposition of Qas. The laterite profile would, therefore, be younger than the main Tertiary lateritization, which affected the region (see later); however, the more recent lateritization may be superimposed on the Tertiary lateritization, for the surface may have been stable during the interval.

Shallow swampy or water-filled depressions occur in parts of the plain which lack surface drainage channels (see the southwestern part of Fig. 7). They have flat floors which are only a few metres below the level of the surrounding plain. The shapes vary from oval to highly irregular. Some are as much as 2 km in diameter, but most are less than 500 m across. There is commonly a rim of ferricrete at the margins of the depression and the

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floor apparently lies below the level of the ferricrete zone.

Similar depressions have been observed in the lateritic areas of Cape York Peninsula, where they are more rounded in outline. Valentine (1959) described these Cape York depressions and suggested that they might be 'forms of a novel "tropical pseudokarst" due to the solution of silica'. He did not elaborate on the process involved. Smart et al., (1974) reported on the drilling of two shallow auger holes (BMR Weipa 4 and 5) in and adjacent to one of these depressions north of Weipa. The drill holes indicated that the pisolitic zone dipped below the depression but thinned slightly. The pallid zone was not intersected by the auger.

Small pits up to 1.5 m deep and several metres wide also occur in the Doomadgee Plain. Some have a small drainage hole at the bottom, and this extends under the ferricrete bed. They appear to be due to subsidence into a cavity beneath the ferricrete. K. Grant (pers. comm.) reports a large sinkhole on the old firebreak northwest of Corinda (see Fig. 1) at grid reference 110758 WESTMORELAND. He describes this as a 'large sinkhole in massive laterite with numerous small satellites. The laterite is up to 10 feet (3 m) thick around the sinkhole. The depth of the hole is greater than 15 feet (5 m)'.

These depressions are apparently formed by a process which could be referred to as 'laterite-karst', that is, by the subsurface removal of material in solution as a part of the lateritic process. Trendall (1962) discussed denudation by lateritic processes and considered that the surface was lowered mainly by removal of material in solution from the pallid zone of the laterite profile. If we accept this process, then the rate of solution in any part of a flat laterite plain would depend on the amount of rainwater passing through the relatively impermeable ferricrete zone into the pallid zone. If the permeability of the ferricrete zone were increased at any point (e.g., at intersecting joint planes, or by fracturing due to the uprooting of a tree) then the rainwater would penetrate more readily at that point and greater solution would occur beneath it. As a result the overlying ferricrete and the ground surface would subside locally to form a closed depression. Once this stage were reached the process would become self-perpetuating as additional surface water would be channeled into the depression, and solution would be maintained at a greater rate than the surrounding areas. The depression would enlarge horizontally but not vertically, as solution is restricted to the zone of the fluctuating watertable. A broad, shallow depression of the type observed would eventually result. The small sink-holes would represent the early stage of the process.

Tricart (1972) discussed the origin of similar closed depressions in cuirassed (lateritized) plateau surfaces, and considered that a tunnelling (piping) process was the dominant agent for the subsurface removal of material. While piping could be effective on a well dissected plateau, the depressions on the Doomadgee Plain can be up to 10 km from the nearest stream channel, and this seems an excessive distance for piping to occur. Solution, therefore, appears to be the dominant process forming the Doomadgee Plain depressions.

*(4) Armraynald Plain

This is the flat, grass-covered black-soil plain along and between the Gregory and Leichhardt Rivers, and Lawn Hill Creek. It corresponds to the outcrop area of the Armraynald Beds. It represents the western member of the two areas which Twidale (1966) referred to as the Wondoola Plain. Most of Twidale's comments on the Wondoola Plain can be applied here. The Armraynald Plain rises from 20 m in the north to 150 m above sea level at its inland margin. The general slope is to the northeast at about 1 in 1500 (about 0.7 m per km). The only local relief is in the stream channels and associated low levees. The Gregory River is incised up to 15 m into the plain in some places. The drainage network is densest (1.2 per km) in the western part of the plain, where the numerous anabranches of the Gregory River and Lawn Hill Creek form a reticulate net of the type described by Whitehouse (1944). The Gregory River system is spring-fed in its headwaters and has three permanently flowing channels where it crosses the Armraynald Plain; these are the Gregory River, Beames Brook, and the Barkly River-Running Creek channel. These permanent streams are lined by belts of thick forest, which is in marked contrast with the dry grasslands and open savanna of the adjacent plains. Towards the eastern margins of LAWN HILL there are only a few intermittent stream channels and the plain extends for long distances with no drainage lines. The drainage density here approaches zero, and sheet flow is the main means of drainage.

(5) Karumba Plain

This is the coastal plain named by Twidale (1956), and further described by Doutch et al.,(1972). It rises to about 10 m above sea level at its inland margin. The plain forms a continuous coastal fringe about 10 km wide, but widens to about 35 km where the coastal mudflats have been built out at the mouth of the Nicholson and Leichhardt Rivers. On the Wellesley Islands there are also small isolated pockets of coastal deposits which can be considered equivalent to the Karumba Plain (Fig. 1). The Karumba Plain continues into the Northern Territory, where it forms part

Figs 4 & 5 Two views of a coral reef which lies above the present high-water mark. Mouth of Gee Wee Creek, Mornington Island. (Neg Nos GA 9294 & GA 9287)

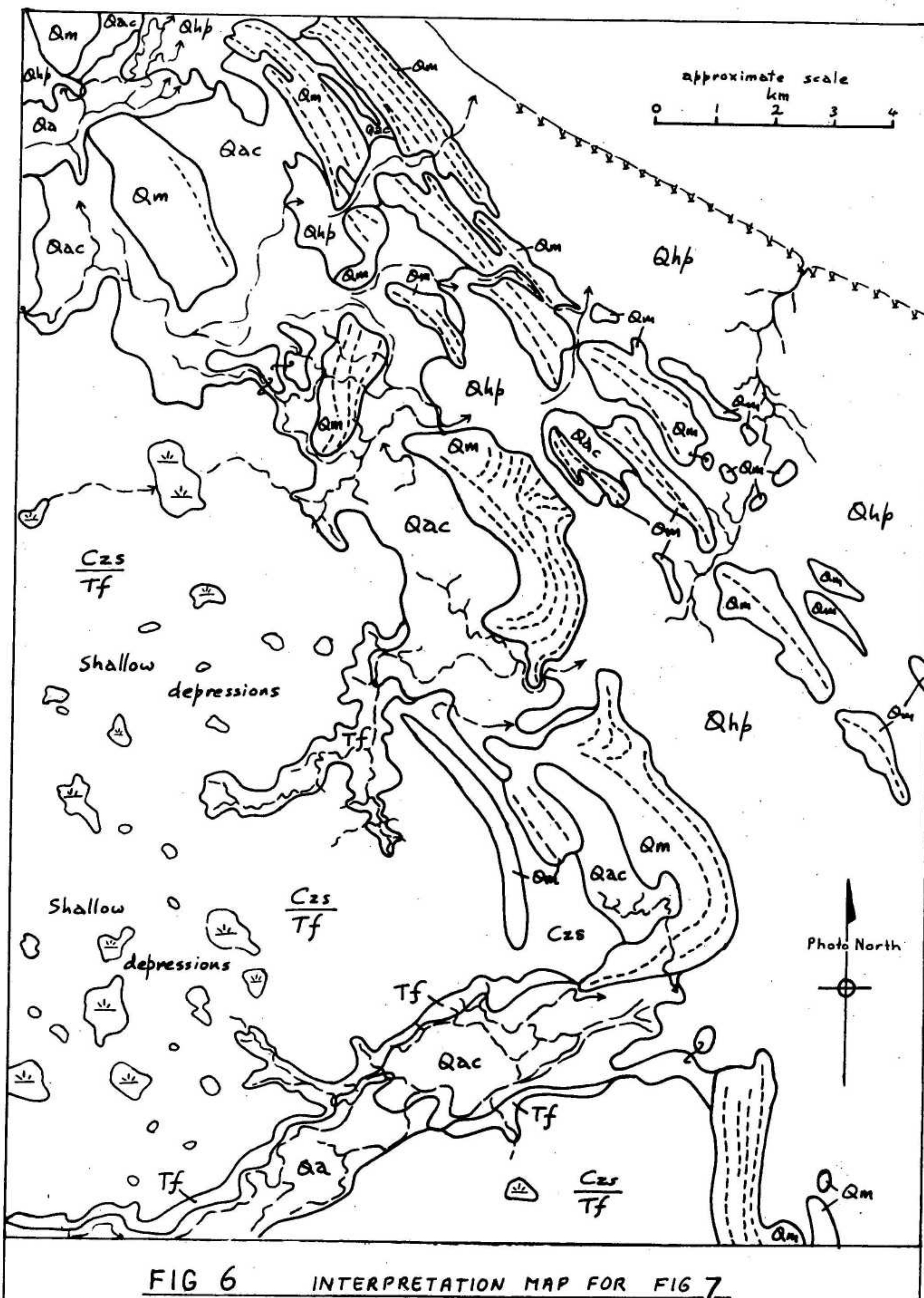

FIG 6 INTERPRETATION MAP FOR FIG 7

Karumba Plain

- Qhp — Tidal flats
- Qac — Vegetated coastal flats
- Qm — Sandy beach ridges
- Ridge trends

Doomadgee Plain

- Czs — Thin sand sheet
- Tf — Ferricrete exposed in breakaways
- Shallow, swampy depression

from Westmoreland Run 3
Photo 4262 (CAB 4018)

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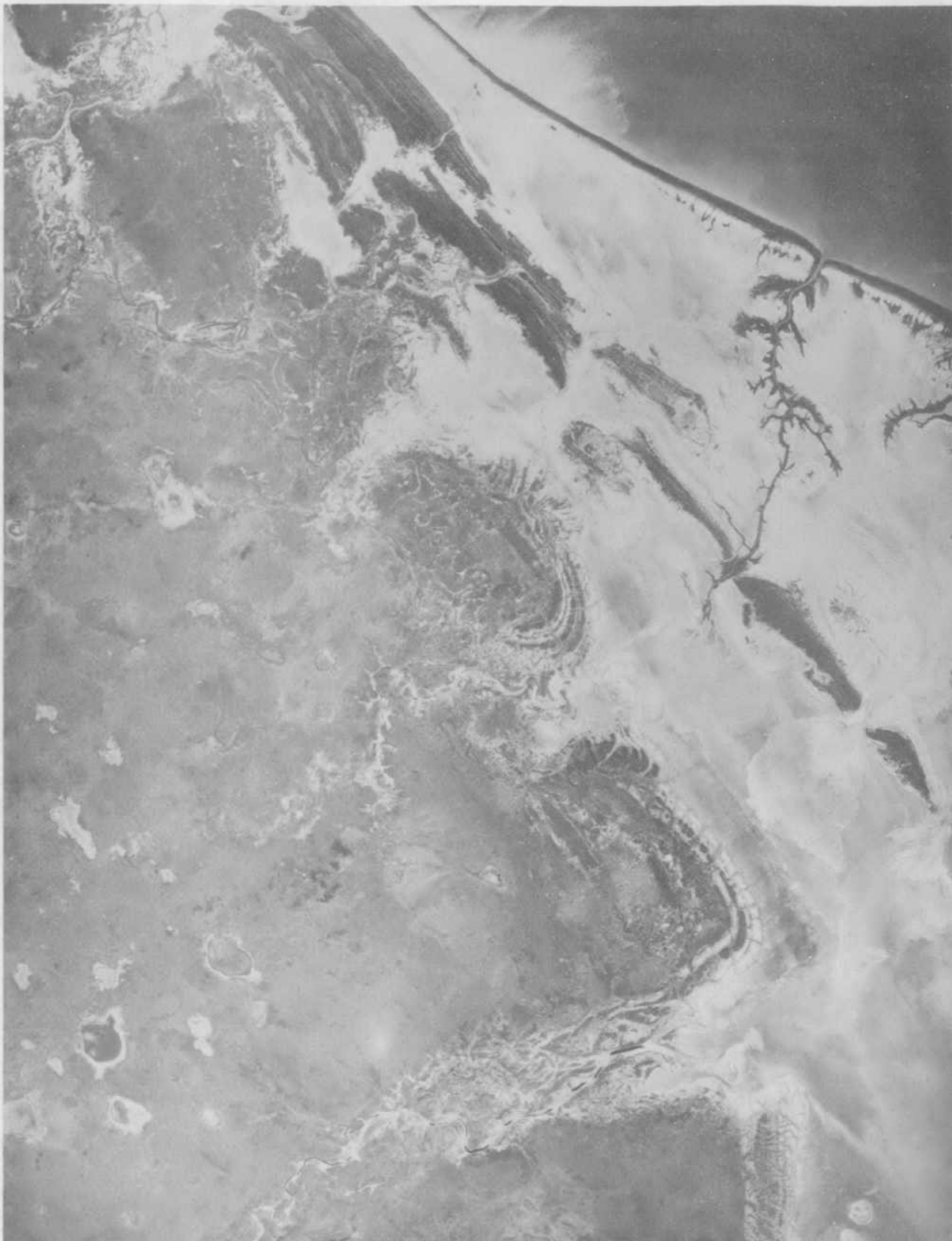

Fig. 7 Features of the Karumba Plain and a part of the Doomadgee Plain.
See Fig. 6 for interpretation.
(WESTMORELAND, CAB 4018, Run 3, Photo 4262).

of the 'Coastal Plain' of Yates (1963).

The inland part of the plain is a flat vegetated belt; the coastal part consists of bare tidal flats interspersed with linear, timbered, sandy beach ridges. Figures 6 & 7 illustrate part of the Karumba Plain on WESTMORELAND.

The tidal flats (Qhp in Fig. 6) are bare, salt-crusted, sandy, silty, or muddy. Some of the higher areas are only covered by water when the inland streams are flooded, or the northwesterly winds of the monsoon season generate exceptionally high tides. The flats are drained by dispersed dendritic and meandering channels, but much of this area is flat and featureless. Where the major streams from the inland plains cross the tidal flats, the lower gradient causes them to adopt a strongly meandering habit which contrasts with the braided patterns found farther inland. Where the tidal flats front onto the sea the coastline is indistinct, or marked by a fringe of mangroves. Beaches are found only where the Qm or Qac units front onto the sea.

The Qac plain is vegetated with open forest or grassland and lies mainly in the inland part of the Karumba Plains, but, closer to the coast, low grassy areas in places bound the sand ridges. This is a zone of old abandoned tidal flats together with flood-out deposits from the streams which in flood times dump much of their load as they flow out onto the flatter coastal plains. Many of the smaller streams terminate in a small fan-shaped structure built out onto the tidal flats, and only the larger rivers cross the tidal zone to reach the sea. The drainage channels of the tidal flats are generally separate entities which are not related to termination points of the inland streams. Drainage over much of the flats is by sheet flow.

The beach ridges (Qm) lie subparallel to the coast. They consist of elongate areas of narrow sandy rises; swampy swales separated by broader expanses of tidal flats lie between them. Their form changes gradually inland from the present coastline; the ridges nearest the coast are generally composite, sharply defined, and composed of white shelly sand. The shell content decreases inland, and the ridges become less well defined and tend to be single rather than multiple. Some of these might better be referred to as Cheniers (Curray, 1969). The most landward ridges are a discontinuous line of single, low, broad, poorly defined ridges of pink quartz sand with no shell material. The decrease in shell material away from the coast could be a depositional feature or it could represent progressive removal of the shell material by rainwater solution. This latter suggestion would also explain the reduced relief of the older inland ridges. Some of the inland ridges are curved and abut embayments associated with the streams of the Doomadgee

Plain. (Figs. 6 & 7). The inland ridges could represent the coastline at the time of the highest level of the Holocene sea, though they might date back to an earlier sea level.

*Carbon 14 age determinations for the ridges at Edward River Mission, on the west coast of Cape York Peninsula, can probably be applied to the ridges in the area described in this report (see Table 2). These dates indicate a progressive ageing of the ridges from the coast inland; the oldest shelly ridge is 3935 years BP, and the oldest date obtained from beach ridges so far is 5630 BP ± 120 years BP from north of Snake Creek in GALBRAITH. Ridges farther inland with no shelly material may also be Holocene in age, but because they are separated from the main belt of ridges, from which they can be distinguished by their more degraded appearance, they might date from an earlier, late Pleistocene, sea level (Doutch, pers.comm.).

TABLE 2. C^{14} AGES FOR YOUNGER BEACH RIDGES AT EDWARD RIVER MISSION

Location (distance from present coast)	BMR sample number	University of Sydney Radiocarbon Lab. no.	Age (years B.P.)
200 m	72796244	SUA 198 A	750 ± 70
"	72796244	SUA 198 B	980 ± 75
600 m	72796245	SUA 199	995 ± 75
1000 m	72796246	SUA 200	3935 ± 85

The Holocene (or Flandrian) transgression is generally thought to have reached its highest point about 6000 years ago (e.g. Fairbridge, 1961; Shepard, 1963, p. 267). However, there is disagreement as to the amount of fall (if any) since that time. If, as suggested by Shepard (op. cit.) and others, the sea level has remained stationary since the Flandrian transgression, then the beach ridges of the Karumba Plain must be due to progradation. As neither the younger ridges nor the wave-cut platforms in the report area appear to be affected by tectonism the platforms suggest a sea level drop has occurred since they were formed. Other authors consider that there has been a recent drop o several metres (e.g. Fairbridge, op. cit.). Twidale (1966) quotes a 20-ft (6-m) difference in height between his oldest and youngest ridges in the Karumba Plain and attributes this to a 6-m fall in sea level. Ingram (1973), however, could see 'very little difference in height

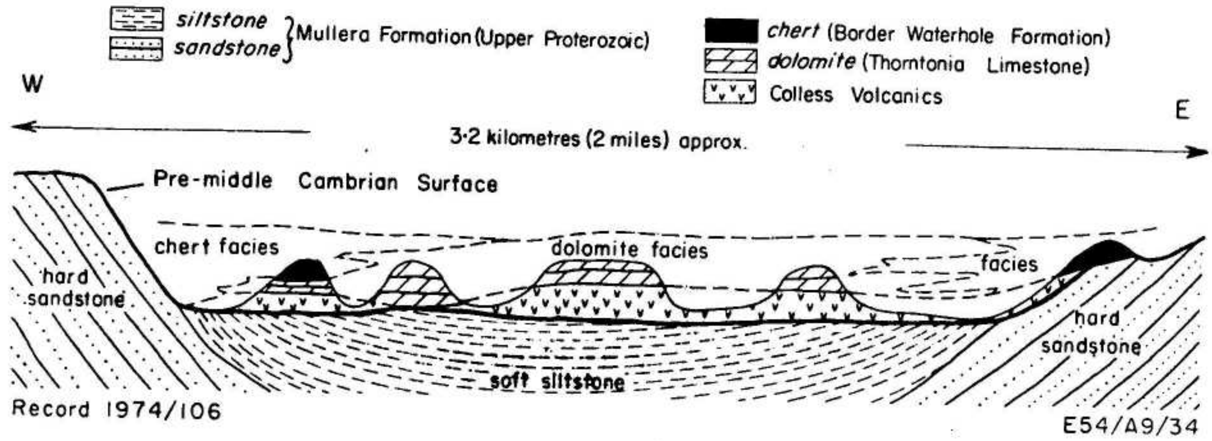

Fig.8 Early Cambrian Surface exhumed as the valley of the Babbling Brooke Hills area, 19km west southwest of Lawn Hill homestead. After de Keyser & Cook (1972, fig 33)

above mean sea level of the nearest and farthest ridges from the coast' in BURKETOWN. He was able to recognize nickpoints in the Leichhardt and Flinders Rivers, however, which he attributed to a drop in sealevel (Ingram, 1972). Beach ridges near Cape Keer Weer, south of Weipa, were levelled for BMR in 1973, and samples were collected from the younger ridges for future C^{14} dating. The levelling showed that the younger ridges are higher above sea level than the older ones.

In some places the beach ridges have been modified by recent wind action to form small crescentic dunes, some of which are still active. These are best developed on the southeastern side of Mornington Island. The dunes have been shown separately (as Qhd) on the geological maps. They are composed of medium to coarse shelly or quartzose sand.

GEOMORPHIC HISTORY: PREVIOUS LAND SURFACES

The area has undergone a sequence of erosional and depositional events since Precambrian times. In the upland areas present erosion is eating into remnants of a Tertiary lateritized plateau (the Mid-Tertiary Surface) and exhuming parts of a buried Mesozoic Surface. It has also exposed relicts of an Early Cambrian Surface. Summit concordances can be used to trace the levels of the old surfaces in some places. The surfaces are best preserved in western LAWN HILL.

The oldest surface in the area is the Early Cambrian Surface, recognized by de Keyser (1969) in southwestern LAWN HILL. This is present in the valley between Riversleigh and Lawn Hill Creek (mapped as an extension of the Cloncurry Plain in Fig. 1); and also in the Babbling Brooke Hills area, 19 km west-southwest of Lawn Hill, where isolated mesas of Middle Cambrian sediments lying in an old valley cut into relatively soft Precambrian siltstone are surrounded by higher hills of Precambrian sandstone (Fig. 8). The form of these two valleys shows that the surface at that time must have had a relief perhaps similar to that of the present Isa Highlands. These old valleys were probably formed by the same period of erosion that fashioned the unconformity surface beneath the Cambrian dolomites to the southwest.

The geomorphological history of the remainder of the Palaeozoic and of the Early Mesozoic in this area is uncertain. The cause of the dissection which preceded the deposition of the Late Mesozoic deposits may have been epeirogenic uplift in the early Mesozoic.

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The Early Mesozoic Surface was preserved as the unconformity beneath the Jurassic and Cretaceous sediments, which first filled the valleys and then extended over the interfluves as the area was flooded by a shallow sea that covered much of the area (see Mesozoic Geology). The surface is still preserved as the unconformity at the base of the Carpentaria Basin; however, Tertiary planation destroyed much of it in the Isa Highlands, where only parts of it are preserved beneath areas of late Mesozoic rocks. These relics of the surface are now being exhumed and destroyed by present erosion; they show that the Mesozoic surface was one of fairly strong relief and contained valleys and depressions bounded by steep slopes (Figs 9, 10). In some places the surface can be extrapolated by recognition of summit concordances, but care must be taken in such extrapolations as the Tertiary Surface is also reflected in summit concordances.

In several valleys in the Westmoreland area, long (several are over 1 km), narrow (25 to 50 m wide), winding, steep-walled outcrops of rock project 5 to 10 m above the valley floors; their dimensions have been estimated from aerial photographs. They have the winding and branching form one would expect in a stream channel, and they may owe their present preservation in positive relief to the cementation of more porous channel sands, and the subsequent preferential erosion of the less well cemented deposits on either side of the old channel. The best examples of these features are apparently about 15 km west of Westmoreland homestead (between 638815 and 650820: WESTMORELAND, yards grid); they have not been visited.

Locally, both the Early Mesozoic Surface and the Early Mesozoic Surface and the Early Cambrian Surface are lithologically controlled. The present erosional surface is similarly controlled. The Tertiary Surface, on the other hand, appears to have approached a planar geometry: erosion has truncated both hard and soft lithologies, and has left only minor irregularities in the relief. This surface is the result of a period of upland erosion which commenced in the Late Cretaceous and continued through the early Tertiary; the Floraville Formation was deposited contemporaneously on the Carpentaria Plains. The erosion culminated in planation and lateritization of both the erosional and depositional surfaces. Some residual, unlateritized hills may have remained in the Westmoreland area (Stewart, 196).

In the Isa Highlands the Tertiary Surface now remains as summit plateaux that commonly have siliceous or ferruginous duricrust cappings. Its original presence is also indicated by summit concordances in some areas of more recent dissection. Figure 11 shows a reconstruction of the form of the surface before the present dissection. The surface undulates gently and tends to be lower over the less resistant lithologies. Remnants of its old

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REFERENCE

H	Holocene erosional surface
H/M	Holocene surface overlying buried Early Mesozoic Surface.
T	Tertiary Surface
T+M	Tertiary Surface with some influence from the Early Mesozoic Surface
T/M	Tertiary surface over buried Early Mesozoic Surface
M	Exhumed Early Mesozoic Surface
Ms	Summit concordance reflecting the Early Mesozoic Surface
....	Relict drainage channels on the Tertiary surface
⟶	Present streams

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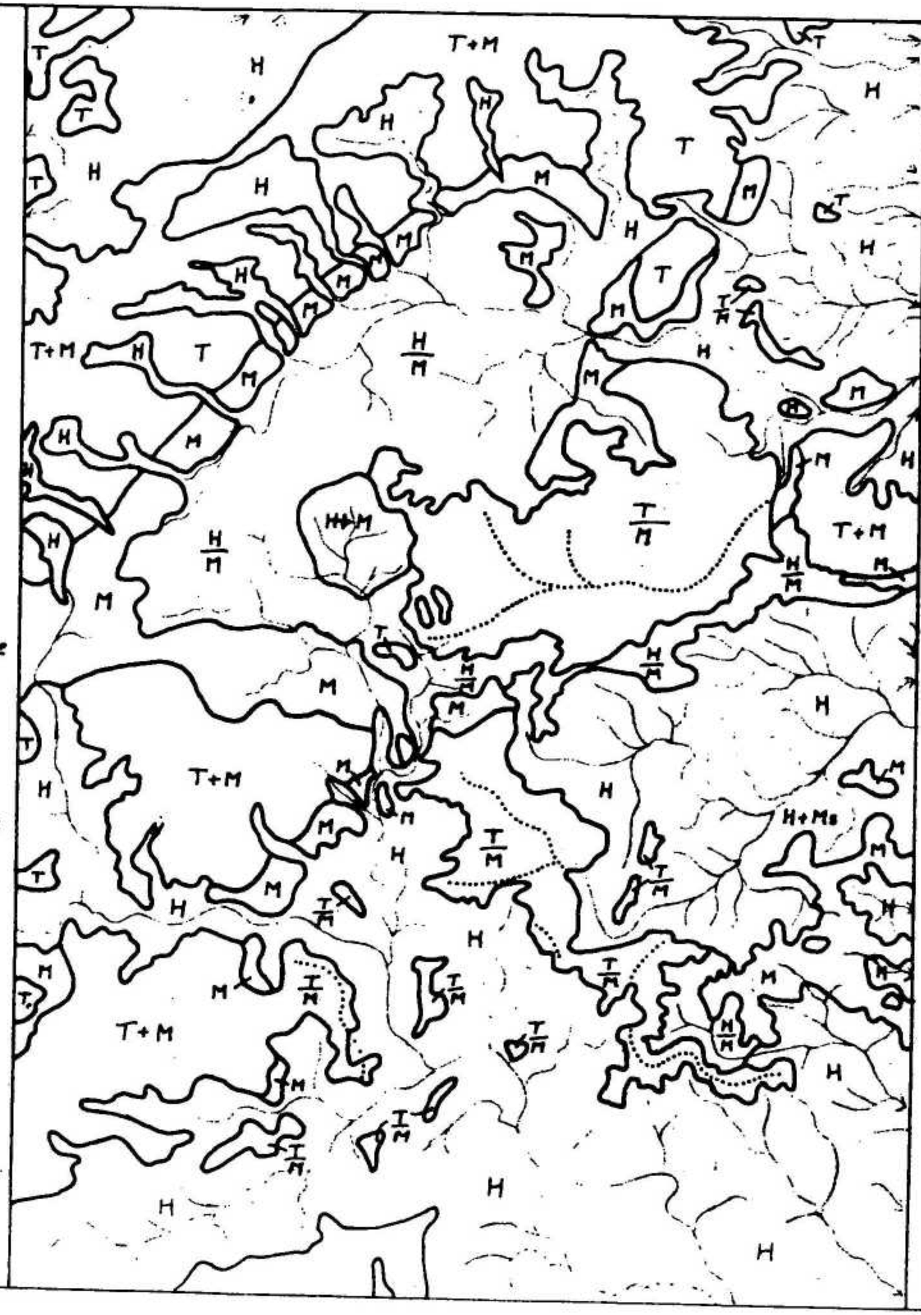

FIG 9

interpretation map for Fig.10

RELICT LAND SURFACES

IN THE ISA HIGHLANDS

West of Stockyard Camp

LAWN HILL Sheet area

km

0 1 2 3 4

0 1 2

miles

N

LAWN HILL SHEET AREA

Figs 9 & 10

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Fig. 10 Stereotriplet showing relicts of the Early Mesozoic and Tertiary Surfaces in western Lawn Hill. See Fig. 9 for interpretation. (LAWN HILL, CAB 4012, Run 4, Photos 2284, 6, & 8)

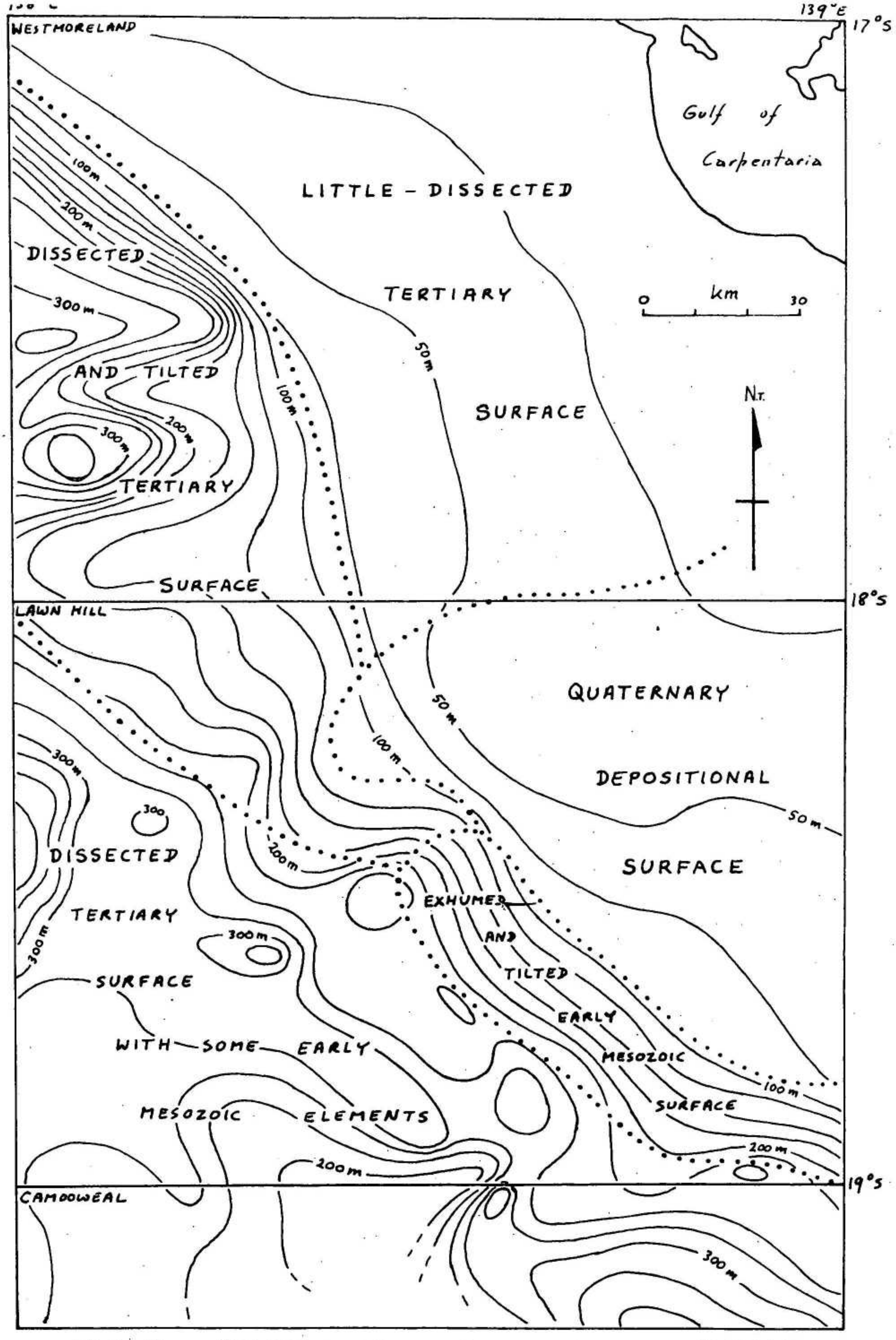

FIG II GENERAL TREND OF THE TERTIARY SURFACE

Derived from summit spot heights which are presumed to represent a gipfelflur derived from the Tertiary Surface as it appeared before the Quaternary dissection of the highlands. The contours on the Carpentaria Plains are derived from gravity survey spot heights.

drainage system are still preserved on some of the plateaux (Fig. 10), and some of the streams of the present landscape appear to be inherited from the Tertiary surface and are superimposed on the Precambrian structure (e.g. Musselbrook Creek - see Physiography).

In dissected areas where both are now exposed, the Tertiary Surface can be distinguished from the Early Mesozoic Surface, which has greater relief and underlies scattered relic late Mesozoic deposits. There is commonly a break in slope where the Early Mesozoic Surface slopes and valley sides are truncated by the Tertiary Surface (e.g., the valley sides marked 'M' in the northwest of Figs 9 and 10).

The present form of the Doomadgee Plain probably reflects the nature of the Tertiary Surface in that area. Because of its low-lying position and lack of major uplift, the plain has escaped major dissection, and the main agent of degradation may have been the lateritic process (as described in Trendall, 1962), which could still be operating in parts of the area as both the climate and the absence of rapid erosion would favour lateritization. The surface of the Doomadgee Plain could, therefore, be considered as a younger laterite surface overprinted on the older Tertiary Surface.

The Mornington Plateau has been subjected to rather more erosion as a result of gentle upwarping. The Tertiary Surface is, therefore, not as well preserved in that area.

The Undissected Barkly Tableland within this report area is probably dominantly the Tertiary surface of planation. There is a black-soil cover, and there is no laterite, however, and it may have been an area of slow deposition, or swamps, during the lateritic period. Opik et al., (1973) consider that the tableland existed before the Cretaceous, apparently because relic Cretaceous deposits are present in stream beds in the dissected areas. These would indicate only the presence of a nearby Mesozoic surface, which must have been of higher relief than the present Tableland. It seems that here, as in the Isa Highlands, the Early Mesozoic Surface has been largely truncated by the Tertiary surface.

The age of the main lateritized surface could be Mid-Tertiary as it appears to correlate with the Tennant Creek Surface (Hays, 1967), which is the main laterite surface in the Northern Territory. However, lateritized surfaces in northern Australia should be correlated with caution, as climatic conditions appear to have been favourable to lateritization throughout much of the Cainozoic. The lateritic surface in northwest Queensland postdates the

Cretaceous or early Tertiary Floraville Formation, and antedates the upwarping which led to the erosion of the surface in the uplands, and the deposition of the Pleistocene Armraynald Beds. This upwarping may have been Pliocene in age (see Structural Geology). This limits the age of the main laterite surface to the Mid-Tertiary, or possibly early Tertiary if the Floraville Formation is restricted to the Late Cretaceous. If, as suggested by Whitehouse (1940), the Carl Creek Limestone (late Oligocene to early Miocene) is lying on a laterite horizon which correlates with the main laterite surface, then the age of the laterite must be older than late Oligocene. However, correlation of Whitehouse's weathered horizon with the main laterite is uncertain.

The present Surface is that which has been formed by the dissection of the older surfaces (after the upwarping of the Isa Highlands in the Pliocene) together with concurrent deposition in the Carpentaria Plain. Quaternary erosion and deposition is responsible for most of the present topography (see Physiography). More than one phase of erosion may be responsible for this surface. A slight rejuvenation of the coastal streams is possibly due to a Holocene drop in sea level; these streams are now entrenched into parts of the Doomadgee Plain, and into the late Pleistocene surface on the Armraynald Plain.

TABLE 3 - SUMMARY OF MESOZOIC STRATIGRAPHY

AGE	Palynological units	FORMATION	LITHOLOGY	THICKNESS	ENVIRONMENT	NOMENCLATURE REFERENCES			
EARLY CRETACEOUS: late Albian to early Cenomanian?	K2c–K3?	ROLLING DOWNS GROUP: Normanton Formation (Kln)	Labile sandstone, siltstone, mudstone, and minor limestone	Up to 300 m	Paralic and shallow marine	Laing & Power (1959), Smart et al.,(1971)	CONFORMABLE SEQUENCE Transgressive Regressive Continuous with Eromanga Basin	Time equivalent of Winton Formation in Eromanga Basin	
Late Albian	K2b–c	Wilgunya Subgroup: Allaru Mudstone (Kla)	Mudstone, siltstone; minor labile sandstone and limestone	160 - 330 m	Shallow marine	Vine & Day (1964) Vine et al.,(1967) Smart et al.,(1971)		Upper part is time equivalent of Mackunda Formation in Eromanga Basin	
Late Albian	K2a	Toolebuc Limestone (Klo)	Calcareous bituminous shale; thin limestone beds	10 - 22 m	Shallow marine (biostromal banks, restricted circulation?)	Casey (1959) Vine et al.,(1967) Smart (1972)			Oil Shale (Swarbrick 1974), Limestone
Aptian to early Albian	K1b–d & K2a	Wallumbilla Formation (Klu)	Mudstone; minor siltstone, labile and glauconitic sandstone, and limestone	120 - 210 m	Shallow marine	Vine et al.,(1967) Smart et al.,(1972)			Minor aquifers
LATE JURASSIC? TO EARLY CRETACEOUS (lower Aptian)		Gilbert River Formation (JKg)	Quartzose sandstone; minor conglomerate, siltstone, and shale	0 - 67 m	Fluvial and shallow marine	Laing & Power (1959) Smart et al.,(1971)		Overlapped by Wallumbilla Formation Equivalent of Hooray Sandstone in Eromanga Basin	Main artesian aquifer
JURASSIC?		Eulo Queen Group equivalents?	Sandstone, siltstone, and minor shale	less than 100 m	Fluvial	Smart et al.,(1971)		Overlapped by Gilbert River Formation. May be present below eastern margin of the report area. May be equivalent to Eulo Queen Group in eastern Carpentaria Basin	Artesian aquifer
LATE JURASSIC TO EARLY CRETACEOUS (Albian?)		Mulleman Beds (Kl)	Quartzose sandstone, claystone, siltstone, and minor conglomerate	0 - 50 m	Fluvial and shallow marine	Noakes (1949) Skwarko (1965)	Transgressive and regressive. Lateral equivalent of Gilbert River Formation and Wilgunya Subgroup		

MESOZOIC STRATIGRAPHY

The Mesozoic stratigraphy of the area is summarized in Table 3.

Deposition in the Carpentaria Basin commenced in Late Jurassic times with continental sandstones, and continued with marine mudstones and labile Sandstones until late Albian or possibly Cenomanian times. The marine beds were initially transgressive and there was an overlap relation between younger and older units. Regression probably commenced in Albian times, during the deposition of the Allaru Mudstone (Burger, 1973), and the sea had withdrawn completely after the Normanton Formation had been deposited towards the end of the Albian or perhaps in the early Cenomanian. The sequence of events is illustrated by Figure 24 (A-D).

The Mullaman Beds represent a thinner sequence which is equivalent in time to part of the basinal succession. They range from Late Jurassic to Albian? in the Northern Territory, but are not as readily divisible into formations as is the basinal succession.

The Carpentaria Basin is in the report area, in which defined here as the thick basinal sequence of Mesozoic Sediments Subsidence continued during deposition, thereby allowing a considerable thickness of sediment to accumulate (up to 800 m on Mornington Island). This sequence is contrasted with the thinner (generally less than 50 m) flat-lying Mullaman Beds on the presumably stable area to the west, and in much of the northern portion of the Northern Territory (Skwarko, 1966, fig. 3). This was referred to as the 'Northern Territory Shelf' by Brown et al., (1968).

The present margin of the basinal deposits is concealed beneath Cainozoic deposits but is thought to lie only a short distance to the east of the edge of the Precambrian outcrops (Fig. 12), that is, it approximates the eastern margin of the Cloncurry Plain (Fig. 1). The mesas of the shelf deposits are restricted to the westernmost part of the report area (Fig. 12) and are separated from the Carpentaria Basin subcrop margin by a zone 10 to 50 km wide in which there are no Mesozoic outcrops. This zone appears to have been a high area in Gilbert River Formation times as the Gilbert River sandstone pinches out within the basin to the east and is overlapped by the Wallumbilla Formation mudstone (Fig. 12 and cf. Figs. 24 A, B, C), and sandstones, presumably equivalent to the Gilbert River Formation, are present farther to the west at the base of the Mullaman Beds. It is not known if this belt of high land was covered completely by the later Wallumbilla sea. However, it appears to mark the boundary between the Carpentaria Basin and the 'shelf' area of the Northern Territory.

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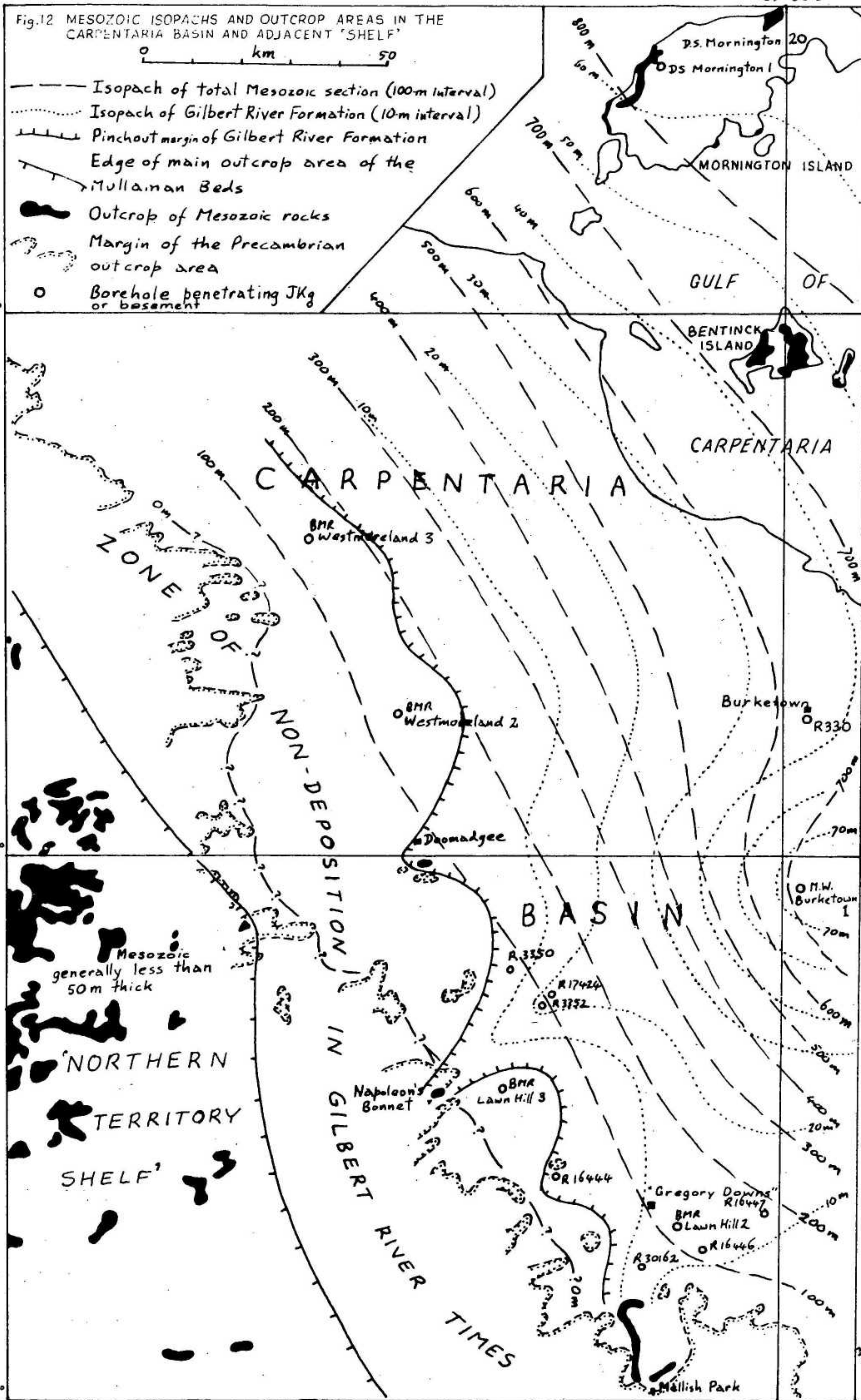
Fig.12 MESOZOIC ISOPACHS AND OUTCROP AREAS IN THE CARPENTARIA BASIN AND ADJACENT 'SHELF'
0 km 50
Isopach of total Mesozoic section (100-m interval)
Isopach of Gilbert River Formation (10-m interval)
Pinchout margin of Gilbert River Formation
Edge of main outcrop area of the Mullaman Beds
Outcrop of Mesozoic rocks
Margin of the Precambrian outcrop area
Borehole penetrating JKg or basement
17° S
18° S
19° S
D.S. Mornington 2
DS Mornington 1
MORNINGTON ISLAND
GULF OF CARPENTARIA
BENTINCK ISLAND
CARPENTARIA BASIN
ZONE OF NON-DEPOSITION IN GILBERT RIVER TIMES
BMR Westmoreland 3
BMR Westmoreland 2
Doomadgee
Burketown
R330
M.W. Burketown 1
R3350
R17424
R3352
Mesozoic generally less than 50 m thick
'NORTHERN TERRITORY SHELF'
Napoleon's Bonnet
BMR Lawn Hill 3
R16444
"Gregory Downs"
R16447
BMR Lawn Hill 2
R16446
R30162
Mellish Park
800 m
700 m
600 m
500 m
400 m
300 m
200 m
100 m
0 m
60 m
50 m
40 m
30 m
20 m
10 m
70 m

33

E54/A/20

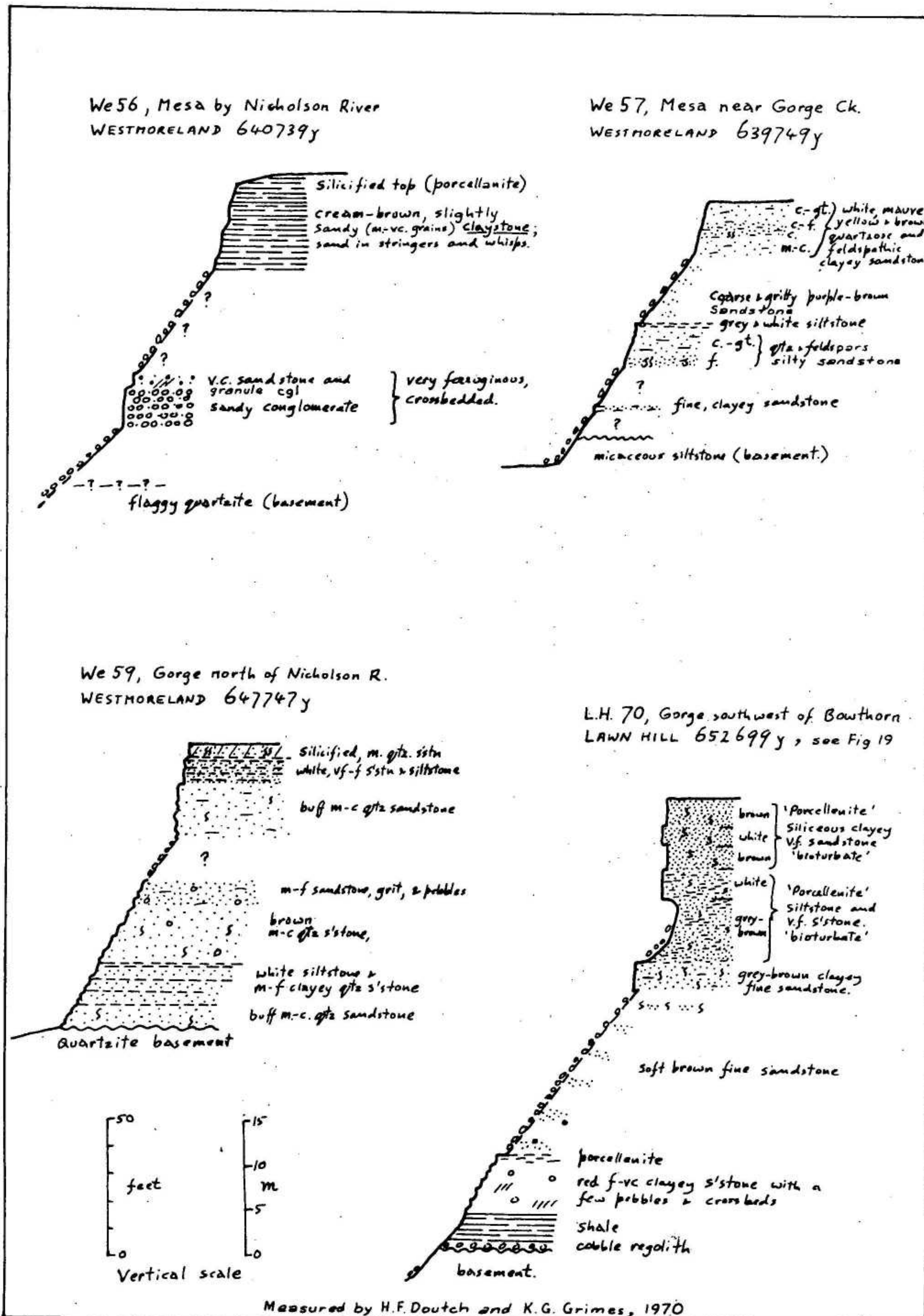

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FIG. 13 MEASURED SECTIONS IN THE MULLAMAN BEDS

MULLAMAN BEDS (Kl)

This unit crops out extensively in the Northern Territory, and it has been described in detail by Skwarko (1966). The outcrops in Queensland are an easterly continuation of them (Fig. 12). The Lees Sandstone and the Polland Waterhole Shale, which are present farther south in CAMOOWEAL and MT ISA (Öpik et al., 1961, 1973), are probably also equivalent to the Mullaman Beds as they have similar lithologies, ages, and stratigraphic settings.

The Mullaman Beds, preserved as isolated or clustered mesas, unconformably overlie the Precambrian rocks of the western part of the report area (Fig. 12). They mainly represent a part of the 'Inland Belt' of Skwarko (op. cit.). The sequence generally consists of sandstone beds in the lower parts, and an overlying siltstone and claystone unit. Either or both can be present in any given outcrop (see Fig. 13).

The sandstones are generally buff or white, in places purple or dark brown (ferruginized), clean or slightly clayey, mostly medium-grained, but variable from very fine to very coarse and granular. They are pebbly in places and contain a few conglomerate beds, and some interbedded brown or white siltstone and claystone. They are massive or cross-bedded. The sandstone grades upwards through very fine-grained sandstone and siltstone into the claystone. Plant fragments in some beds indicate a Late Jurassic to Early Cretaceous age (Carter & Öpik, 1961). At the northernmost outcrop of the unit in WESTMORELAND the marine? trace fossils Rhizocorallium and Gyrochorte are present in the sandstones, and these may, therefore, be in Skwarko's 'Coastal Belt' (which he considers to be marine throughout).

The siltstone and claystone unit is generally massive, pale brown, cream, white, and mauve; it is silicified (porcellanitic) and has thin streaks, wisps, and blebs of sand grains. There appears to have been some bioturbation in places. Carter & Opik (1961) report marine pelecypods in a siltstone from this unit; they indicate a Late Jurassic to Early Cretaceous age.

The mesa outcrops differ in thickness owing to variations in the basal unconformity. The maximum thickness measured was 50 m at LH 70 southwest of Bowthorn homestead, LAWNHILL 652699 y (Fig. 13).

The oldest sandy sediments of the Mullaman Beds were deposited in freshwater streams and possibly lakes. Some of the later sands were marine. The overlying claystones are wholly marine and represent a broad transgression of the late Aptian and Albian seas, which spread beyond the confines of the subsiding Carpentaria Basin and flooded over a broad 'shelf' area of northwestern Queensland and the Northern Territory. The extent of this sea has been described by Skwarko (op. cit., fig. 10).

The Mullaman Beds lie unconformably on the Precambrian and early Palaeozoic rocks of the Mt Isa Block and the Macarthur, South Nicholson, and Georgina Basins. The upper surface of the formation has probably been eroded away, and the youngest beds have been modified by deep weathering beneath a Tertiary land surface. This Tertiary land surface is generally flat and truncates not only Mesozoic rocks, but also adjacent basement hills.

Skwarko's (op. cit.) work in the Northern Territory gives an indication of the age of the beds in this report area, where they are continuous with his Inland Belt. He (p. 32) referred to a prolific flora that was described by Brunnschweiler (in Traves, 1955) and White (1961, unpubl.) from the Northern Territory outcrops of the 'Inland Belt'. The species are generally long-ranging and the flora cannot be dated closer than late Mesozoic. However, Skwarko (p. 32-33) presented some evidence that sedimentation may not have commenced before Neocomian times in the Northern Territory. He also (p. 34) lists Foraminifera from 'unit C' of his 'Inland Belt', which is the equivalent of the upper claystone unit in this report area. The forms listed come from several localities and include Verneuilina howchini and Textularia anacooraensis of lower Albian and lower Aptian ages respectively (Haig, pers. comm.). The age of the claystone in this report area could therefore be from Aptian to lower Albian (Albian or older - Belford, pers. comm.).

Beds containing macrofossils in Skwarko's Coastal Belt and range from late Neocomian to Albian, and overlie a basal non-fossiliferous terrestrial unit (his 'Unit 1'), which he thinks may be mid-Neocomian. Units from his Coastal Belt might be present in the central-western parts of WESTMORELAND, but they were not definitely recognized during the reconnaissance mapping.

The Mullaman Beds in the report area are, therefore, equivalent in time to the upper part, at least, of the Gilbert River Formation, and to most, if not the whole, of the Wilgunya subgroup (as used in Vine et al., 1967).

GILBERT RIVER FORMATION (JKg)

This formation is recognized as the basal unit of the Mesozoic basinal succession in this area, though Ingram's (1972) 'Unit M' (Eulo Queen Group equivalents) of the Burketown Depression may extend a short distance into the area in the east. The Gilbert River Formation crops out poorly as it is generally overlapped by the Wallumbilla Formation. The only outcrops are a line of low scarps near Mellish Park, south of Gregory Downs; Napoleon's Bonnet, a mesa 30 km ENE of Lawn Hill; and two low rubbly rises south of Doomadgee Mission; all are on LAWN HILL (see Fig. 12).

The formation was intercepted by the petroleum exploration wells Burketown 1 and Mornington 1 and 2, and has been tapped by several water bores. BMR shallow stratigraphic holes which reached basement near the basin margin did not intercept the Gilbert River Formation: in BMR Westmoreland 1 and 2, mudstones of the Wallumbilla Formation lie directly on basement; and in BMR Lawn Hill 3, there is only a thin basal succession of 17 m of interbedded mudstone and grey muddy fine-grained glauconitic sandstone, which Gibson et al., (1973) placed in the lower part of the Wallumbilla Formation. Other BMR holes in the area terminated in younger sediments.

At the Mellish Park outcrop there is a 15-m scarp of slightly clayey quartzose sandstone, which is dark brown to medium brown and cream, medium to coarse and fine-grained, massive, and generally bioturbated. The trace fossils Gyrochorte and Planolites occur, and a collection of pelecypod moulds were identified by R.W. Day (GSQ) as Fissilunula clarkei and Maccoyella sp. indet., which suggest an Aptian age for the sediments (see Appendix). The basal contact with the Precambrian rocks was not seen at the site visited.

At Napoleon's Bonnet an Australian Aquitaine Petroleum Company geologist reported a sequence consisting of 'a thin conglomeratic bed overlain by white sandstone. The conglomerate is of small to medium size quartzite pebbles cemented by a slightly ferruginous sandstone. The maximum thickness observed is three feet. The sandstone is hard to medium hard, and occurs in thick beds. In the southern part of the outcrop it contains locally very abundant plant debris and internal moulds of pelecypods. ... structurally the sandstone is nearly horizontal, with the exception of the southeastern margin of the plateau where it has been very clearly distorted' (B. Blangy, pers. comm. to R.R. Vine).

This outcrop is assigned to the Gilbert River Formation on the basis of its lithology, fossil content, and location on the margin of the Carpentaria Basin as here defined. The absence of the Gilbert River Formation from BMR Lawn Hill 3, about 15 km to the east, could be explained if it is assumed that the Napoleon's Bonnet outcrop is part of a narrow valley deposit and that Lawn Hill 3 was drilled over a basement hill where the sandstone is absent. This differs from the interpretation by Gibson et al.,(1973), who thought that

Lawn Hill was sited in a drowned valley, but who gave no explanation for the Napoleon's Bonnet outcrop. The present spatial relationship between the two areas could be due to both penecontemporaneous warping of the basin margin and the post-laterite warping postulated elsewhere in this report.

Eight kilometres south of Doomadgee Mission within an alluvial plain several small hillocks are covered with a rubble of light brown, pebbly, medium to fine quartz sandstone with minor clay shards and pebble bands. There is no in-situ outcrop but the rubble varies from massive to well-bedded (cross-beds?). This lithology is distinct from that in a nearby scarp which consists of poorly sorted and less-well consolidated sandy claystones of the Late Cretaceous or early Tertiary Floraville Formation. The hillocks were interpreted as Gilbert River Formation.

The Gilbert River Formation is recorded in the three petroleum wells as consisting of grey-brown to white and red-brown poorly sorted quartzose sandstone with interbedded grey shale and siltstone, and pebble and granule conglomerate. These lithologies were described in more detail in the well completion reports by Harrison et al., (1961), Perryman (1964), and Meyers (1969).

Meyers differed from the company geologists in his interpretation of the two Mornington Island wells. He included a sequence of glauconitic sandstones and shales in his marine member of the Gilbert River Formation. I prefer to follow Harrison et al., (op. cit.) in placing this sequence in the basal part of the Wallumbilla Formation (their 'Roma Formation'), as this is the interpretation which has been placed on such glauconitic shaley sandstones by BMR elsewhere in the basin (e.g., below 27 m in BMR Lawn Hill 3, Gibson et al., 1973; below 135 m in BMR Lawn Hill 2, Needham et al., 1971).

The top of the Gilbert River Formation is easily recognized in Burketown 1. However, Perryman (op. cit.), Meyers (op. cit.) and Ingram (1972) all differed in their interpretation of the base of the formation (see Fig. 14). Perryman thought that the lower part of the sequence was suggestive of a massive mudflow environment. Meyers, however, considered that this part of the sequence (below 704 m) was tilloidal in texture and could represent glacial deposits. He referred to them as pre-Jurassic undifferentiated, but commented that if they were glacial then their age would be either Permian or Precambrian. (The latter proposition is based on the assumption that the underlying dolomites in the well are Precambrian; however, it is tempting to correlate these with the Cambrian dolomites of the northern Georgina Basin;

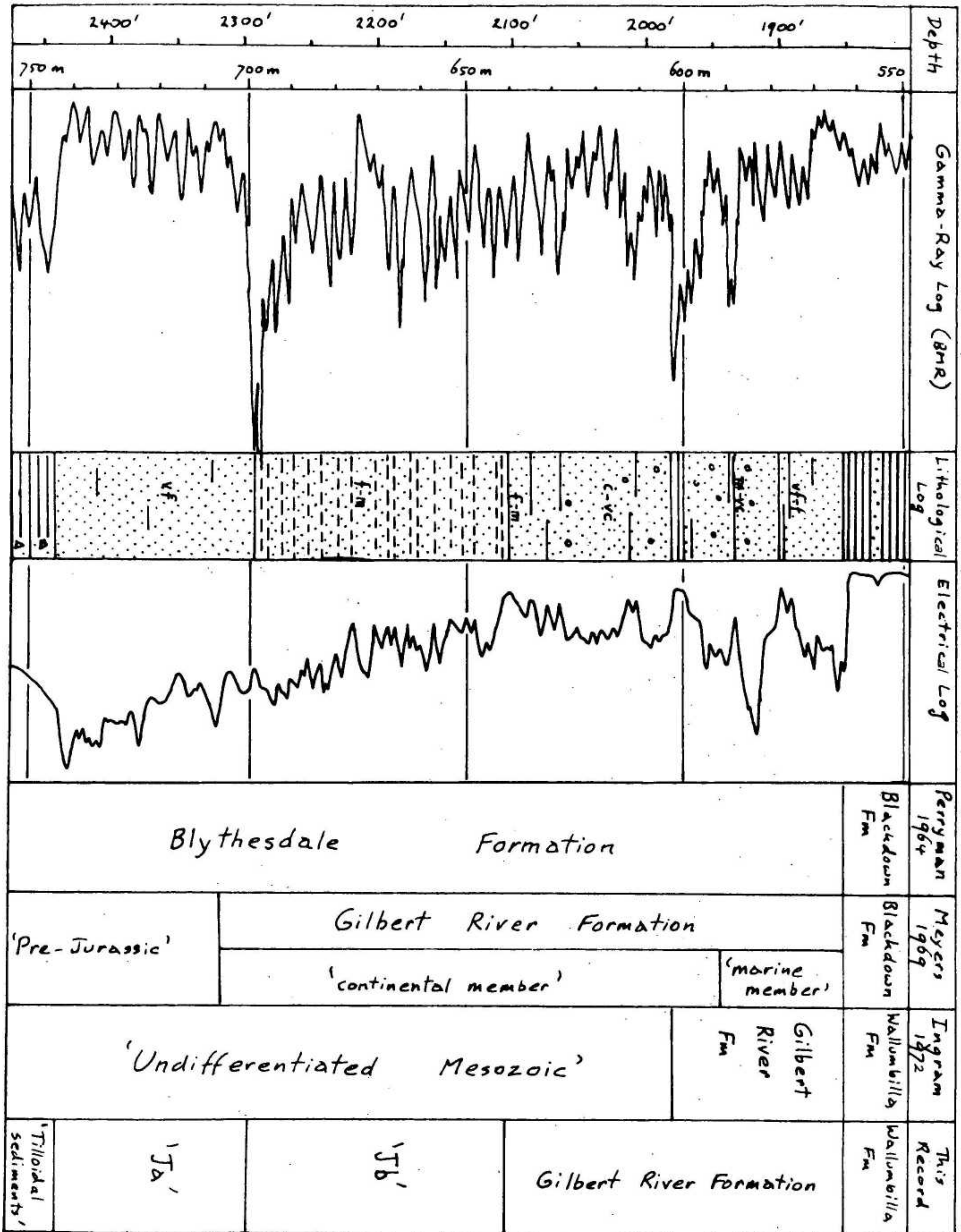

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FIG-14 SANDSTONE SEQUENCE IN MID-WOOD BURKETOWN 1

Note (1) The electric log has been adjusted to allow for a change in scale in the original log at 692 m.

(2) The gamma-ray log was run by BMR in 1972

thus the overlying tilloids, if glacial, would most likely be of Permian age. The Permian glacials nearest to the report area are those suspected from the southern Georgina Basin (Reynolds, 1968) and from the Hughenden area (Vine et al., 1964). Permian glacials are also known from the Galilee Basin.) Ingram (op. cit.) considered that at least part of what he called 'undifferentiated Mesozoic' sediments (see Fig. 14), are equivalent to the Jurassic Eulo Queen Group of Smart et al. (1971), which underlies the Gilbert River Formation on the eastern side of the basin.

In 1972 the BMR ran a gamma-ray log of Burketown 1. The part of the log covering the sandstone sequence is included in Figure 14.

In the first 8 m of the sandstone sequence the log shows a kick to the left (low radioactivity) but below this the log has intermediate to high activity for 130 m without any marked changes. However, at a depth of 700 m there is a sudden kick to the left and the activity remains low for 45 m before rising abruptly again.

The gamma-ray log, therefore, does not indicate the base of the Gilbert River Formation with any certainity and the lithological log is of more use in delineating the extent of the unit. Three lithological groups can be recognized on the lithological logs: a sandstone-shale-conglomerate unit between 563 and 640 m, a soft sandstone-siltstone unit between 640 and 700 m. and a very fine sandstone unit between 700 to 744 m. The last unit corresponds with the low anomaly in the gamma-ray log. These three units have been referred to as Gilbert River Formation, and 'Jb' and 'Ja' units in Figure 14. The Ja and Jb units may be time equivalents of the Eulo Queen Group of the eastern part of the Carpentaria Basin.

I have placed the top of the tilloidal sequence at 744 m as both electric and gamma-ray logs show marked changes at that depth.

The pinchout of the Gilbert River Formation at the basin margin owing to the overlap of the Wallumbilla Formation, and the reappearance of sandstone similar to that of the Gilbert River Formation in the basal Mullaman sequence farther west, suggests that there must have been a belt of high land between the two depositional areas (Fig. 12). This may have provided a source area feeding the fluvial valley and plain deposits on either side. The isolated Napoleon's Bonnet outcrop might represent a flooded valley deposit within this high area as the Gilbert River Formation is missing from Lawn Hill 3 to the east. The presence of trace and body fossils at Mellish Park indicates that the upper part of the sandstone sequence was marine. The Mellish Park outcrops are probably continuous with the Gilbert River Formation beneath the Basin.

The marine pelecypods collected from the Mellish Park area indicate an Early Cretaceous, probably Aptian, age (see Appendix). In the eastern part of the Basin the Gilbert River Formation is made up of probably Late Jurassic to Aptian rocks (Smart et al., 1971). The age of the formation in this western part of the basin is probably similar, though the Jurassic rocks would be restricted to the thicker parts of the sequence in the Burketown-Mornington area.

ROLLING DOWNS GROUP (Klr)

In the Carpentaria Basin the Rolling Downs Group comprises the Wallumbilla Formation, the Toolebuc Limestone, the Allaru Mudstone, and the Normanton Formation. The first three together make up the Wilgunya Subgroup (Vine et al., 1967). The sequence is conformable throughout.

The Wilgunya Subgroup does not crop out within the area of this report, but it is present beneath a thin Cainozoic cover. A few small outcrops are known near the basin margin in DONORS HILL and DOBBYN (Ingram, 1972; Smart, 1973).

Wallumbilla Formation (Klu)

The Wallumbilla Formation lithologies are known from subsurface information and from outcrop elsewhere in the Carpentaria Basin (Doutch et al., 1970). The formation consists of dark grey mudstone with minor beds of grey and grey-green glauconitic and labile fine to very fine sandstone and siltstone, and grey to brown cone-in-cone limestone. The glauconitic sandstone is most common towards the base of the formation and in places grades into the quartzose sandstone of the underlying Gilbert River Formation. In his interpretation of the Mornington Island wells, Meyers (1969) included these basal glauconitic sands in his Gilbert River Formation (see earlier discussion). The Wallumbilla Formation thickens towards the northeast and reaches 210 m in the Mornington Island wells.

The formation is of late Aptian and early Albian age (Vine et al., 1967; Doutch et al., 1970, 1972). Recent foraminiferal investigations of the Mornington Island wells and Burketown 1 by Haig (pers. comm.) substantiate this age for the Wallumbilla Formation in the Carpentaria Basin.

Toolebuc Limestone (Klo)

Drilling and gamma-ray logging of water bores has shown that the Toolebuc Limestone is present below the surface (Needham et al., 1972; Gibson et al., 1973; Harrison et al., 1961; Perryman, 1964). The term

Toolebuc Limestone has now superseded the earlier 'Kamileroi Limestone' used in the Carpentaria Basin (Smart, 1972).

It consists of a thin (1-2 m) bed of flaggy light grey finely crystalline flaggy limestone and interbedded mudstone which overlie a dark brown soft bituminous pyritic shale with thin seams of limestone. There are numerous shelly fossils, and fish scales, teeth, spines, and plates. The unit gives a strong gamma-ray anomaly in bore logs, and has been prospected in the Julia Creek area for its oil-shale potential (Swarbrick, 1974).

It appears to have formed in a shallow sea, the limestone lenses originating as biostromal banks (Williamson, 1967). The fauna is restricted in numbers of species, and this is thought to represent a limited connexion with the open sea (Swarbrick, op. cit.). The formation is of Albian age and lies just above the boundary between the Verneuilina howchini and Neobulimina australiana foraminiferal zones (Haig, pers. comm.), and just below the junction of the K2a and K2b-c palynological units (Burger, pers. comm.), which puts it at the beginning of late Albian times.

Allaru Mudstone (Kla)

The Allaru Mudstone has a similar lithology to the Wallumbilla Formation: dark grey pyritic mudstone with siltstone and minor very fine to fine glauconitic and labile sandstone. There are a few cone-in-cone limestone beds. The thickness of 160-330 m is only determinable from the three petroleum bores, in which there is some difficulty in interpreting the upper boundary of the unit, which is transitional into the sandier Normanton Formation. Burger (1973) considered that the upper part of the Allaru Mudstone in the Carpentaria Basin is equivalent in time to the Mackunda Formation of the central Eromanga Basin, and that the Allaru Mudstone represents a regressive period leading up to the non-marine phase of the lower Normanton Formation.

Normanton Formation (Kla)

This term was originally applied by Laing & Power (1959) to the whole of the Mesozoic sequence above the Toolebuc ('Kamileroi') Limestone. Meyers (1969) recognized that the unit could be divided into two members. Smart et al., (1971) showed that the lower member was equivalent to the Allaru Mudstone, and they restricted the term Normanton Formation to the upper sandy member.

The Normanton Formation crops out on the Wellesley Islands, mostly in sea cliffs and wave-cut platforms (Fig. 15), though some outcrops are present in stream beds within the plateau. It is also exposed on the mainland in the Donors Plateau to the east of this report area (Ingram, 1972, 1973). It should be present below the Cainozoic deposits in the northeastern corner of WESTMORELAND.

The formation has been deeply weathered in its surface exposures by a lateritic weathering episode which has in many places obliterated the original lithologies and structures. The outcrops on Mornington Island are described in detail by Wilson (in Warner, 1960b). Fresh outcrops are uncommon but when present consist of yellow-brown, green-brown, and pink siltstone, medium to fine, rarely coarse-grained labile sandstone, and minor mudstone. A cliff section on Mornington Island is shown in Figure 16. The bedding is thin to thick and commonly lenticular. The sandstone commonly has festoon cross-beds (Fig. 18), slump structures, clay clasts, and a few worm borings (Skolithos and Rhizocorallium). Local unconformities are present in association with large cut-and-fill structures. There are numerous small-scale folds and faults (Wilson, op. cit.).

The subsurface lithologies in the petroleum wells are similar to those in outcrop. The well sequences consist of up to 300 m of interbedded siltstone, sandstone, and mudstone, with minor limestone. The yellow colour of surface outcrop is a weathering effect, and the unweathered rock is generally grey, grey-green, or white in the petroleum bore logs. Glauconite is present in places.

Laing & Power (1959) considered the formation to be Albian. Recent work on the microfaunas and pollens of the petroleum exploration wells in the area support this conclusion (Haig, pers. comm.; Burger, 1973). Burger (1973, fig. 2) extends the uppermost part of the formation into the early Cenomanian.* The unit is a time equivalent of the Winton Formation of the northern Eromanga Basin (Burger, 1973), but the two units were probably never continuous at any time as the two basins had by then become separated by the regression of the sea from the Euroka Arch in Allaru Mudstone times.

Fig. 15 Outcrop of Normanton Formation at Lowaria Point, Mornington Island. Compare with Fig 16. (Neg No. GA 9292)

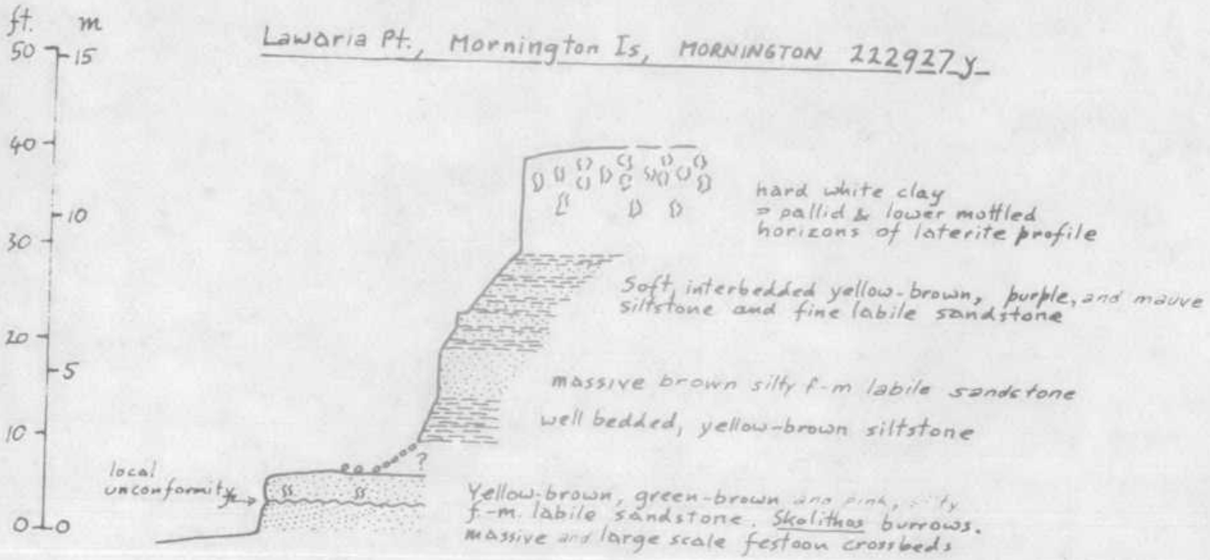

FIG. 16 MEASURED SECTION IN THE NORMANTON FORMATION

based on notes by the author and information from Wilson (in Warner 1960 b)

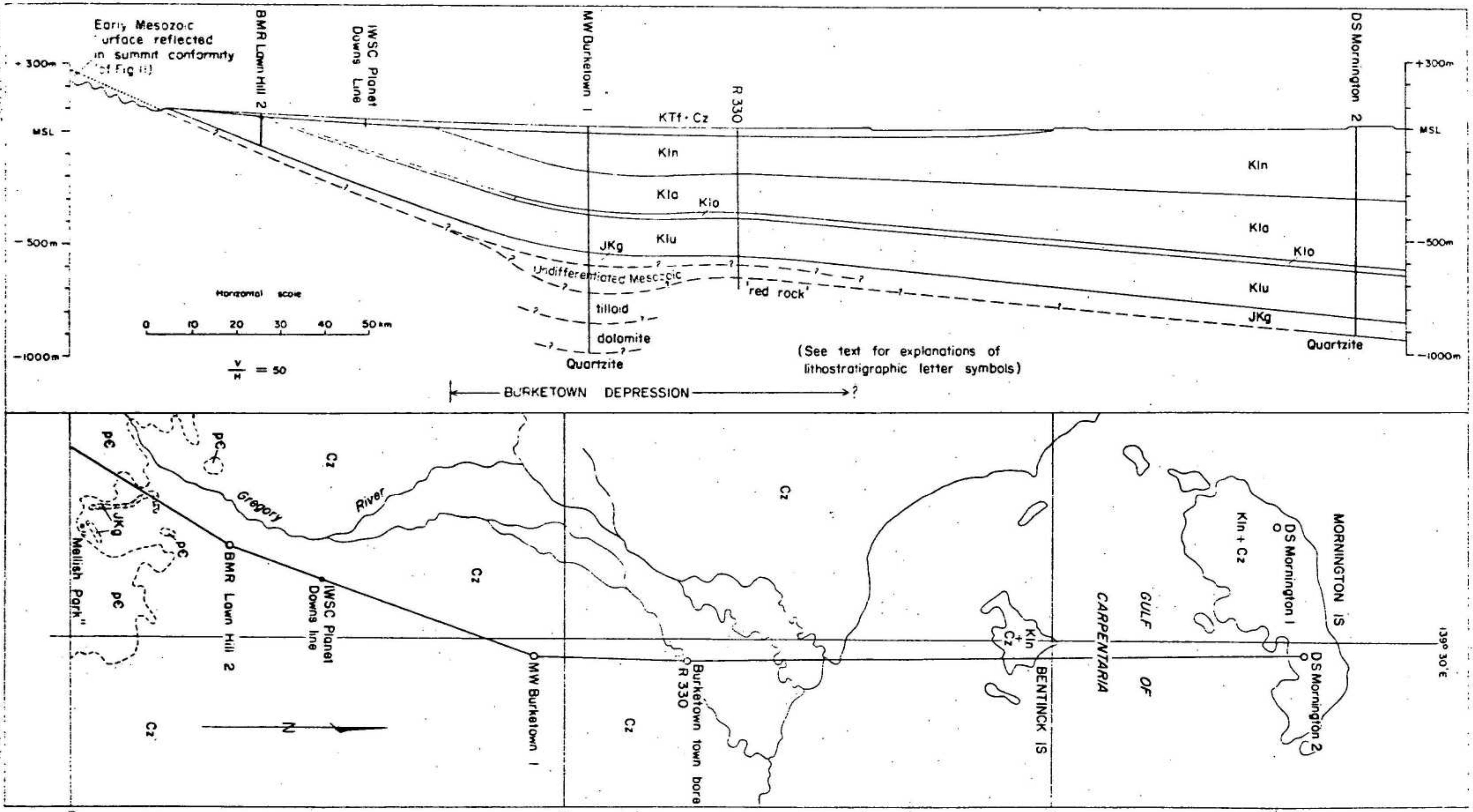

Fig 17 N–S Section of the Carpentaria Basin

Fig. 18 Cross-bedding in Normanton Formation north of Lowaria Point, Mornington Island, (Neg No. GA 9295)

Fig. 19 Mullaman Beds, gorge Southwest of Bowthorn, LAWN HILL. Grid reference 652699y. See Fig. 13. (Neg No. GA 9293)

TABLE 4 - SUMMARY OF CAINOZOIC STRATIGRAPHY

AGE		FORMATION	LITHOLOGY	THICKNESS	ENVIRONMENT	REFERENCES Nomenclature and earlier descriptions	DISTRIBUTION	ECONOMIC ASPECTS
QUATERNARY	Holocene	Qhp 'Qcp' on preliminary maps	Silt and clay, sandy in part, salt.	superficial <5 m?	Intertidal and estuarine flats.	Ingram (1973)	Tidal and seasonally flooded flats of the Karumba Plain	Salt deposits (up to 2 mm thick - Doutch et al., 1972)
QUATERNARY	Holocene	Qhd 'Qd' on preliminary maps	Calcareous and quartzose sand	<10 m	Aeolean dunes	-	Active dunes in the Karumba Plain	Possible ground-water in perched aquifers
QUATERNARY	Holocene	Qhe 'Qre' on preliminary maps	Sand, silt, and clay	superficial <5 m	Fluvial: point bars, levees, and oxbow lakes	-	Meander scrolls and point bar deposits where the Nicholson River flows onto the Karumba Plain	Possible groundwater
QUATERNARY	Holocene	Qha 'Qra' on preliminary maps	Sand, silt, and clay	•	Fluvial: stream channel	-	In and immediately adjacent to present stream channels	Groundwater
QUATERNARY		Qac	Sand, silt, and minor clay	<23 m	Littoral, paralic, and estuarine	Ingram (1973)	Karumba Plain	-
QUATERNARY		Qr	Shelly quartzose sand, calcarenite, coquina	<5 m?	Paralic, littoral	• •	Linear beach ridges of Karumba Plain	Limestone; possible perched aquifers
QUATERNARY		Qa	Silt, sand, or clay	5-10 m	Fluvial	Needham & Doutch (1973)	Alluvial valley flats and plains throughout the area	Isolated aquifers in channel sands
QUATERNARY		Qas	Quartzose sand	<5 m?	Fluvial: channel or levee	• •	Linear sand 'ridges' on the Doomadgee Plain	Possible perched aquifers
	Pleistocene to Holocene ?	Armraynald Beds, Qc	Clay, silty clay, sandy clay; minor sand and gravel	up to 25 m	Fluvial	Smart et al., (1972)	Armraynald Plain	Minor groundwater in isolated channel deposits
	Late Tertiary ? to Quaternary	Czs	Silty quartzose sand and minor gravel	<5 m?	Sheetwash, colluvial, or residual	-	Doomadgee and Cloncurry Plains	-
	Late Tertiary ? to Quaternary	Czc not shown on preliminary maps	Grey sandy silt and clay, chert gravel.	?	Residual, colluvial, and fluvial	Carter & Öpik Stewart (1954)	Undissected Barkly Tableland	-
TERTIARY	Middle to late Tertiary	Gregory Downs Limestone, Tr. 'Tc' on preliminary maps	Crystalline, micritic, and arenitic limestone; minor claystone; chert nodules and veins	up to 12 m	Lacustrine?	-	Gregory Downs area	Limestone
TERTIARY	Oligocene to Miocene	Carl Creek Limestone, Tc	Limestone; chert conglomerate	up to 43 m	Lacustrine	Whitehouse (1940) Tedford (1967)	Riversleigh area	Limestone
TERTIARY	Tertiary	Tf	Ferricreted sediments	1 m+	Deep weathering	-	Beneath Czs of Doomadgee and Cloncurry Plains, and on Wornington Plateau	Possible bauxite
TERTIARY	Late Cretaceous or early Tertiary	Floraville Formation, KTf	Clayey quartzose sandstone, claystone; minor conglomerate and siltstone	5-40 m	Fluvial	Smart et al., (1971)	Underlies most of the Carpentaria Plains in the report area	-

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CAINOZOIC GEOLOGY

The Cainozoic stratigraphy of the area is summarized in Table 4. The time relations of the units are shown in Fig. 20. The dating of the Cainozoic events is difficult as there is little paleontological control. A sequence of events is apparent from the geomorphological and stratigraphic relations, but the age of many of these events is based almost entirely on their relative position within this sequence. The main sequence is deposition of the Floraville Formation (late Cretaceous or early Tertiary); uplanation and the main deep-weathering period (early to mid-Tertiary); upwarping of the Isa Highlands (Pliocene?); and deposition of the Armraynald Beds (Pleistocene and Holocene?). The only accurately dated unit in the report area, the Carl Creek Limestone of late Oligocene to early Miocene age, is difficult to fit into the main sequence as its outcrop area is small and its stratigraphic relations with other units also unknown. Its possible correlate, the Gregory Downs Limestone, lies between the Floraville Formation and the Armraynald Beds. A vertebrate fauna from the Armraynald Beds may be of Pleistocene age.

The oldest Cainozoic unit in the report area is the Floraville Formation, which unconformably overlies the Mesozoic rocks. It was lateritized, along with the older rocks in Tertiary times. The Carl Creek Limestone, and possibly the Gregory Downs Limestone, represent isolated events in late Oligocene to early Miocene times, when calcareous waters, originating in the Cambrian dolomites to the south, deposited limestones in lakes and swamps associated with the ancestral Gregory River. The Armraynald Beds were later deposited in the flood plains of the Leichhardt and Gregory Rivers, and Lawn Hill Creek. There are a number of bodies of Late Cainozoic and Holocene sediments which have been recognized on the basis of lithology, geomorphology, and depositional locale.

FLORAVILLE FORMATION (KTf)

This unit was first mapped and defined in the DONORS HILL and DOBBYN areas (Smart et al., 1971; Doutch et al., 1970; Ingram, 1972), where it crops out in and adjacent to the Leichhardt River. It extends beneath much of the Carpentaria Plains in this report area, but owing to a widespread cover of younger sediments its outcrop is restricted to the Nicholson River and a small outlier on Mornington Island. It has been identified in all of the BMR scout holes drilled within the area (Needham et al., 1971; Gibson et al., 1973), and in recent borelines drilled by the Queensland Irrigation and Water Supply Commission (IWSC) (Cox, 1973). The subsurface information is listed in Table 5.

FIG. 20 AGE RELATIONSHIPS OF CAINOZOIC UNITS

Note the figure is diagrammatic and intended to indicate relative ages rather than absolute ages. The time divisions on the left are approximate only.

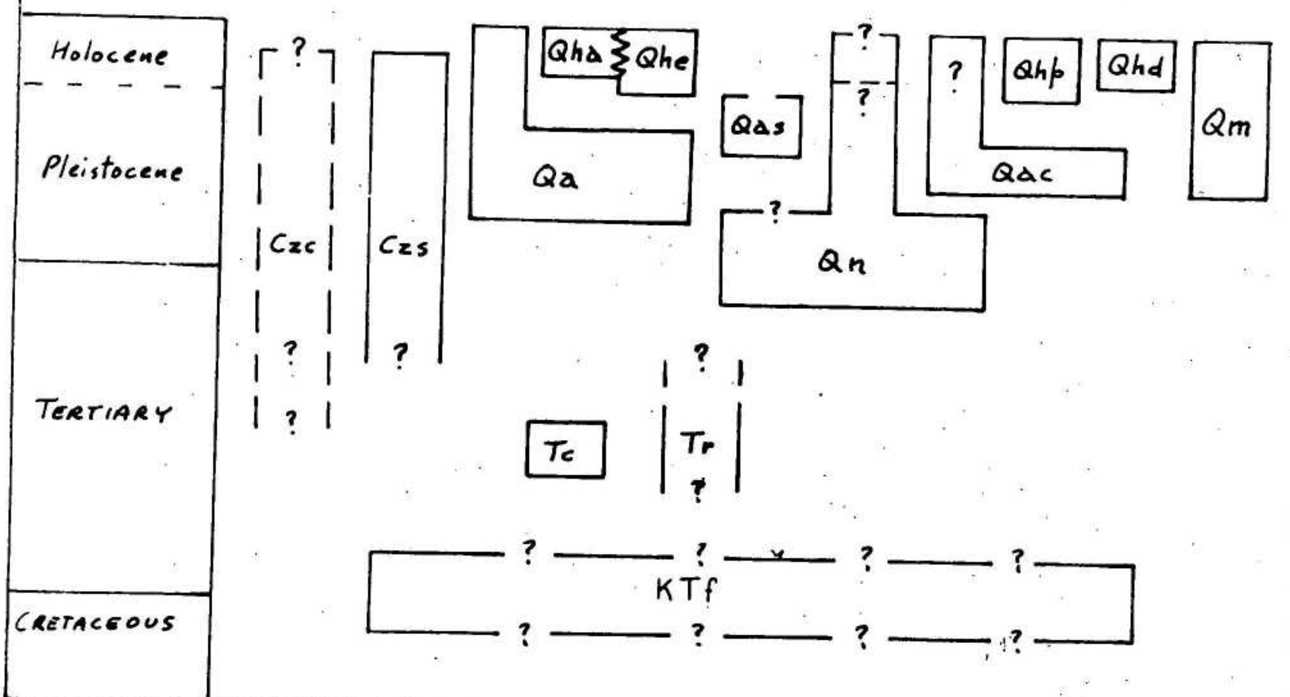

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Table 5

DETAILS OF LITHOLOGIES OF THE FLORAVILLE FORMATION IN BMR SCOUT HOLES AND IWSC BORELINES

(From data by Needham et al., (1971), Gibson et al., (1973), and Cox (1973))

Borehole (listed from north to south)	Thickness	Lithology
BMR Westmoreland 3	18 m	Pisolitic ironstone overlying gravel and mottled sandy claystone, and white silty clay; minor sand.
BMR Westmoreland 2	40 m	Brown, grey, cream, and pale green sandy claystone with beds of brown and red medium to very coarse sand and gravel.
BMR Westmoreland 1	25 m	Grey and white medium to very fine, slightly clayey sandstone and pale green mudstone; grades down into mottled red and grey sandy claystone with minor sand beds.
IWSC Beames Brook Line	29 m max., 18 m average	Grey, brown, and yellow sandy clay and clay, with beds of red and white ferruginous siltstone and of gravelly clay.
IWSC Punjaub Line	21 m max., 13 m average	Brown and grey calcareous sandy clay and clay, with some limestone nodules; minor beds of sand and ferruginous fine gravel.
BMR Lawn Hill 1	18 m	Mottled orange and grey clay and siltstone with minor fine sand; overlying brown medium to fine sand, clay, and gravel.
BMR Lawn Hill 3	11 m	Pebbly, fine sand and white sandy clay.
IWSC Planet Downs Line	35 m max., 24 m average	Red-brown and grey clay and silty clay, and pink sandstone and gravel. A bed of pink and grey limestone at the top may be Gregory Downs Limestone. White limestone at the base could be Mesozoic.

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Table 5 (contd)

Borehole (listed from north to south)	Thickness	Lithology
IWSC Gregory Downs Line	24 m max., 15 m average	Brown and grey silty and sandy claystone, and pink, red-brown, and grey sandstone. Beds of white limestone and a basal clayey conglomerate.
BMR Lawn Hill 2	18 m	White and mottled very fine to medium sandstone, and white clay.

The outcrops consist of white, grey, and brown, commonly mottled, medium to very coarse clayey quartzose sandstone with minor conglomerate and pale sandy mudstone. The sediments are generally not well sorted and are massive or poorly bedded. In the BMR stratigraphic holes the formation consists of mottled red-brown and grey sandy and silty claystone with minor sandstone and conglomerate (see Table 5). In water test bores along the Gregory River (Fig. 1) Cox (1973) recognized a unit of partly consolidated brown and grey calcareous sandy clay and clay with limestone nodules, and beds of sand, ferruginous gravel and ferruginous siltstone (see Table 5). He placed these in the Floraville Formation.

The unit has a maximum observed thickness of 39.5 m in BMR Westmoreland 2, but thins to 5 m in some places along the Gregory River. The average thickness is slightly less than 20 m. The formation is overlain by the Armraynald Beds in the south and east; and by a ferricrete zone (Tf) topped by a thin sand sheet (Czs) in the Doomadgee Plain to the north and west. It lies unconformably on weathered, in places mottled, mudstones of the Rolling Downs Group, and towards the western margin of the Carpentaria Basin it is unconformable on the Precambrian Rocks.

The localization of the Floraville Formation might be due either to renewal of subsidence controlled by structures of the Carpentaria Basin, or to the more rapid rate at which the relatively soft Cretaceous sediments of the basin were cut down to the new base level after the sea withdrew, while the relatively hard Precambrian rocks remained as high land. The only independent evidence for subsidence is the pre-laterite structures of Mornington Island (see Structural Geology).

The sediments were derived from the adjacent Precambrian rocks of the Mt Isa Block and the South Nicholson and MacArthur Basins, and the Mesozoic rocks overlying these areas, with perhaps a smaller contribution from the Palaeozoic rocks of the Georgina Basin. They were probably spread out by streams to form a broad floodout fan and alluvial plain, with swampy or lacustrine conditions in places.

A definite age cannot be put on the formation as no fossils have been found, though Dixon (1957) reports 'a few spores, probably lower Tertiary age' from an unspecified outcrop on Mornington Island. Smart et al., (1971) consider it to be possibly early Tertiary, though it could be as old as Late Cretaceous. It appears to be equivalent to the Bulimba Formation of the western side of Cape York Peninsula.

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DEEP-WEATHERING PROFILES (Tf)

These are of several types and ages, and are developed on a variety of rocks. They have been indicated on the geological maps in two ways. Where only a nodular ferricrete zone of a standard laterite profile (Hays, 1967) is exposed it is mapped as 'Tf'. Where the underlying mottled zone is exposed on its own through stripping of the overlying ferruginous zone, it is indicated on the maps as a stippled pattern superimposed on the symbol for the formation on which it is developed. The complete laterite profile is only exposed in a few river and sea-cliff sections (e.g., Fig. 21).

The most extensive area of deep weathering is that which underlies the Doomadgee Plain and parts of the Cloncurry Plain. A standard laterite profile (Hays, 1967) is developed on the Floraville Formation. A similar profile is present on Mornington Island, where it is developed mostly on the Normanton Formation. The sea cliffs of Mornington Island show the best exposures of the standard laterite profile (Figs. 21 & 22). It consists of a hard nodular ferricrete, about a metre thick, overlying a softer thin ferruginous zone, which grades down into a mottled zone up to 10 m thick. A pallid zone is also present in some places, but generally appears to lie below the present sea level. On the Doomadgee Plain the laterite profile is covered by a widespread, though thin, sand sheet (Czs); outcrops of ferricrete are restricted to breakaways and stream beds. The best exposures are near Doomadgee and along the Nicholson River to the west of the mission where the full profile is exposed in places.

In the southwestern part of the region the Mullaman Beds generally form flat-topped mesas, and there are also flat-topped hills of Precambrian rocks (see Physiography). These have been silicified and ferruginized by a deep-weathering process. These areas of deep weathering are not symbolized on the geological maps accompanying this report.

Several authors (e.g., Hays, 1967; Wyatt & Webb, 1970) consider that the laterites of northern Australia are of several ages but that there was a main lateritic event before or during the early Miocene (e.g., the Tennant Creek Surface of Hays, 1967). The laterite profiles developed on the Tertiary Surface of the Isa Highlands may be equivalent to the early or mid-Tertiary Tennant Creek Surface of Hays (op. cit.) as they postdate the Cretaceous or early Tertiary Floraville Formation, and antedate the Pliocene upwarping, which initiated the dissection of the Tertiary Surface.

Fig. 21 Part of a standard laterite profile in the sea cliffs near Gee Wee Point, Mornington Island. A hard ferricrete zone overlies a soft ferruginous zone, which in turn overlies a thick mottled zone. The pallid zone is below the surface here but is visible elsewhere on the island. (Neg. No. GA 9280).

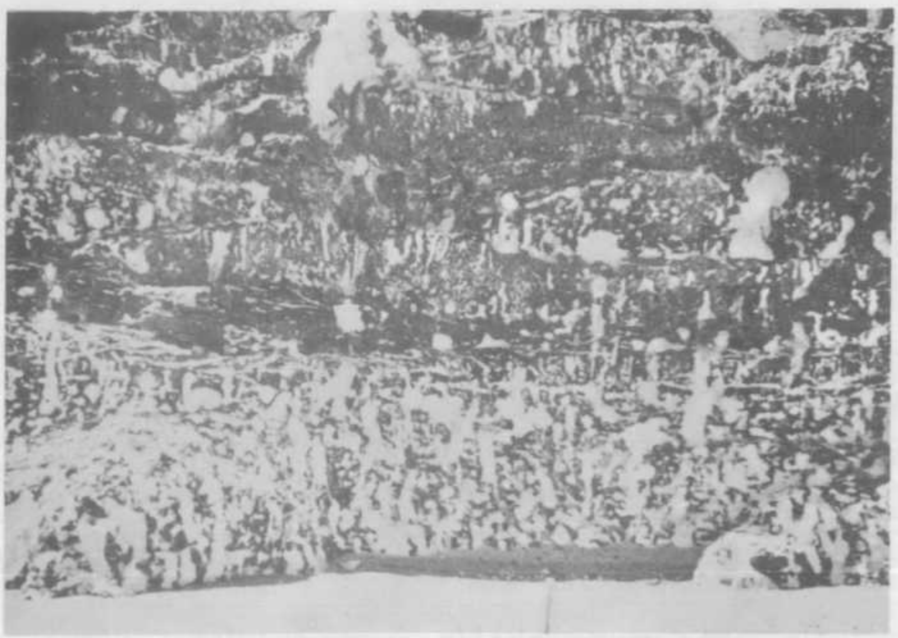

Fig. 22 A closer view of the Mottled zone of the laterite profile, same locality as Fig 21 (Neg. No. GA 9288)

The laterite profiles of the Mornington Plateau and the Doomadgee Plain were probably also initiated during this main lateritic period of the early to mid-Tertiary. However, the Doomadgee Plain has escaped dissection and has received only minor deposition since that time. It may, therefore, have been subjected to lateritization for a longer period if the climate was suitable. The ferricrete zone of the Doomadgee Plain appears to follow the local rise and fall of the gently undulating surface of the plain and outcrops in only the banks of recently incised streams. This close correspondence to the form of the present land surface suggests that this is a younger (Pleistocene) ferricrete, possibly 'overprinted' on to the main laterite profile.

CARL CREEK LIMESTONE (Tc)

This formation has been described by Whitehouse (1940) and Tedford (1967). It consists of a lower member of breccia comprising pebbles and boulders of chert and, rarely, quartzite in a sandy matrix with calcite cement, and an upper member of clastic limestone with much arenaceous material. Fossil vertebrates and freshwater gastropods occur in the upper member. White vuggy pellet limestone also occurs in some outcrops and appears to be a deeper-water facies (Tedford, op. cit.).

Tedford assigned a late Oligocene to early Miocene age to the fossils in these limestones. The deposits are thought to have formed in lakes by precipitation from lime-rich waters issuing from the Cambrian dolomites immediately to the southwest. The unit crops out for a short distance along the Gregory River near Riversleigh. In some outcrops it overlies a poorly developed, weathering zone which Whitehouse (op. cit.) equated with the main lateritic profile in the area. The degree of weathering does not appear sufficient to justify this correlation.

In the Gregory Downs area, 50 km to the northeast, there are similar limestone outcrops adjacent to the Gregory River. These have been named the Gregory Downs Limestone and are described below.

GREGORY DOWNS LIMESTONE (Tr, shown as Tc on the preliminary geological maps).

This new name is given here to the outcrops of limestone in the Gregory Downs area, LAWN HILL. The best outcrop, and type locality, is in the bed and banks of Macadam Creek where it is crossed by the track from Gregory Downs to Lawn Hill (191940y LAWN HILL). Other outcrops are scattered across the black-soil plains to the north and southwest of the type area.

The outcrop at Macadam Creek consists of up to 5 m of white massive or thick-bedded fine to coarsely crystalline limestone with a few small pale green clay shards (Fig. 23). There are a few thin beds of softer white calcareous claystone, and of pink calcarenite. The beds appear to be horizontal. The outcrop is overlain by about 3 m of black soil. Elsewhere in the area the limestones have been partly replaced by veins and nodules of chert. There are some small circular calcareous structures which could be algal in origin. Thin sections exhibit both sparry calcite and cloudy micrite, with a scattering of quartz grains. No fossils have been found.

The maximum thickness reported is 12 m of 'weathered limestone' in water-bore R30163, about 5km southwest of the type area. The formation appears to have a varied thickness, however, as in an IWSC drill hole 0.5 km to the east of the type area there are only red silty clays with no limestone (Cox, 1973). Other IWSC holes along the Gregory River penetrated thin lenses and nodules of limestone, the thickest of which was 4.3 m of 'hard pinkish-brown to grey crystalline limestone containing some silica and some bands of yellow sandy clay' (Cox, op. cit.). The general picture built up from the IWSC and water-bore data is of one or more lenses of limestone lying with apparent conformity at or near the boundary between the Floraville Formation and the younger Armraynald Beds. An exception is a bed of 'hard and soft white limestone' lying between the Floraville Formation and the Mesozoic sequence in the IWSC Planet Downs line. This was interpreted by Cox (op. cit.) as Toolebuc Limestone; however, this is unlikely for the Toolebuc Limestone should be considerably deeper at this point (see Fig. 17). This limestone may be a bed within the Allaru Mudstone, which is known to contain thin limestone beds, or it may represent a basal part of the Floraville Formation.

The Gregory Downs Limestone was probably formed by precipitation in shallow lakes and swamps from the lime-rich waters of the ancestral Gregory River. In the absence of fossils an accurate age cannot be given to the unit. It could be considered as a facies member of either of the adjacent formations, but it may represent a separate event occurring between them. The Carl Creek Limestone has a similar lithology and lacustrine origin to the Gregory Downs Limestone, and the two formations might be contemporaneous. The lakes might have been caused by a reduction in stream gradient owing to a rise in base level related to the transgression which affected much of Australia in the late Oligocene and early Miocene (Brown et al., 1968, p. 295).

Fig. 23 Outcrop of the Gregory Downs Limestone at its type locality in Macadam Creek, LAWN HILL. (Neg. No. GA 8771).

Table 6

DETAILS OF LITHOLOGIES OF THE ARMRAYNALD BEDS

IN BMR SCOUT HOLES AND IWSC BORELINES

From data in Needham et al., (1972), Gibson et al., (1973), and Cox (1973)

Borehole (listed from north to south)	Thickness	Lithology
BMR Westmoreland 1	11 m	Grey and brown clay and silt, with minor sand; pebble band at base.
IWSC Beames Brook Line	25 m max., 15 m average	Brown and grey calcareous sandy and gritty clay; coarse to fine sand, clayey sand, and gravel; minor limestone nodules.
IWSC Punjaub Line	12 m max., 9 m average	Red-brown, brown, and some grey calcareous silty and sandy clay; minor sand and limestone nodules.
BMR Lawn Hill 1	12 m	Grey and brown clay with some very fine sand and silt.
BMR Lawn Hill 3	6 m	Brown, yellow, grey, and white sandy and silty clay; some pebbles.
IWSC Planet Downs Line	8 m max., 5 m average	Red-brown clay; minor sand and pebbles; limestone lens at base is probably part of the Gregory Downs Limestone.
IWSC Gregory Downs Line	23 m max., 12 m average	Red and brown calcareous silty clay and slightly sandy clay; some sand and gravel, and limestone nodules; brown clayey gravel at base.
BMR Lawn Hill 2	8.5 m	Grey and brown clay.

Until more definite age data becomes available the Gregory Downs Limestone is tentatively assigned to the middle or late Tertiary.

ARMRAYNALD BEDS (Qn)

This unit, defined by Smart et al., (1972), underlies the Armraynald Plain. There is only poor outcrop in stream banks so the information on its lithology is largely derived from borehole data (see Table 6).

The unit consists of brown and grey clay, silty clay, and sandy clay, with minor beds of sand and claybound gravel, and a few limestone nodules (Table 6). In general the beds are finer-grained and less well consolidated than the underlying Floraville Formation, which, in contrast to the Armraynald Beds, is commonly mottled and ferruginized. However, it is difficult to distinguish the two units in many drillers' logs of water-bores.

Near the upper Leichhardt Falls (DONORS HILL) the Armrayald Beds contain a vertebrate fauna including Nototherium sp. and crocodilian remains. These indicate a Pleistocene age (Bartholomai, pers. comm.).

Smart et al., (1972) quoted a thickness of up to 50 m for the Armraynald Beds in DONORS HILL; however, in LAWN HILL and WESTMORELAND it averages only 10 m with a maximum thickness of 25 m in the IWSC Beames Brook line. The Beames Brook boreline is also notable for the highest proportion of sand and gravel present in the unit.

The boundary between the Armraynald Beds and the Floraville Formation appears to be a disconformity: a deep-weathering profile was partly stripped by erosion before the Armraynald Beds were deposited. There is no field evidence for an angular unconformity, though this is not impossible in view of the postulated warping which occurred between the times of deposition of the two units.

Smart et al., (1972) placed a Pleistocene to Holocene age on the Armraynald Beds, though deposition appears to have ceased in most areas before the Holocene (Doutch, pers. comm.), and many streams are incised into the Armraynald Plain.

UNCONSOLIDATED DEPOSITS

By a combination of lithological and morphological criteria, it has been possible to recognize several distinct thin unconsolidated sedimentary units forming much of the surface of the Carpentaria Plains. These have not been given formal names and will be referred to here by the letter symbols used on the 1:250 000 geological maps. A summary description of the units is given in Table 4. Some aspects will be enlarged on in this section; others are noted under Physiography. The age relations of the units are illustrated in Figure 20.

Dominantly Colluvial Deposits

Czs. This is a widespread sandy unit which forms a thin cover of sheetwash and colluvial material spread over the Floraville Formation and other units of the Doomadgee and Cloncurry Plains. The unit is commonly underlain by a layer of ferricrete (Tf) at shallow depth. An attempt has been made on the WESTMORELAND 1:250 000 preliminary map to photo-interpret a boundary between areas of shallow Tf and others of thick Czs cover. This photo-interpretation has not yet been checked in the field.

The Czs unit has a fairly broad time range. In some places it appears to be a sandy-facies equivalent of the Armraynald Beds. In others it appears to be older than them; elsewhere, surface sands could be as young as Holocene. The Czs is therefore referred to the late Cainozoic.

Czc is used for the dominantly residual 'black soils' (deep grey or brown cracking clays; Isbell et al., 1968) overlying the Cambrian dolomites in the southwesternmost part of LAWN HILL. The unit has not been studied in detail and does not appear on the 1:250 000 preliminary maps, but it is shown on the 1:1 000 000 preliminary map of the Southern Carpentaria Basin. The unit coincides with the Tertiary Swamp (a geomorphological unit) of Stewart (1954).

Alluvial Plain Deposits

Qa is a general symbol used for alluvial flood-plain and valley-fill deposits and soils; it includes some small areas of Qha, Qas, and Czs. The sediments are generally poorly sorted and are composed of silt and very fine sand; the average grainsize varies with change in provenance. The soils break down readily to 'bulldust'.

Qas. This symbol is used to designate low linear sand 'ridges' on the Doomadgee Plain and the flood plain of the Nicholson River. The ridges probably represent fluvial channel and levee deposits which have since been abandoned by the streams that formed them.

Qha. (Qra on the preliminary editions of the geological maps). This is a Holocene deposit associated with the present streams. It is a stream bed deposit which may be wholly or partly eroded by each flood and re-deposited farther downstream or out to sea. Lithology is generally sandy, though silt and clay are present in some streams.

Coastal Plain Deposits

Qac, Qhp, Qm. and Qhd are all coastal deposits. The nature of the coastal plain deposits has been discussed at length by Doutch et al., (1972), and under Physiography in this report. The geology is summarized in Table 4. The tidal flats, Qhp (Qcp on the preliminary geological maps), are still receiving sediments, as are the present beaches and spits (Qm). The Qm beach ridges become progressively older inland and the shell content decreases rapidly, the oldest (innermost) line of ridges being composed of pure quartz sand. The oldest ridge forms a discontinuous margin to the coastal plain and probably marks the line of the farthest transgression of the Holocene sea about 6000 years ago (see Physiography). The absence of shell material in the older beach ridges may be due to leaching since that time. The Qac are older coastal deposits at a slightly higher level than the presently forming Qhp.

Qhe. (Qre on the preliminary geological maps). These are Holocene deposits associated with the major streams flowing across the coastal plain. They are point-bar deposits associated with the meanders formed where the stream gradient is reduced as it flows out onto the coastal plain.

STRUCTURAL GEOLOGY

The report area lies on the southwestern flank of the broad gentle downwarp of the Carpentaria Basin. Doutch (1973) classes the basin as 'an epeirogenic intracratonic downwarp' which formed during Jurassic and Cretaceous times. The distinction between the Carpentaria Basin and the adjacent 'shelf' area, the 'Northern Territory Shelf' of Brown et al. (1968), has been discussed under Mesozoic Stratigraphy. The distinction is mainly stratigraphic and based on the presence of an erosional high area between the two areas in earliest Cretaceous times (Fig. 12). There is also a structural distinction: the 'shelf' sediments are flat-lying, while the deposits of the basin show the effects of a gentle downwarping. This subsidence was contemporaneous with deposition. The margin of the Carpentaria Basin may have been accentuated by the Pliocene upwarping of the shelf area (see below).

Within the basinal part of the report area the Mesozoic strata dip uniformly towards the northeast with shallow gradients of between 1 in 100 and 1 in 250. There is generally insufficient subsurface data to delineate any local trends, though Wilson (in Warner, 1960a) constructed a contour map of a marker horizon within the Normanton Formation which he identified in a series of scout bores drilled on Mornington Island. This showed an anticlinal structure with two areas of closure. The structure was tested by the two Mornington Island petroleum exploration wells (Harrison et al., 1961) but no hydrocarbons were found.

Mornington Island has numerous small-scale folds and faults, which have been mapped in detail in several places by Wilson (op. cit.). There is some variation in trends between the different locations on the island. The general trends are to the NW and NE for the faults; and to the NNE, NE, and NNW for the fold axes (Wilson, op. cit.). The dips on the flanks of the folds are generally less than 20°, though some reach 70°. Where the nature of the throw of the faults could be determined these were generally of the normal type. The age of these small-scale structures is uncertain: some appear to be truncated by the standard laterite profile and may date back to the late Mesozoic? termination of the Carpentaria Basin; others have displaced the lateritized surface and may have resulted from the Pliocene movements which affected the lateritized surfaces elsewhere (see below); however, uplift of old beach ridges in Sweers Island (Ingram, 1973) before the development of wave-cut platforms suggests faulting may have occurred at the end of Pleistocene times.

The Cainozoic history of the area can be explained by a combination of eustatic and tectonic events. Brown et al. (1968, pp. 294-5) refer to transgressions and regressions which occurred synchronously in most of the epicontinental basins of Australia during the Tertiary; these are illustrated in Figure 25. We can probably assume that these are eustatic in part at least and therefore would have had some effect in the Gulf area, but downwarping in the area as well cannot be discounted.

The erosion of the lateritized Tertiary Surface of the Isa Highlands and the consequent deposition of some of the eroded material to form the Armraynald Beds could be explained by a Pliocene regression - the pre-glacial low sea level of Galloway (1970) - followed by higher seas in the early Pleistocene. In such a purely eustatic explanation for the erosion of the Isa Highlands it is simpler to assume that the planar, lateritized Tertiary Surface of the highlands was initially formed at its present level, higher than the equally planar and lateritized surface of the Doomadgee Plain, and that the two areas were separated by a sloping zone similar to that of the present. (An alternative assumption, for which there is no supporting evidence, is that the Isa Highlands and Doomadgee Plain were subjected to differential uplift or downwarping). Thus, the surface represented in Figure 11 would be essentially the form of the Tertiary Surface at the time it was formed.

The objection to such a purely eustatic hypothesis is that it is difficult to see, firstly how the higher part of the surface achieved its planar form at the same time as and in such close proximity to the lower surface, and secondly how it escaped dissection for long enough to develop a standard laterite profile.

There is direct evidence for post-laterite tectonism in the Mornington Islands, and Pliocene epeirogenic warping is known in the southeastern margin of the Carpentaria Basin (Doutch et al., 1970). I, therefore, suggest that the present elevation difference between the two parts of the Tertiary Surface is due to post-laterite upwarping of the Isa Highlands. This upwarping would also explain the onset of dissection in the highlands and the consequent deposition of a part of the eroded material on the lowlands to form the Armraynald Beds.

By correlation with similar epeirogenic activity of Pliocene age in the eastern part of the Basin (Doutch et al., 1970), a late Tertiary, possibly Pliocene, age is assumed for the warping in the report area. Such an age is compatiable with the internal evidence of the report area: the upwarping postdates the main deep-weathering period, which is thought to be early to mid-Tertiary in age (see discussion in Cainozoic Geology), and it is responsible for the erosion which generated the sediments that now form the

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Pleistocene Armraynald Beds. The relation between the late Oligocene to early Miocene Carl Creek Limestone and the upwarping is not certain. The erosion of the valleys in which the limestone was deposited might indicate some upwarping; however, this erosion could also be due to the regression of the sea in the Oligocene as discussed earlier.

If we examine Figure 11, which is a contour map of summit spot heights in the Isa Highlands, and assume that the contoured surface is a gipfelfur representing the present position of the Tertiary Surface, then the area in the southwest, lying generally above the 250-m contour, represents the uplifted Tertiary Surface in the Isa Highlands; the low, flat lying area in the northeast, below the 100 m contour, is the relatively undisturbed Tertiary Surface of the Doomadgee Plain; and the sloping zone between these two areas could be attributed to a monoclinal flexure at the margin of the uplifted Isa Highlands. This slope is not entirely due to simple warping of the Tertiary Surface, because, firstly, Stewart (1954) recognized hilly land in the Westmoreland area which rises above the general level of the laterite surface; this is shown in Figure 24F. The warping would have accentuated the pre-existing slope along the northeast margin of this hilly belt, but reduced the slope along the southwestern margin (cf. Figs 24F and 24H). Secondly, the slope in the southeastern part of Figure 11, while partly due to warping, probably represents the exhumed Early Mesozoic Surface rather than the Tertiary Surface, as the slope of the gipfelflur here is continuous with that of the buried unconformity beneath the Carpentaria Basin (see Fig. 17).

It is probably significant that this 'monoclinal' zone coincides with the margin of the Carpentaria Basin. This zone acted during the Cretaceous as a hinge between the stable 'shelf' and the subsiding basin. In the Pliocene it again acted as a junction between the two areas. It must therefore represent a zone of weakness or a change in structural character in the basement. Unfortunately the exact nature of the zone is unknown: the basement structures visible in the Isa Highlands are at an angle to the trend of the zone and there are no obvious discontinuities in the basement geology, though admittedly the basement underlying the Carpentaria Basin is poorly known.

This zone lies parallel to the trend of the Pine Creek Upwarp, which is in the Northern Territory and was active several times during the Tertiary (Hays 1967). It is also parallel to the margins of the Gilbert Mitchell Trough (Doutch et al., 1972) and to a number of long lineaments within the Carpentaria Basin which can be interpreted from ERTS imagery (Doutch, pers. comm.).

Most of the raised marine platforms and related coastal features of the Wellesley Islands (see Physiography) can probably be explained by Holocene eustatic changes of sea level, though the 10-m high bench on the southern end of Sweers Island (Ingram, 1973) is exceptional and may point to Holocene warping in that area. Beach or dune limestones are known up to 40 m above sea level in the Pellew Islands, in the Northern Territory (Smith, 1963).

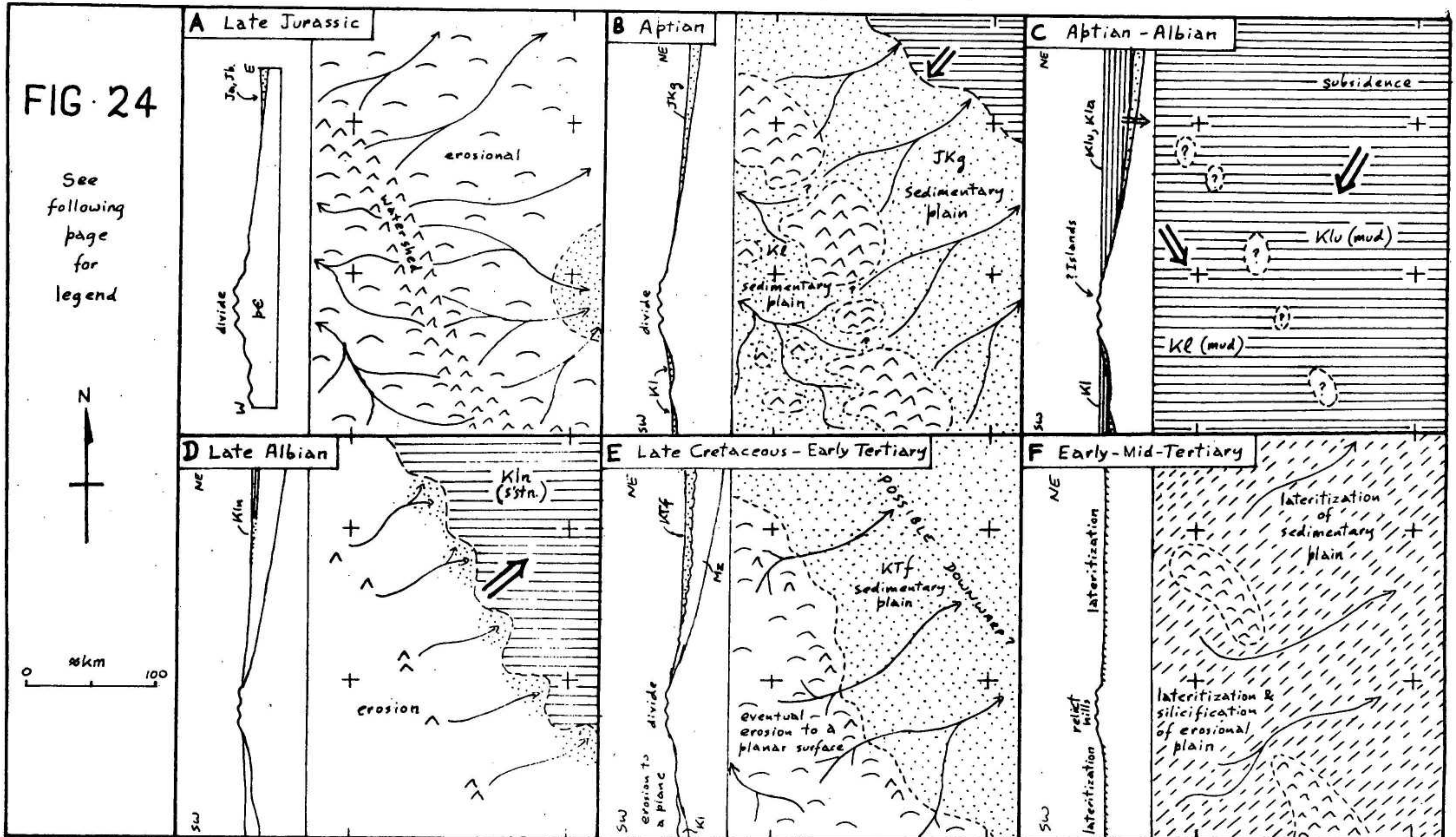
GEOLOGICAL HISTORY

The Mesozoic and Cainozoic geological history of the area is summarized in Figures 24 and 25.

After a period of erosion which fashioned the Mesozoic land surface, deposition of sandy riverine sediments commenced in the central part of the Carpentaria Basin (Fig. 24A) and later spread towards the margins. At the same time, valley-fill sands were deposited on parts of the 'shelf' to the southwest which was separated from the basinal area (Fig. 24B). In Early Cretaceous times the sea transgressed beyond the previous margins of the basinal downwarp, and muddy deposits of the Wallumbilla Formation overlapped the older sands and spread out over most of the area (Fig. 24C). In mid-Albian times the sea began to retreat and erosion commenced; the final deposits of the Carpentaria Basin were paralic in nature (Fig. 24D) and restricted in area.

Erosion continued in late Cretaceous times. This became restricted to the southwest as deposition of the terrestrial Floraville Formation occurred to the northeast (Fig. 24E). The southwestern area was eventually reduced to an erosional plain and at the same time a sedimentary plain was built up to the northeast. The ridge which had formed the watershed in Early Cretaceous times (Fig. 24B) may have been partly exhumed by this erosion and remained as a small area of hilly country. Both planar areas were lateritized in mid-Tertiary times (Fig. 24F). Freshwater limestones were deposited in small areas near Gregory Downs and Riversleigh in the late Oligocene or early Miocene (Fig. 24G).

Lateritization may have persisted in the stable areas until the Pliocene uplift of the southwestern area (Fig. 24H). This resulted in renewed erosion, especially in the southwest, and the eroded material from the southwest was deposited on the lowlands to form the Armraynald Beds in Pleistocene times (Fig. 24I). Lateritization may have continued on those stable areas which escaped erosion or deposition; e.g., in parts of the Doomadgee



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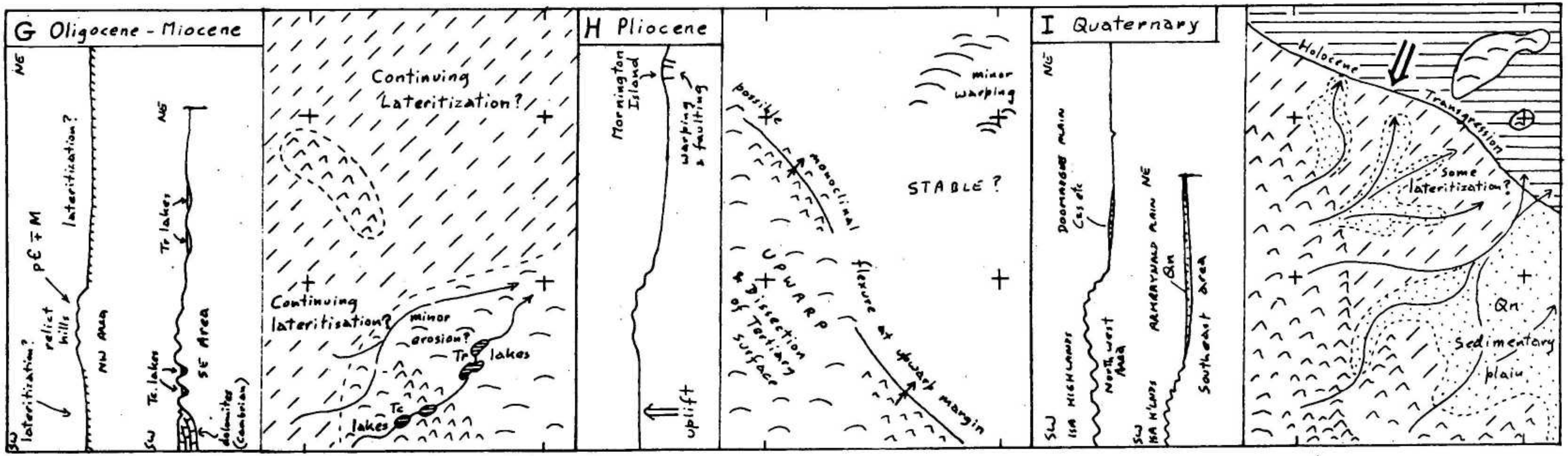
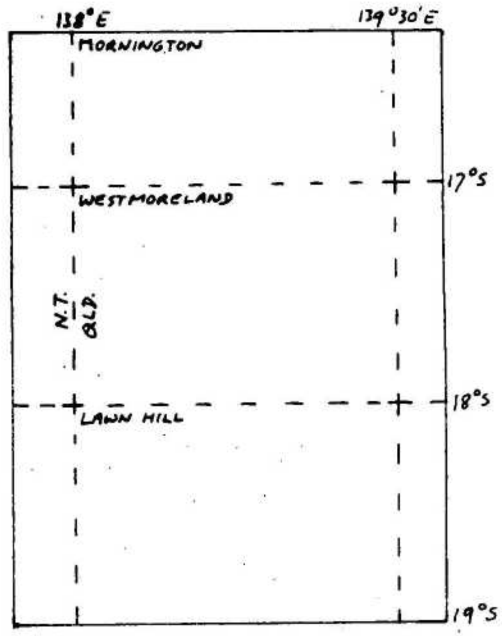


FIG. 24 PALEOGEOGRAPHICAL SKETCH MAPS

Approximate scale

0 km 200

Marine deposition	High hills, strongly dissected
Terrestrial deposition	Low hills, moderatly dissected
Lacustrine deposition	Ancient drainage trends
Deep weathering (Lateritization, etc.)	Direction of movement of the shoreline of transgressive and regressive seas.
	Monoclinal fold



(See text for explanations of lithostratigraphic letter symbols)

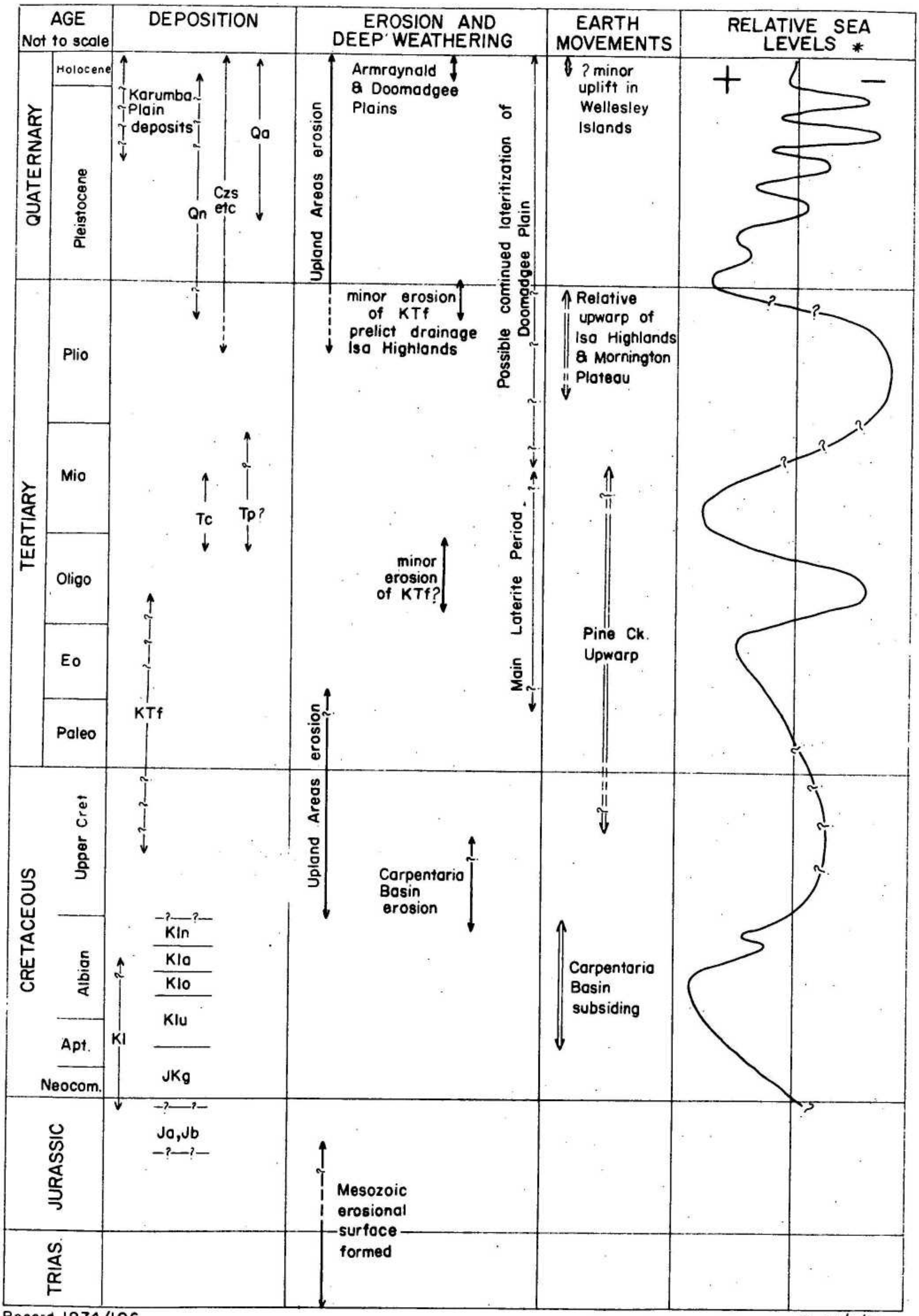


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Fig. 25 Geological History

* Sea level based on:
Holmes (1965); p706-7; Quaternary.
Galloway(1970); Pliocene.
Brown, et. al.;(1968),p294-5; Tertiary.
Burger(1973); arly Cretaceous.

Plain it may have continued up to the present. Sea level fluctuated during the Pleistocene and reached its last high point about 6000 years ago. A drop of several metres in late Holocene times has resulted in progradation of the coast with the formation of a series of beach ridges, and has caused incision of stream channels in the lowlands. There may have been some minor upwarping of the Wellesley Islands in late Holocene times.

ECONOMIC GEOLOGY

Groundwater

Several aquifers are present in the area. Springs rising from the Proterozoic sandstones and Cambrian dolomites in the Lawn Hill area suggest that drilling in these units could yield groundwater. Whitehouse (1940) noted that the flows from the springs had decreased in historic times and he considered that the supply is from 'fossil' water stored from a wetter climate in the Pleistocene, and that the reserves are not being replaced during the present lower rainfall regime.

IWSC lists several artesian bores, RN 14799 to 14804, in the Elizabeth Camp area (670705y, LAWN HILL). Lithological logs are not available for these wells, but they mostly spudded into the Precambrian Mullera Formation and obtained their supplies from depths between 30 and 100 m.

Water-bores on the Barkly Tableland tap the water from the Cambrian dolomites. In Mid-Wood Burketown 1 the main artesian flow is obtained between 960 and 1008 m from the dolomite sequence penetrated towards the base of the well.

The Mesozoic Gilbert River Formation aquifers are only present in the deeper parts of the Carpentaria Basin. Figure 12 shows the pinchout margin of this formation. The water quality from these aquifers is fair, but high fluoride content could restrict water use in some areas where it exceeds the 4-ppm limit for human consumption. Artesian flows are sometimes obtained from these aquifers. Smaller supplies of poorer quality water are present in places in sandy beds near the base of the Wallumbilla Formation.

Water supplies have also been tapped in some unconsolidated Cainozoic deposits. Sand and gravel lenses in the Armraynald Beds and Floraville Formation yield water, but supplies are variable and dry holes are common. IWSC drilled a series of borelines along the Gregory River to test the Cainozoic deposits; results were poor (Cox, 1973).

On the Doomadgee Plain, springs sometimes rise from below the ferricrete zone, and BMR Westmoreland 2 struck water at shallow depth, just below this zone. Such shallow supplies might not be dependable in dry years.

The Qm and Qhd sandy beach ridges and the Qas sand ridges might yield supplies from perched aquifers but have not been tested.

Petroleum

Three petroleum exploration wells have been drilled in or near to the report area: Delhi-Santos Mornington 1 and 2 (Harrison et al., 1961), and Mid-Wood Burketown 1 (Permian, 1964). A series of scout holes were drilled on Mornington Island (Warner, 1960). No petroleum reserves were found although dead oil staining was reported from the Gilbert River Formation in DS Mornington 2.

The area is lacking in structural traps. Stratigraphic traps may exist in the Mesozoic succession where the Gilbert River Formation pinches out towards the Carpentaria Basin margin. The limited data from the petroleum wells and water-bores in the area suggests that any potential reservoirs have been flushed by groundwater.

Oil Shale

The Toolebuc Limestone (Smart, 1972) contains oil shale in the Julia Creek area (Swarbrick, 1974), and the unit extends into the report area. It was penetrated by BMR Westmoreland 2 and 3 and Lawn Hill 2 stratigraphic holes at depths of 70, 52, and 26 m respectively (Gibson et al., 1973; Needham et al., 1971). In both the Westmoreland holes the formation contained bituminous mudstones in its lower part.

There are no exposures of the unit in the area as it is buried beneath Cainozoic deposits. This factor, and the tendency for the formation to be weathered for some depth beneath the surface, will probably prevent economic mining of the oil shales for some time to come.

Sedimentary Uranium

Some interest has been expressed in recent years about possible sedimentary uranium deposits in the basal Mesozoic sandstones.

Company drilling in DOBBYN (Brunt, 1972) disclosed a small gamma-ray anomaly at 350 m depth. Brunt extrapolates the Eulo Queen Group terminology of the Millungera Depression in the eastern part of the basin (Smart et al., 1971) into the Burketown Depression, where similar units can be interpreted on the gamma-ray logs of his boreholes. He placed the anomaly in the upper part of the 'Hampstead Sandstone' of the 'Eulo Queen Group'. He thought that the anomaly might be from a 'weak geochemical cell' and that it might represent a small uranium deposit.

The extent of his 'Eulo Queen Group' report area is not known. The Gilbert River Formation appears to have little potential for uranium (Brunt, 1972).

Bauxite

The lateritic Doomadgee Plain has a number of features in common with the bauxite regions of Cape York Peninsula, but no bauxite outcrops were found during the survey. Three samples were collected from the nodular ferricrete zone of the laterite profile and submitted for analysis. All were high in silica and iron, and low in alumina (see Table 7).

Table 7. Analyses of samples from the ferricrete zone of the Doomadgee Plain laterites

SAMPLE	Alkali soluble Al_2O_3 %	SiO_2%	Total Fe%
2184/72/GS* BMR Westmoreland 2, 1.2-1.5 m depth	4.7	62	15.2
2182/72/GS*, Scarp 16 km west of Corinda 0.2-1.1 m depth	5.7	48.8	23.4
2183/72/GS*, 21 km NNE of Jam Tin Yard, surface sample	5.1	48.5	30.9

* Geological Survey of Queensland Assay Number

Limestone

The scattered outcrops of the Tertiary Gregory Downs Limestone are of little significance because of their chert content and alluvial cover. The Toolebuc Limestone is buried beneath Cainozoic deposits and has only thin beds of limestone.

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Some of the shelly beach ridges could be a source of lime. Ingram (1973) reports an abandoned lime kiln on Sweers Island.

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APPENDIX

LOWER CRETACEOUS (PROBABLE APTIAN) MARINE BIVALVES FROM THE LAWN HILL 1:250 000 SHEET AREA

by R.W. DAY

Locality: LH162, 3.2 km north of Reids Tank on scarp on east bank of Horse Creek; map ref. 192638y Lawn Hill 1:250 000 Sheet.

Collector: K.G. Grimes, May 1972.

Lithology: Reddish fine-grained quartzose sandstone with clayey matrix.

Determinations: *Fissilunula clarkei* (Moore)

Maccoyella sp. indet.

Indet. elongate bivalve

Age: Early Cretaceous (probable Aptian).

Remarks: The occurrence of *Fissilunula clarkei* (Moore) indicates a Lower Cretaceous (probable Aptian) age for this collection. The species is represented by 5 internal moulds of closed, slightly displaced valves; are internal mould of a right valve; and one of a left valve. All have the characteristic shape of this species, although none shows the hinge features completely. *Fissilunula clarkei* is confined to Aptian strata except for a possibly reworked example in basal Albian sediments of the Tambo area (Day, 1969).

A dorsally incomplete external mould of a right valve designated *Maccoyella* sp. indet. has sparse radial ribbing Several species bear this type of ornament. The range of the genus is Neocomian? - Aptian and Albian.

APPENDIX (Contd)

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R.W. Day
Principal Geologist
Geological Survey of Queensland
10-1-1973

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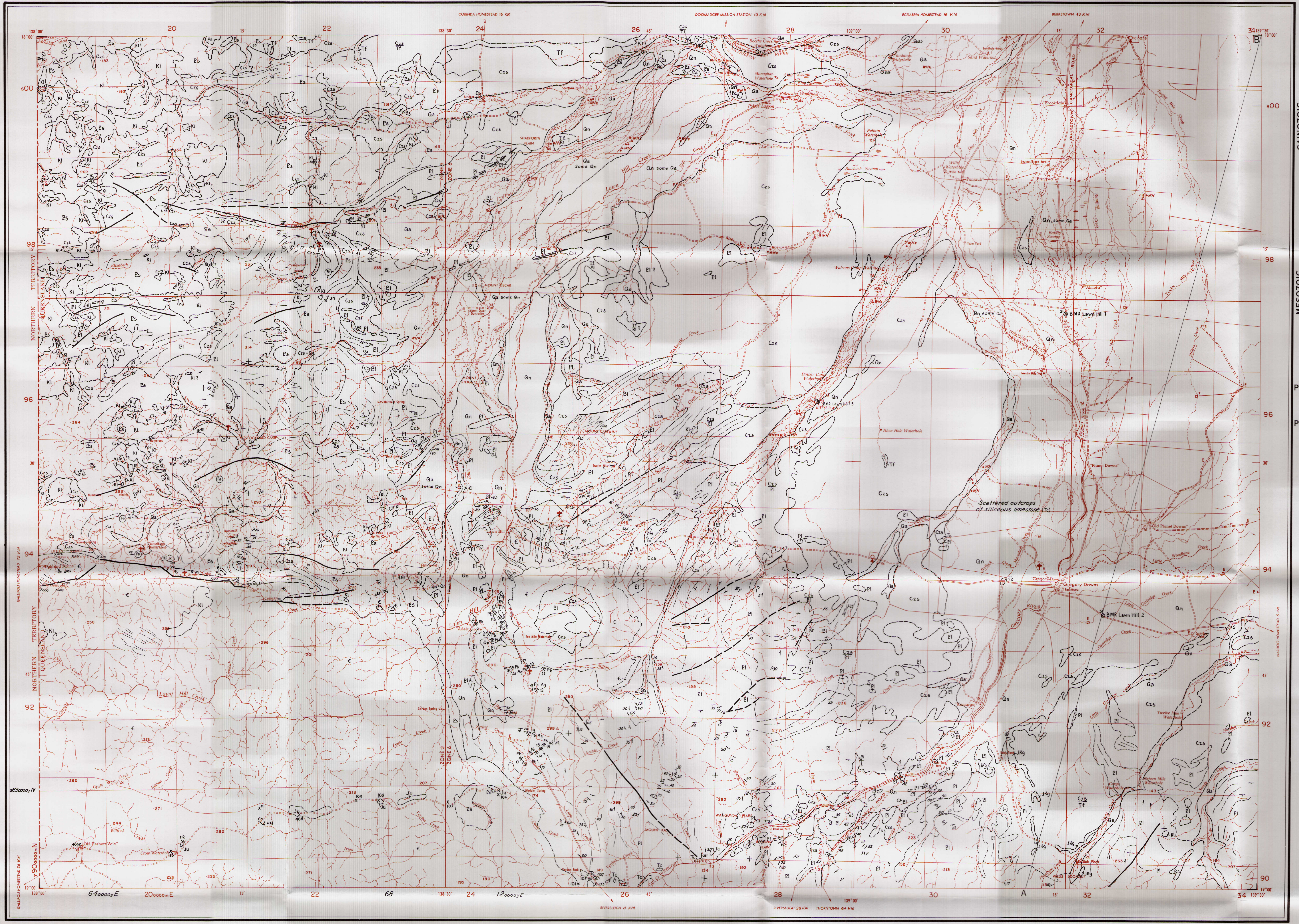
AUSTRALIA 1:250,000 GEOLOGICAL SERIES

LAWN HILL

QUEENSLAND

SHEET SE 54-9



Mines

1 Cu *Waanyee*
2 Pb *Hanns*
3 Pb *Black Snake*
4 Pb *Little Wonder*
5 Pb *Dorothy*
6 Pb *Union Jack*
7 *Star Spangled Banner*
8 Pb *Anglo-American*
9 Pb, Ag *Silver King*
10 Pb *Bell's Lode*
11 Pb *Tunnel Hill*
12 Pb, Ag *Mended Hill*
13 Pb, Ag *Lucky Dollar*
14 Pb *Stardust*
15 *Star of the East*
16 Pb *Star of the South*
17 Pb, Ag *Lilydale*

Reference

CAINOZOIC	QUATERNARY		Qa	*Sand, silt, clay: undivided alluvium* (Alluvial Plain Deposits)
			Qra	*Quartzose sand, silt, clay: stream bed deposits* (Alluvial Plain Deposits)
			Qas	*Quartzose sand: abandoned river channels* (Alluvial Plain Deposits)
		Armraynald Beds	Qn	*Clay, silt, sand: fluvial deposits* (Alluvial Plain Deposits)
			Czs	*Quartzose sand and gravel: colluvium and alluvium*
	TERTIARY	Carl Creek Limestone	Tc	*Clastic limestone (calcarenite and calcirudite)*
			Tf	*Ferruginised colluvium and alluvium, laterite*
				Deeply weathered sediment (kaolinised, silicified and ferruginised)
	UPPER CRETACEOUS TO TERTIARY	Floraville Formation	KTf	*Quartzose clayey sandstone, claystone, siltstone, conglomerate*
MESOZOIC	LOWER CRETACEOUS	Rolling Downs Group: Normanton Formation	Kln	*Labile sandstone, minor siltstone, mudstone and limestone* (Section only)
		Rolling Downs Group: Allaru Mudstone	Kla	*Mudstone, siltstone, minor labile sandstone* (Section only)
		Rolling Downs Group: Toolebuc Limestone	Klo	*Calcareous mudstone, limestone* (Section only)
		Rolling Downs Group: Wallumbilla Formation	Klu	*Mudstone, siltstone, minor labile and glauconitic sandstone* (Section only)
			Kl	*Quartzose sandstone, claystone (porcellanite), siltstone, and minor conglomerate*
	UPPER JURASSIC TO LOWER CRETACEOUS	Gilbert River Formation	JKg	*Quartzose sandstone, siltstone, minor conglomerate*
	UPPER JURASSIC		Ju	*Quartzose sandstone*
PALAEOZOIC *	CAMBRIAN		€	*Dolomite, limestone; basalt*
PRECAMBRIAN *	MIDDLE PROTEROZOIC		Ꝑs	*Sandstone, siltstone, oolitic iron beds*
			Ꝑl	*Sandstone, shale, dolomite, minor volcanics; intruded by granite*

* *Refer to First Edition, 1960, for detail as only some geological data has been transferred to this topographic base*

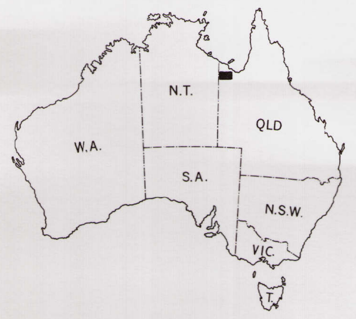
Geological boundary
Fault
Where location of boundaries and faults is approximate, line is broken
Strike and dip of strata measured
Strike and dip of strata unmeasured
Horizontal strata
Trend line } *air-photo interpretation*
Joints } *air-photo interpretation*
Macrofossil locality
×371 *Speciment locality and reference number*
Mine
(Fe) *Unexploited mineral deposit*
Ag *Silver*
Cu *Copper*
Fe *Iron*
Pb *Lead*
$\otimes^{St}$ *BMR stratigraphic hole*
Sub-artesian bore — R15938 *refers to bore Reg. No. (Qld. Irrig. Water Supply Comm.)*
Windpump
E *Earth tank*
Dam on stream
WH *Waterhole*
Spring
Swamp
Road
Vehicle track
Fence
Landing ground
'Lawn Hill' *Homestead*
Yd *Yard*
Trigonometrical station
·201 *Elevation in metres, approximate*

NOTE ON GRID COORDINATES

Brown lines with black italic numbers (numbers shown only at SW corner of map and change of zone), indicate the 10,000 yard grid, Zone 6 (Australia Series), CLARKE 1858 SPHEROID. Transverse Mercator Projection

Brown numbered ticks (with larger upright numbers), inside the neatline are 20,000 metre intervals of the superimposed Australian Map Grid, Zone 54 AUSTRALIAN NATIONAL SPHEROID. Transverse Mercator Projection

Compiled by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development. Issued under the authority of the Hon. R.W. Swartz, M.B.E., E.D., Minister for National Development. Base map compiled by the Royal Australian Survey Corps from aerial photography at 1:50,000 scale. Transverse Mercator Projection



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WALLHALLOW SE 53-7	CALVERT HILLS SF 53-8	WEST-MORELAND SE 54-5	BURKETOWN SE 54-6	NORMANTON SE 54-7
BRUNETTE DOWNS SE 53-11	MOUNT DRUMMOND SE 53-12	LAWN HILL SE 54-9	DONORS HILL SE 54-10	CROYDON SE 54-11
ALROY SE 53-15	RANKEN SE 53-16	CAMOOWEAL SE 54-13	DOBBYN SE 54-14	MILLUNGERA SE 54-15
FREW RIVER SF 53-3	AVON DOWNS SF 53-4	MOUNT ISA SF 54-1	CLONCURRY SF 54-2	JULIA CREEK SF 54-3

5°E, 6°E

ANNUAL CHANGE 0'20"E

Scale 1:250,000

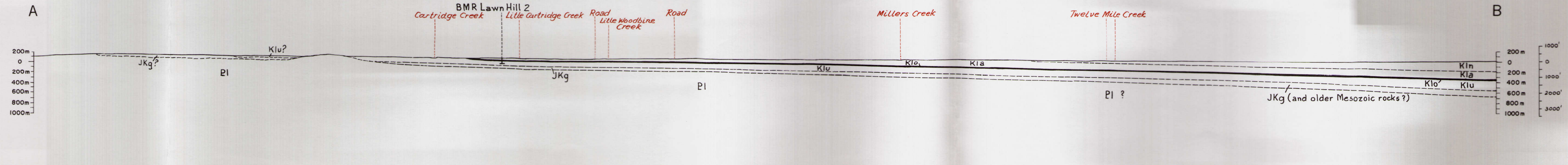
5 0 5 10 15 20 25 KILOMETRES

5 0 5 10 MILES

Section

Cainozoic sediments omitted

Scale: V/H = 4



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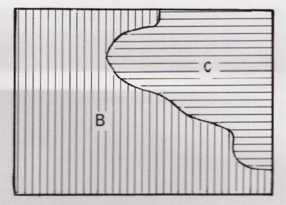
1971 by K.G. Grimes (GSQ)
Compiled 1972 by K.G. Grimes (GSQ); J. Kopras (BMR)
Cartography by Geological Branch BMR
Drawn 1972 by J. Kopras

RELIABILITY DIAGRAM



B Detailed Reconnaissance: numerous traverses, and air-photo interpretation

C General Reconnaissance: few traverses, mainly air-photo interpretation

PRELIMINARY TO SECOND EDITION 1972

SUBJECT TO AMENDMENT

LAWN HILL

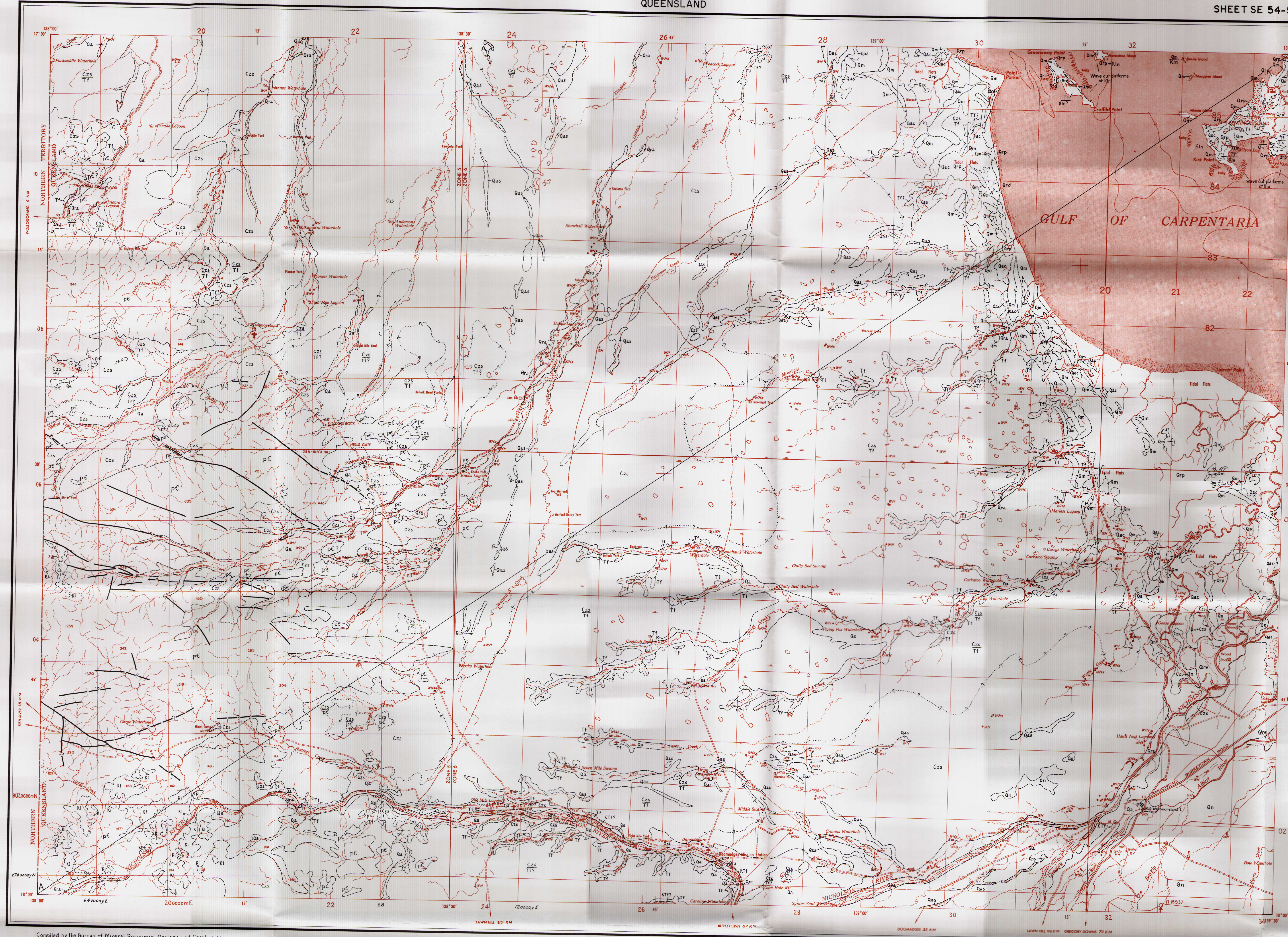
SHEET SE 54-9

AUSTRALIA 1:250,000 GEOLOGICAL SERIES

WESTMORELAND

QUEENSLAND

SHEET SE 54-5



Reference

CAINOZOIC	QUATERNARY	Armraynald Beds	Qa	Sand, silt, clay: undifferentiated river alluvium	Alluvial plain deposits
			Qre	Clay, silt, sand: meander belt (point bar) deposits	Alluvial plain deposits
			Qra	Quartzose sand, silt, clay: stream bed deposits	Alluvial plain deposits
			Qas	Quartzose sand: abandoned river channels	Alluvial plain deposits
			Qn	Clay, silt, sand: fluvial deposits	Alluvial plain deposits
			Qac	Quartzose sand, silt, clay: undifferentiated coastal deposits	Coastal plain deposits
			Qrd	Quartz and calcareous sand: aeolian sand dunes	Coastal plain deposits
			Qrp	Sandy clay, silt: tidal flats	Coastal plain deposits
			Qm	Coquina, calcarenite, shelly quartzose sand: beach ridges	Coastal plain deposits
	TERTIARY		Czs	Quartzose sand and gravel: colluvium and alluvium	
			Tf	Ferruginized colluvium and alluvium, laterite	
				Deeply weathered sediments (kaolinised, silicified and ferruginized)	
	UPPER CRETACEOUS TO TERTIARY ?	Floraville Formation	KTf	Quartzose sandstone, conglomerate; minor mudstone and siltstone	
MESOZOIC	LOWER CRETACEOUS	Rolling Downs Group: Normanton Formation	Kln	Labile sandstone, siltstone, mudstone	
		Rolling Downs Group: Allaru Mudstone	Kla	Mudstone, siltstone, minor labile sandstone	Section only
		Rolling Downs Group: Toolebuc Limestone	Klo	Calcareous mudstone, limestone	Section only
		Rolling Downs Group: Wallumbilla Formation	Klu	Mudstone, siltstone, minor labile and glauconitic sandstone	Section only
			Kl	Quartzose sandstone, sandy claystone, porcellenite	
	UPPER JURASSIC TO LOWER CRETACEOUS	Gilbert River Formation	JKg	Quartzose sandstone, siltstone, minor conglomerate	Section only
PRECAMBRIAN			p€	Metamorphic and igneous rocks	

Geological boundary
Fault

Where location of boundaries and faults is approximate, line is broken; where inferred, queried; where concealed, boundaries are dotted, faults are shown by short dashes

Stratigraphic hole, with B.M.R. reference number

R 15937 Sub-artesian bore of post Wallumbilla artesian aquifer system — R 15937 refers to bore registration number of the Queensland Irrigation and Water Supply Commission records

Earth tank
Waterhole
Intermittent lake, with heavy clay floor
Swamp
Marine flats
Coral reef
Bathymetric contour, in metres

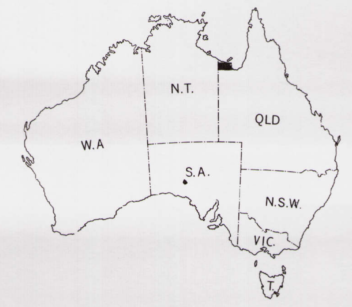
Road
Vehicle track
Track
Fence
"Westmoreland" Homestead
Landing ground
Yard
Astronomical station
Trigonometrical station
Elevation in metres, approximate

Compiled by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development. Issued under the authority of the Hon. R.W. Swartz, M.B.E., E.D., Minister for National Development. Base map compiled by the Royal Australian Survey Corps from aerial photography at 1:50,000 scale. Transverse Mercator Projection

NOTE ON GRID COORDINATES

Brown lines with black italic numbers (numbers shown only at SW corner of map and change of zone), indicate the 10,000 yard grid, Zones 5,6 (Australia Series), CLARKE 1858 SPHEROID. Transverse Mercator Projection

Brown numbered ticks (with larger upright numbers), inside the neatline are 20,000 metre intervals of the superimposed Australian Map Grid, Zone 54 AUSTRALIAN NATIONAL SPHEROID. Transverse Mercator Projection



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MOUNT YOUNG SD 53-15	PELLEW SD 53-16			RUTLAND PLAINS SD 54-15
BAUHINIA DOWNS SE 53-3	ROBINSON RIVER SE 53-4	MORNINGTON SE 54-1	CAPE VAN DIEMEN SE 54-2	GALBRAITH SE 54-3
WALLHALLOW SE 53-7	CALVERT HILLS SE 53-8	WEST-MORELAND SE 54-5	BURKETOWN SE 54-6	NORMANTON SE 54-7
BRUNETTE DOWNS SE 53-11	MOUNT DRUMMOND SE 53-12	LAWN HILL SE 54-9	DONORS HILL SE 54-10	CROYDON SE 54-11
ALROY SE 53-15	RANKEN SE 53-16	CAMOOWEAL SE 54-13	DOBBYN SE 54-14	MILLUNGERA SE 54-15

ANNUAL CHANGE 0°15'E

Scale 1:250,000

KILOMETRES 5 0 5 10 15 20 25

MILES 5 0 5 10

Geology 1970 by K. Grimes, G.S.Q.
Compiled 1971 by K. Grimes, G.S.Q.
Cartography by Geological Branch B.M.R.
Drawn 1971 by I.T. Lamberts, J. Kopras

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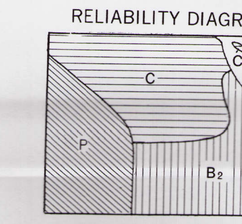
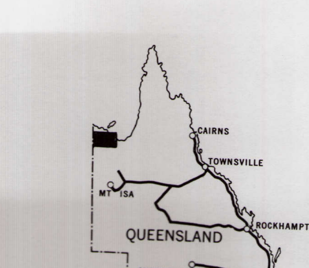


B2 General Reconnaissance: few traverses, mainly air-photo interpretation

C Air photo interpretation

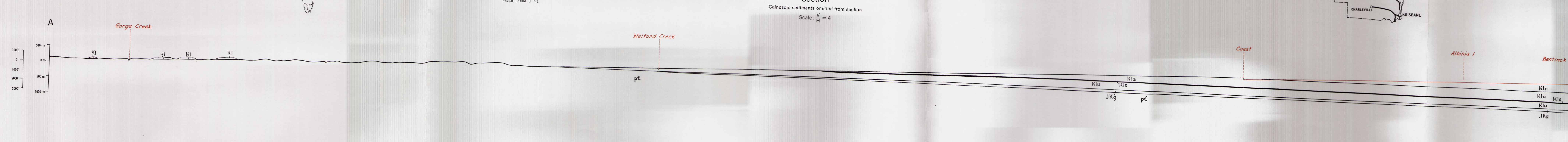
P Published 1958 at 1:253,440 scale as Westmoreland E54-5



Section

Cainozoic sediments omitted from section

Scale $\frac{V}{H} = 4$



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SUBJECT TO AMENDMENT

WESTMORELAND

SHEET SE 54-5

AUSTRALIA 1:250,000 GEOLOGICAL SERIES

MORNINGTON - PART CAPE VAN DIEMEN

QUEENSLAND

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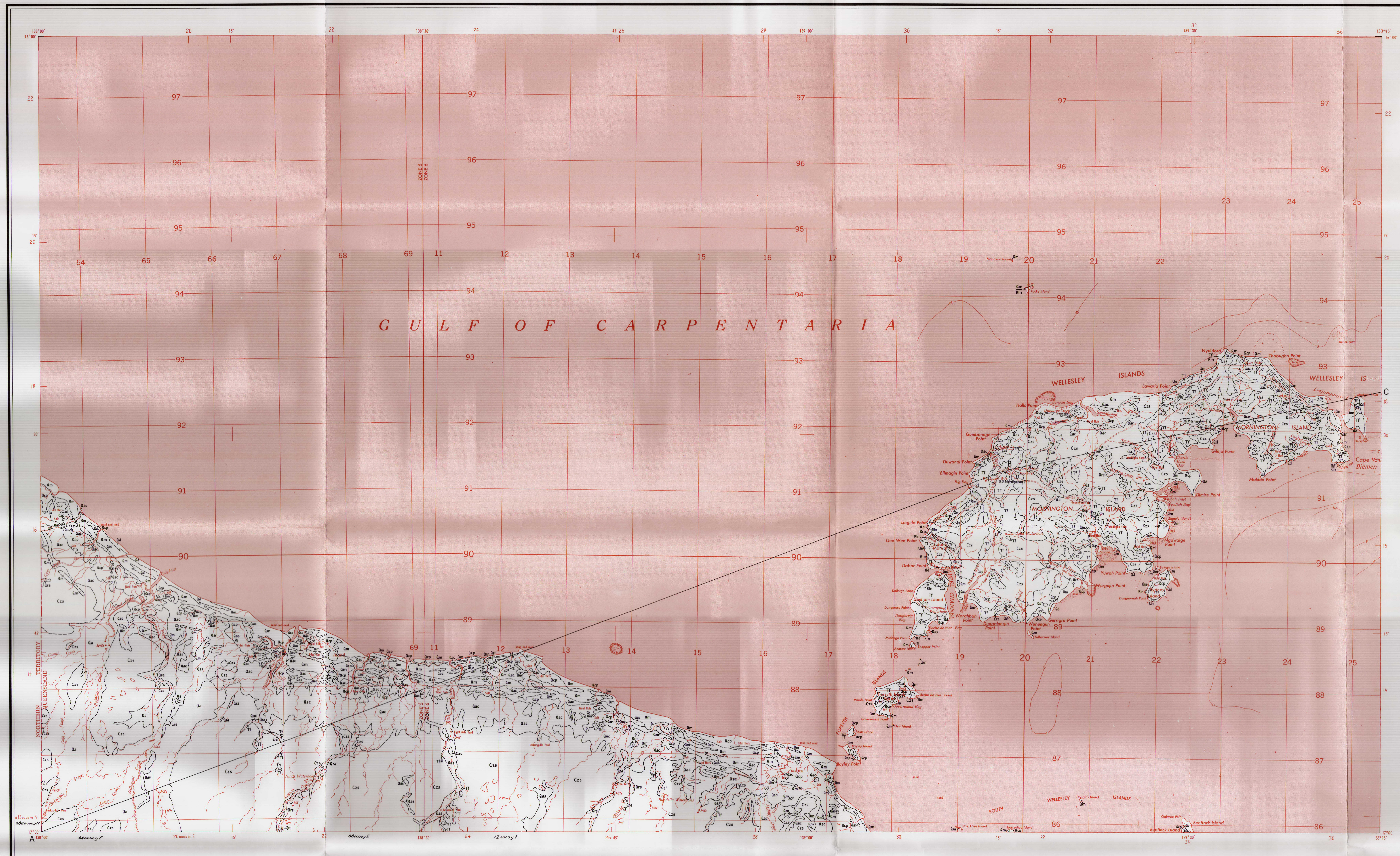


Reference

CAINOZOIC	QUATERNARY		Qra	Stream bed sediment: quartzose sand, silt, clay
			Qcp	Salt and tidal flats: silty clay, salt
			Qd	Sand dunes: quartzose sand
			Qm	Beach ridges: coquina, calcarenite, shelly quartzose sand
			Qas	Abandoned river channels: quartzose sand
			Qa	Flood plain alluvium: sand, silt, clay
			Qac	Coastal alluvium: quartzose sand, silt, minor clay
			Czs	Colluvium and alluvium: quartzose sand and gravel
	TERTIARY		Tf	Ferruginized colluvium and alluvium, 'laterite'
			(stippled)	Deeply weathered sediments (kaolinized, silicified and ferruginized)
		Floraville Formation	Tfl	Quartzose sandstone and conglomerate; minor mudstone and siltstone
MESOZOIC	LOWER CRETACEOUS	Normanton Formation (Rolling Downs Group)	Kln	Labile sandstone, siltstone, mudstone
		Allaru Mudstone (Rolling Downs Group)	Kla	Mudstone and siltstone, minor labile sandstone (Section only)
		Toolebuc Limestone (Rolling Downs Group)	Klo	Calcareous mudstone, limestone (Section only)
		Wallumbilla Formation (Rolling Downs Group)	Klu	Mudstone and siltstone, minor labile and glauconitic sandstone (Section only)
	UPPER JURASSIC-LOW. CRETACEOUS	Gilbert River Formation	JKg	Quartzose sandstone, siltstone, minor conglomerate (Section only)

----- Geological boundary, approximate

Petroleum exploration well, dry - abandoned

WH Waterhole

WH Waterhole on stream

Intermittent lake with heavy clay floor

Swamp

Marine flats

Coral reef

Submerged rocks

6 Bathymetric contours, in metres

Vehicle track

Landing ground

Building

Yd Yard

Astronomical station

Compiled by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development. Issued under the authority of the Hon. R.W. Swartz M.B.E., E.D., Minister for National Development. Base map compiled by the Royal Australian Survey Corps from aerial photography at 1:86,000 Scale. Transverse Mercator Projection

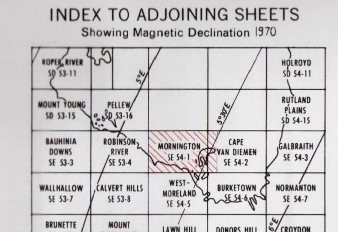
NOTE ON GRID COORDINATES

Brown lines with black italic numbers (numbers shown only at SW corner of map and change of zone), indicate the 10,000 yard grid, Zones 5,6 (Australia Series). CLARKE 1858 SPHEROID. Transverse Mercator Projection

Brown numbered ticks (with larger upright numbers), inside the neatline are 20,000 metre intervals of the superimposed Australian Map Grid, Zone 54 AUSTRALIAN NATIONAL SPHEROID. Transverse Mercator Projection

INDEX TO ADJOINING SHEETS

Showing Magnetic Declination 1970



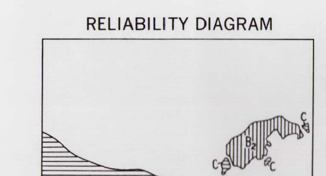
ANNUAL CHANGE 0°13' E

Scale 1:250,000

5 0 5 10 15 20 25 KILOMETRES

5 0 5 10 MILES

RELIABILITY DIAGRAM



Geology B_2 General reconnaissance: some traverses and air-photo interpretation

C Air-photo interpretation

Geology 1970 by K. Grimes (G.S.Q.); H.F. Doutch (BMR)
Compiled 1971 by K. Grimes (G.S.Q.)
Cartography by Geological Branch BMR
Drawn 1971 by R. Ritschel

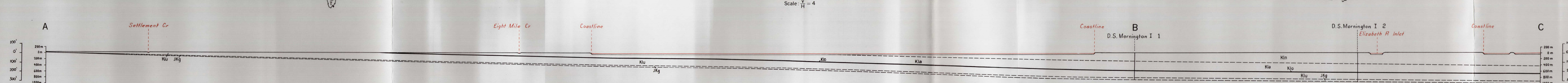
PRELIMINARY EDITION, 1971

SUBJECT TO AMENDMENT

Section

Cainozoic sediments omitted

Scale: $\frac{V}{H} = 4$



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