Geomorphology of the Leichhardt–Gilbert Area of North-west Queensland

By C. R. Twidale

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MAP

Geomorphology of the Leichhardt–Gilbert Area, North-west Queensland, Australia

GEOMORPHOLOGY OF THE LEICHHARDT–GILBERT AREA OF NORTH-WEST QUEENSLAND

By C. R. Twidale*

Summary

The Leichhardt–Gilbert area includes elements of three continental tectonic and physiographic units: the Isa highlands are at the margin of the western shield, the Carpentaria and inland plains are the northernmost extensions of the central basin, and the Einasleigh uplands are part of the eastern highlands of Australia.

The major relief is consequent upon an ancient tectonic framework. Structural influences are expressed directly in that upstanding major relief usually denotes upraised structures and lowlands areas of subsidence; indirectly, structure is expressed through patterns of drainage and minor relief.

Three major cycles of erosion have been recognized, and the surfaces related to these are important components in the present relief. The surfaces are as follows: early Mesozoic; early Tertiary; and late Tertiary–Quaternary. In addition there are limited relics of a pre-Middle Cambrian erosional plain.

The extent to which the early Mesozoic surface has been resurrected in the present relief is remarkable: this is due to the lithological contrasts between the rocks in which the surface was eroded, and those subsequently deposited on the surface.

The nature of the early Mesozoic and early Tertiary surfaces is uncertain, but the late Tertiary–Quaternary surface of erosion is an excellent example of a peneplain. Only in limited areas of the late Tertiary–Quaternary plains are pediments developed; elsewhere relief has been reduced by stream erosion and downwasting of interfluves, and only in the prevalence of braided channels do these surfaces depart from the type Davisian peneplain.

Only one period of lateritization is evidenced, and its age range is considered to be early to mid Tertiary. The interruption of the early Tertiary cycle of erosion probably occurred in the Miocene.

The drainage pattern of the area is Tertiary or later in age and largely results from deformation of the early Tertiary surface. In detail, orogenic structures exert a strong influence in upland areas. The centripetal drainage of the Carpentaria plains consists of intermittent braiding streams subject to flooding in lower sectors.

There was late Tertiary and Quaternary vulcanicity of multiple-vent type in the east of the area. Three phases have been distinguished and a general south-to-north movement of vulcanicity discerned.

There is evidence of a Recent eustatic emergence of about 20 ft at the coast and of geologically recent warping in several areas, but particularly along the Selwyn upwarp, which forms the present divide between drainage to the Gulf of Carpentaria and to Lake Eyre.

Twenty-eight physiographic regions are described under the four main divisions: the Isa highlands, the Carpentaria plains, inland plains, and Einasleigh uplands.

* Formerly Division of Land Research, CSIRO, Canberra, A.C.T. Present address: Department of Geography, University of Adelaide.

I. Introduction

(a) *Purpose of the Report*

During the years 1952–55 the writer served as geomorphologist in a team of scientists engaged in the mapping, analysis, and evaluation of the Leichhardt–Gilbert area of north-west Queensland (Perry *et al.* 1964). This report is a specialized account of the geomorphology of the area.

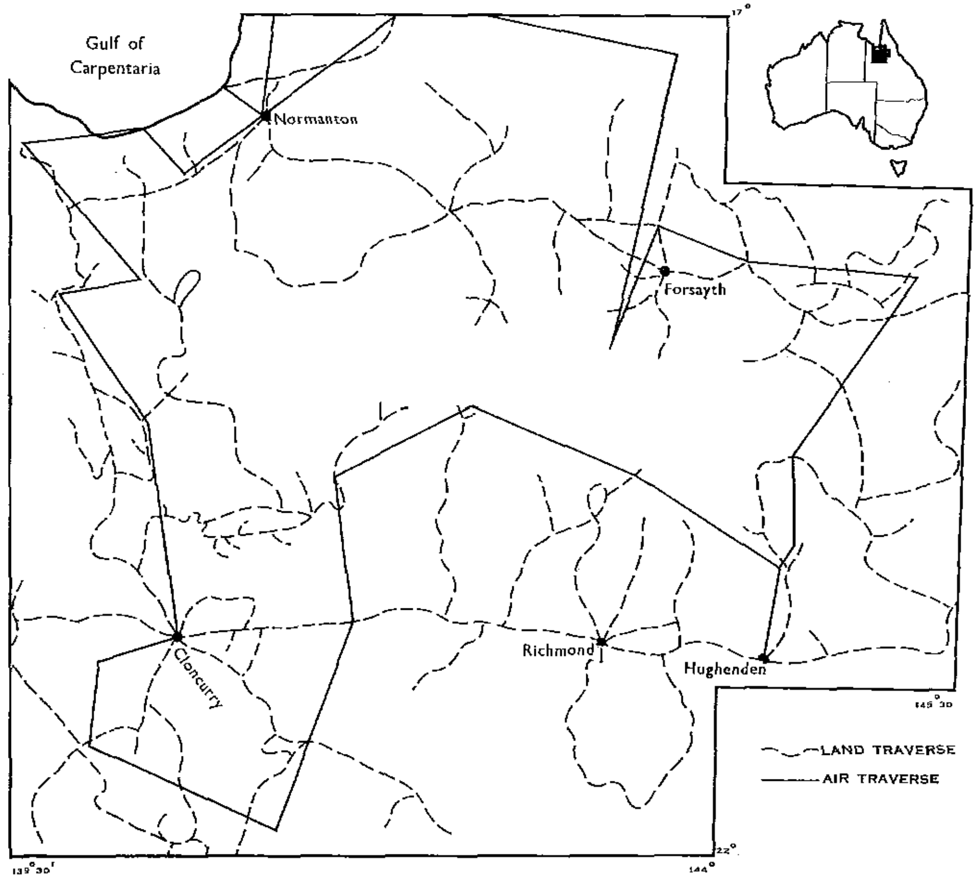

Fig. 1.—The Leichhardt–Gilbert area showing field traverses.

The land surface is the scene of and at the same time a vital component in a complex of interactions involving many factors. An understanding of land forms and their evolution is thus necessary for the comprehension of interrelationships in the whole land complex; and conversely, in order to understand surface morphology, reference must be made to the several causal factors, notably structure (including lithology) and climate, both past and present.

(b) *Extent and Location of the Area*

The Leichhardt–Gilbert area occupies some 117,000 sq miles of north-western Queensland (Fig. 1) and consists essentially of the basins of the Leichhardt, Flinders, and Gilbert Rivers. In comparison with more western parts of northern Australia, north-west Queensland is well settled and has good communications. Considerable tracts of country were difficult of access, but the survey was facilitated by the network of roads and station tracks.

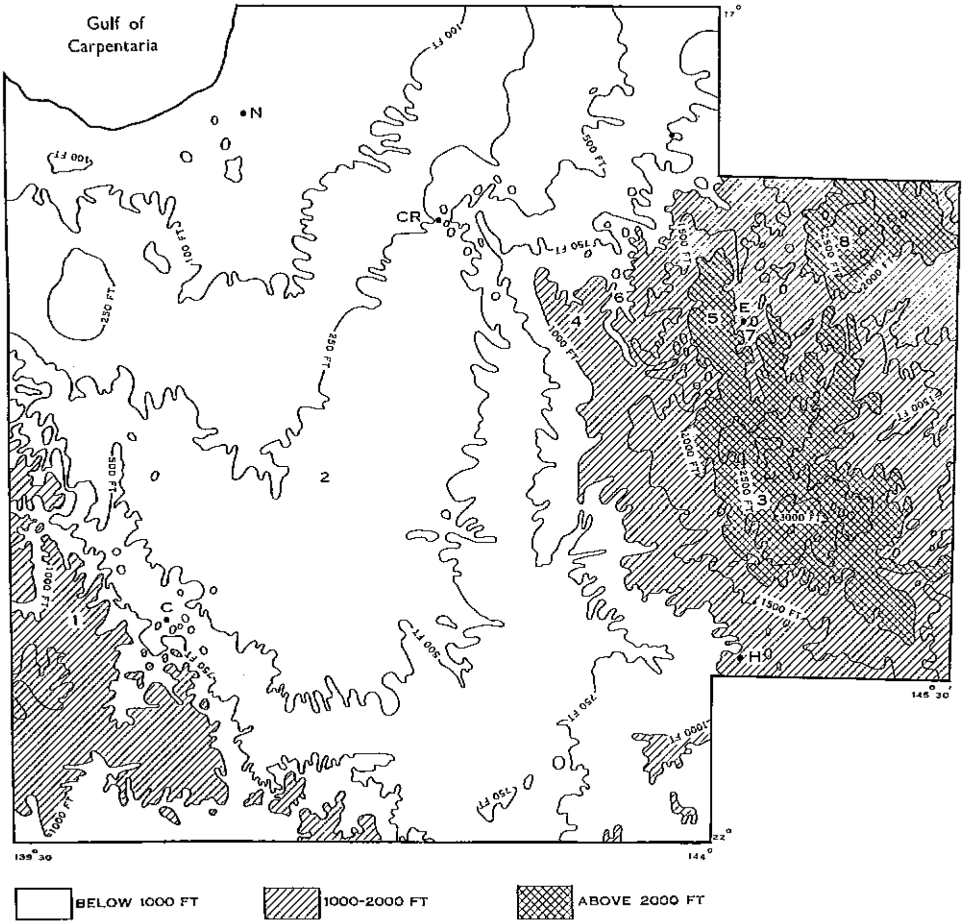

Fig. 2.—Form lines of the Leichhardt–Gilbert area.

C, Cloncurry	1, Isa Highlands	5, Newcastle Range
CR, Croydon	2, Carpentaria Plains	6, Gilbert Plain
N, Normanton	3, Gilberton Plateau	7, Einasleigh–Copperfield Plain
E, Einasleigh	4, Gregory Range	8, McBride Plateau
H, Hughenden		

(*c*) *Previous Work*

Little formal geomorphological research had previously been accomplished in the area, although physiographic observations and interpretations had been recorded incidentally by geologists and others in several localities, and other writers had referred to the area in relation to broader themes. Reference is made to many of these, but the pioneering efforts of Taylor (1911) and Whitehouse (1930, 1940, 1941, 1944) deserve special mention.

(*d*) *Survey Method*

The method employed in this research was that used in the surveys of the Division of Land Research. Essentially it involves the plotting of field data and mapping by extrapolation upon aerial photographs.*

After a study of the relevant literature, photo patterns are delineated on aerial photographs, which in the case of the Leichhardt–Gilbert area were at a scale of 1 : 50,000. Subsequently, traverses are planned to sample photo patterns, and the team of scientists, which may consist of a geologist, geomorphologist, pedologist, and botanist, then works along these traverses in the field. With the knowledge

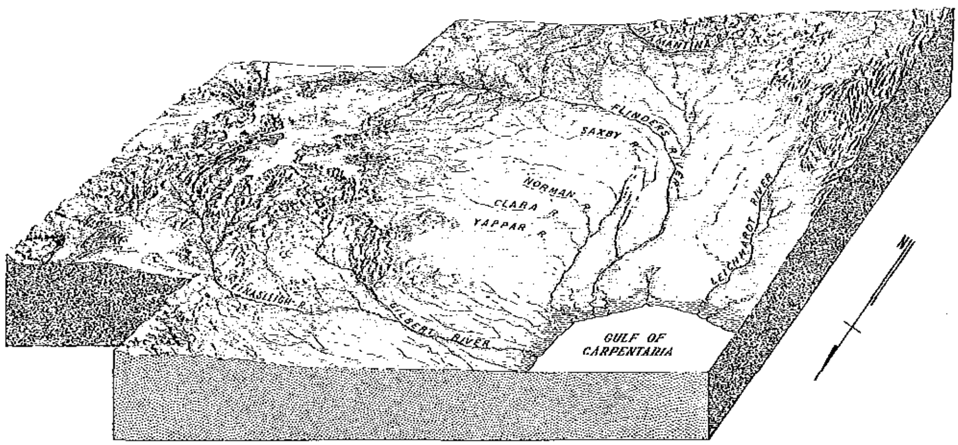

Fig. 3.—Block diagram of the Leichhardt–Gilbert area. The Einasleigh uplands in the east rise to nearly 3000 ft and the Isa highlands in the west to 1650 ft. Between the two high areas are the Carpentaria plains and the inland plains.

gained, a second photo-interpretation is carried out and patterns are further delineated with the aid of field notes and by extrapolation of field data. In a second field season any remaining problems are resolved and interpretations checked. In the Leichhardt–Gilbert area, the various land traverses were supplemented by an air traverse which was useful in understanding the relationships of various units (Fig. 1).

The method employed is of a reconnaissance nature and the results may need to be modified after more detailed investigations.

II. The Relief and its Evolution

(*a*) *Relief Divisions*

The Leichhardt–Gilbert area comprises two upland divisions separated by a broad lowland corridor (Figs. 2 and 3). In the south-west the Isa highlands exceed 1500 ft in height in places; they have a distinct plateau form in many areas and fall away abruptly to the north-east along an escarpment that trends NNW.–SSE.

* More complete accounts of procedure are given by Christian (1952) and Christian, Jennings, and Twidale (1957).

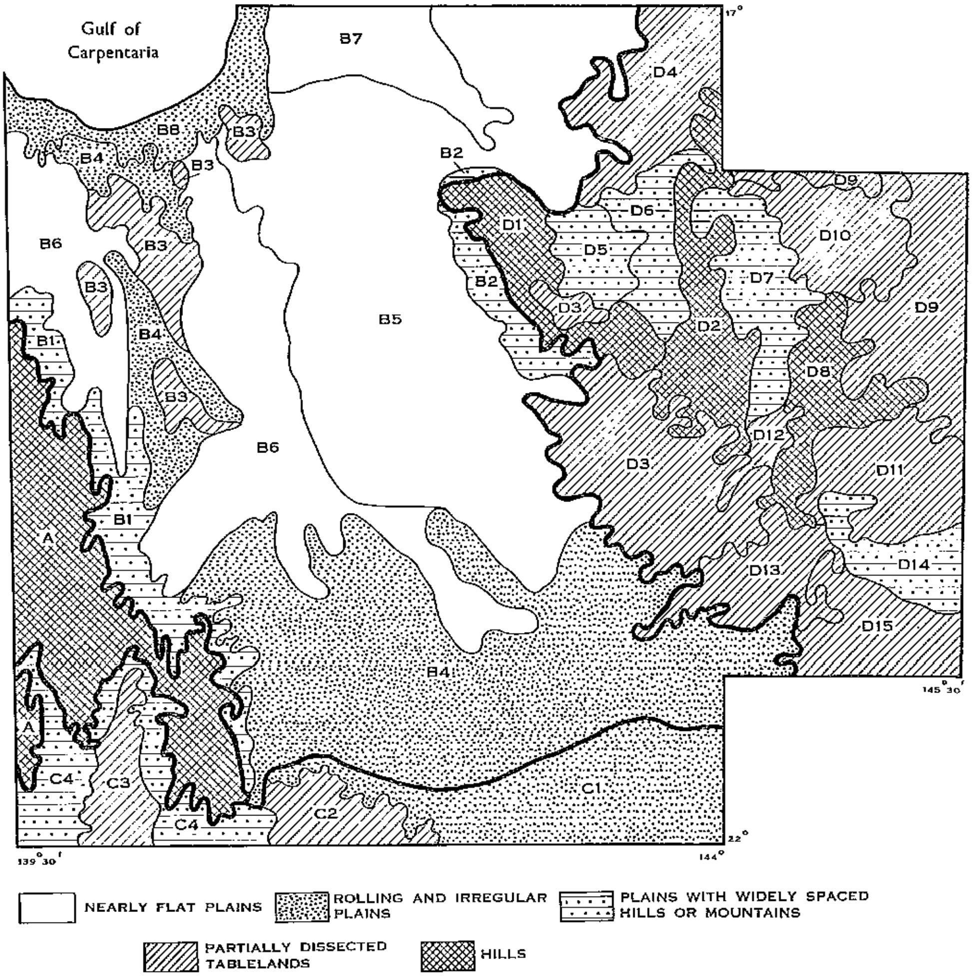

Fig. 4.—Physiographic divisions and relief types. The relief types in the legend are after Hammond (1954). The physiographic divisions are as follows:

A, Isa highlands

B, Carpentaria plains
1, Cloncurry plain
2, Croydon plain
3, Donors plateau
4, Julia plain
5, Claraville plain
6, Wondoola plain
7, Stirling plain
8, Karumba plain

C, Inland plains
1, Diamantina plain
2, Kynuna plateau
3, Devoncourt upland
4, Burke plain

D, Einasleigh uplands
1, Gregory Range
2, Newcastle Range
3, Gilberton plateau
4, Red plateau
5, Gilbert plain
6, Georgetown upland
7, Einasleigh–Copperfield plain
8, Uplands and ranges of the divide
9, Burdekin upland
10, McBride plateau
11, Nulla plateau
12, Chudleigh plateau
13, Sturgeon plateau
14, Cape upland
15, Baronta plateau

Occupying the eastern third of the area, the Einasleigh uplands rise to over 3000 ft in a few localities and form a complex of ridges, plateaux, and high plains. The western part of the Einasleigh uplands is dominated by the Gilberton sandstone plateau, from which radiate several major spurs and ridges such as the Gregory and

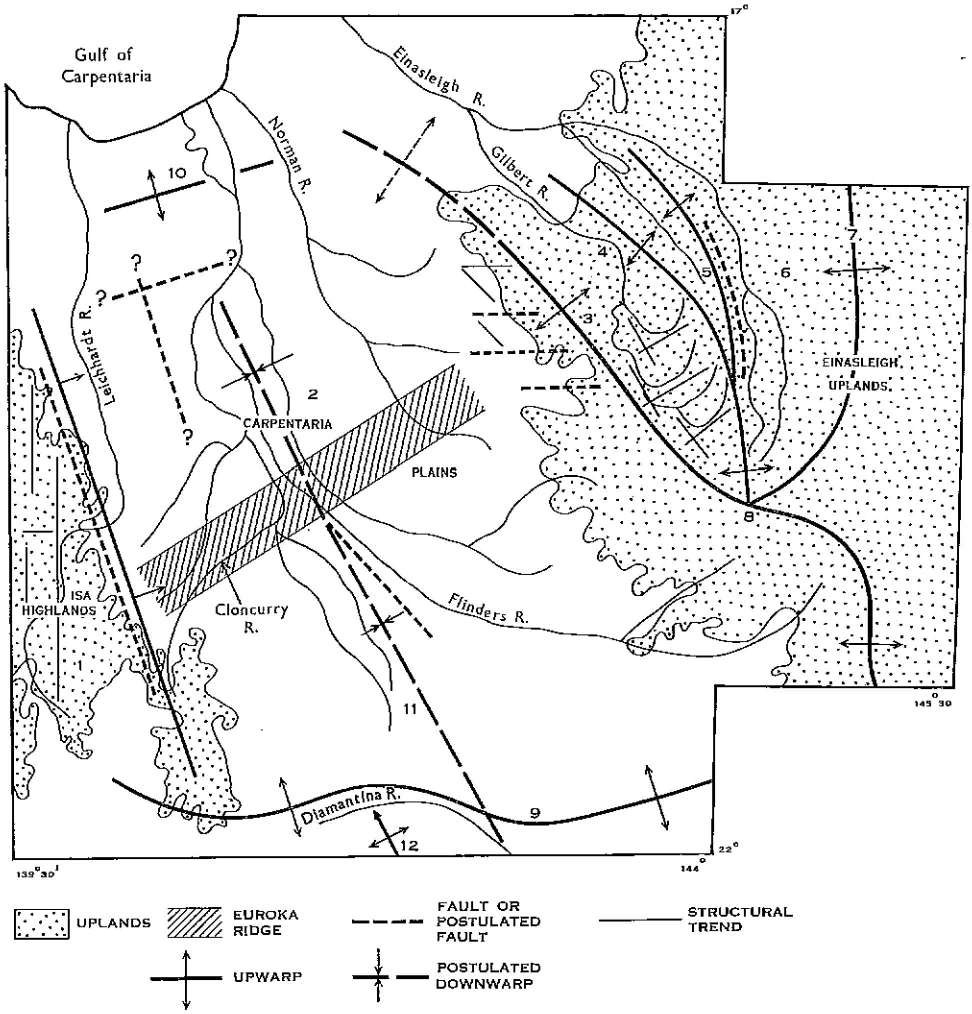

Fig. 5.—Major structural elements and related relief features.

1, Western upwarp	5, Newcastle Range upwarp	9, Selwyn upwarp
2, Central downwarp	6, Downfaulted Einasleigh valley	10, Coastal upwarp
3, Gregory Range upwarp	7, Upwarp of the divide	11, Flinders lineament
4, Gilbert River downwarp	8, Cheviot "knot"	12, Kynuna upwarp

Newcastle Ranges, the average elevations of which diminish away from the central plateau. In the east there are many intricate ridges and ranges, but two major basalt domes, the McBride and Sturgeon plateaux, dominate.

Between these two major upland divisions is a series of rolling, undulating, or flat plains together with isolated mesas and plateaux on major interfluves. The plains rise to elevations of over 700 ft in the far south, and the plateaux south of Kynuna reach over 1000 ft above sea level. The south-western and north-eastern borders of the plains run roughly parallel to about 70 miles from the coast, where there is a broadening and where the lowland loses its corridor form. The lowland is separated into two divisions, the Carpentaria plains and the inland plains, on the basis of drainage. As has been indicated, there are considerable morphological and relief variations within each of the four major divisions (Fig. 4). A geomorphological map accompanies this report and regional details are given in Section III.

The present form of the land surface—the distribution of high and low land—is not fortuitous. Several factors have combined in its evolution, and of these, structure, climate, and the geomorphic history of the area are the most significant.

(b) *Structural Influences*

(i) *Major Structural and Relief Units*.—Both regionally and in detail, the relief of the Leichhardt–Gilbert area directly reflects underlying structures (Fig. 5) and is what has been termed primitive (Birot 1958, p. 28). Tectonic highs correspond to uplands and depressed structures to lowlands, whilst the detailed distribution of high and low ground and the relief trends are directly related to local lithology and the disposition of strata. Thus the south-west, corresponding to the Isa highlands, and the north-east (Einasleigh uplands) have been raised relative to the intervening plains. The eastern margin of the Isa block is set by a strong tectonic lineament trending NNW.–SSE. Warping is clearly evident, but there are also faults parallel to this lineament at the margin of upland and plain (Carter and Öpik 1959). Similarly, at the western border of the Georgetown massif, the Precambrian block occupying the west of the Einasleigh uplands, there has again been pronounced warping and faults also exist.

That the Carpentaria plains occupy a basin of subsidence is attested to by dips and displacement of the basin strata as well as by the attitude of erosion surfaces (Twidale 1956*a*). In several places rocks of the same age are separated by steep scarps, e.g. Lower Cretaceous sandstone, including a thin basal conglomerate, occurs at about 300 ft near Croydon and at over 1000 ft on the nearby Gregory Range. Similarly, rocks of the same age occur both as small residuals atop the Isa highlands at elevations of some 1600 ft and at less than 500 ft above sea level at the foot of the eastern bounding scarp. An early Mesozoic erosion surface occurs at a maximum of over 1600 ft in the Isa highlands, plunges comparatively steeply beneath the Cretaceous sediments of the basin, and reappears on its eastern side, rising to the crest of the Gregory Range; thence it can be traced still further eastwards, displaying considerable undulations, until it is lost high in the ranges close to the east coast.

There is evidence that subsidence in the area of the Carpentaria plains was not symmetrical; as in the Lake Eyre and Murray basins to the south, the deepest part of the structural basin lies towards its western side (Fig. 6; see also Laing and Power 1960, Fig. 49, p. 325). Physiographically, this asymmetry has resulted in a westerly displacement of the northward-flowing rivers, resulting in shorter western and long eastern tributaries (Figs. 5 and 7).

The major tectonic components of the Leichhardt–Gilbert area are, however, complex crustal blocks, and within each are large-scale structures, some of which are accordant with the major epeirogenic lineaments which outline the blocks, others of which are discordant. Beneath the Carpentaria plains and the inland plains, for instance, two major structural depressions affect the sub-Cretaceous floor (early Mesozoic erosion surface). These are the Carpentaria and Eromanga basins, within which again there are minor structural highs and lows. They are separated by the Euroka Ridge, which trends SW.–NE. between the vicinity of Dugald River and Esmeralda (Fig. 5). On this structural high, and protruding above the plains, are two small Precambrian inliers, Mt. Brown and Mt. Fort Bowen. Within the Isa

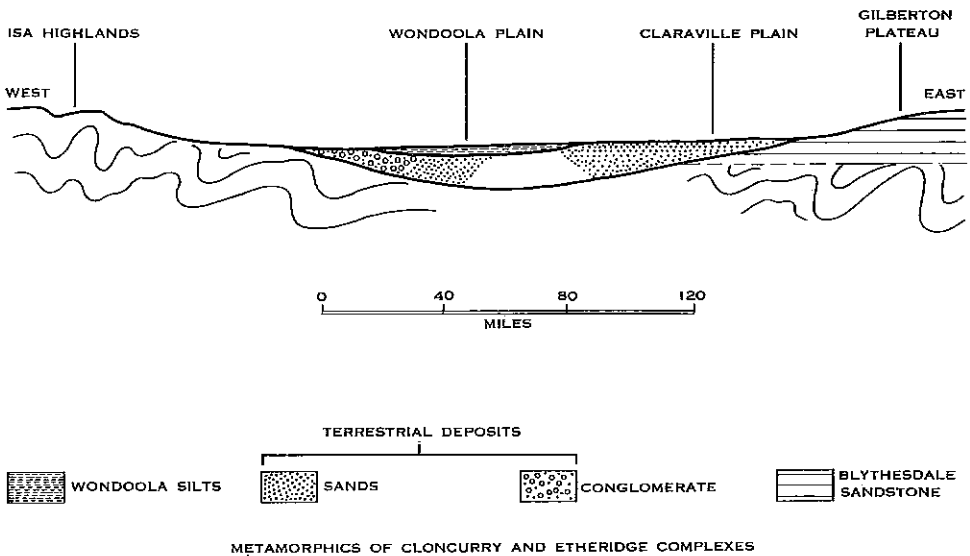

Fig. 6.—Section across the Carpentaria plains.

highlands the many major fold axes run meridionally and are cut across by NNW.–SSE. lineaments. The Einasleigh uplands contain two distinct raised structures, the Gilbert upwarp and the upwarp of the Great Dividing Range. The former is a complex elongate dome within which there are many minor but physiographically significant structures. Numbered amongst them are the upwarps of the Gregory and Newcastle Ranges, the Gilbert River downwarp, and the downfault of the Einasleigh valley. Here again, epeirogenic structures transgress orogenic fold axes in Precambrian and Palaeozoic strata. Meridional warps in and adjacent to the Gilbert River basin, for instance, cut obliquely across tight angular sigmoidal folds with E.–W. axes in the areas of the Gilbert and Langdon Rivers.

(ii) *Structural and Relief Trends*.—Major structures directly affect the drainage of the area in that drainage basins tend to be tectonically determined; in detail, also, individual streams are guided by structure. The straight middle course of the Flinders River, for instance, follows a NNW.–SSE. direction, parallel to the front of the Isa highlands, and it may reasonably be suggested that this course is influenced by a structural trend in the sedimentary rocks which is inherited from a major structure in the Precambrian basement (Hills 1953, 1955). In greater detail, tectonic control of relief is demonstrated by analyses of direction of linear relief and structural trends in the two upland areas.

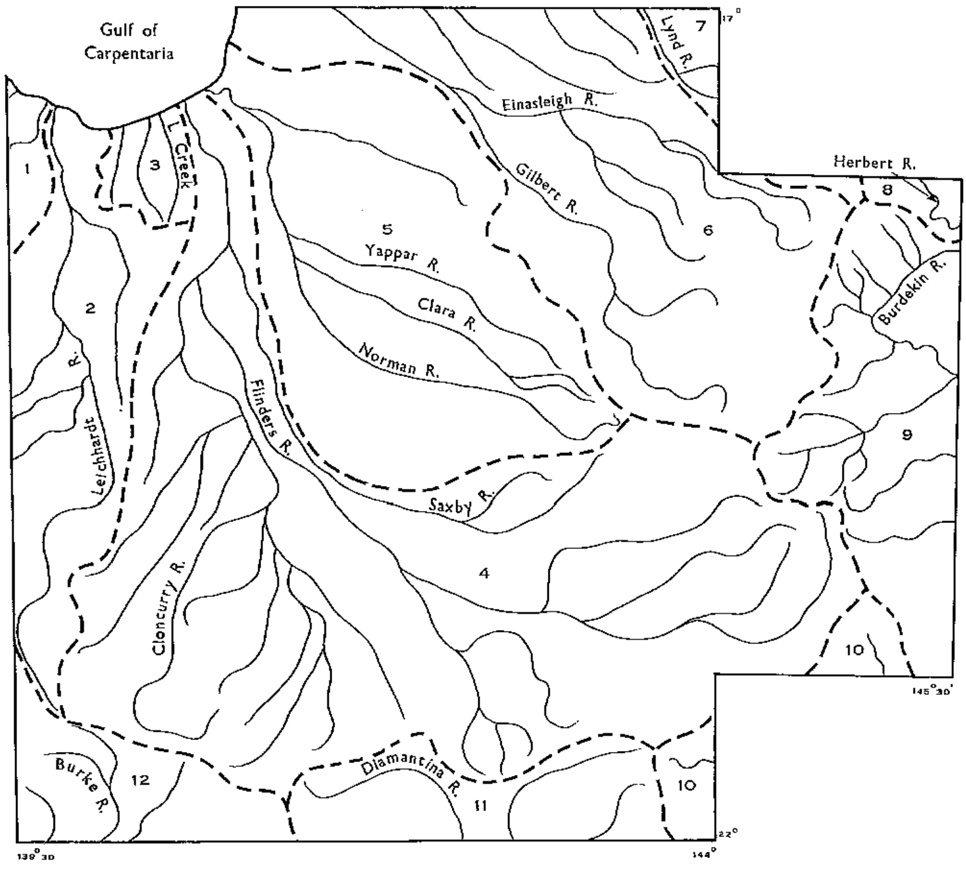

Fig. 7.—Principal streams and drainage basins.

Drainage Basins

1, Nicholson, Gregory, Albert	5, Norman, Clara, Yappar	9, Burdekin
2, Leichhardt	6, Gilbert, Einasleigh	10, Thompson
3, Morning Inlet, L Creek	7, Mitchell, Lynd	11, Diamantina
4, Flinders, Cloncurry, Saxby	8, Herbert	12, Burke

The structural trends (major joint systems, fold axes, faults) and major relief trends were measured from air photographs and the percentage lengths of trends plotted under arbitrary directional limits (Fig. 8). Certain preferred trends are apparent in both diagrams, for almost half the relief trends are south-east, and a further 30% are NE.–SW.* Two structural trends are prominent, namely N.–S. and NE.–SW.

* Inspection of the photographs shows that most of the trends designated NW.–SE. are in fact NNW.–SSE., bearing 330–332°.

In the Isa highlands, more than half the major relief trends, including the spectacular, straight, NE.-facing front of the block, follow a NW.–SE. direction. Within the Isa block the N.–S. structural trend is prevalent, though the NW.–SE. trend is still strong. In the Einasleigh uplands, two major relief trends, NE.–SW. and NW.–SE., are discernible, but in detail within the region, E.–W. and N.–S. trends are also significant.

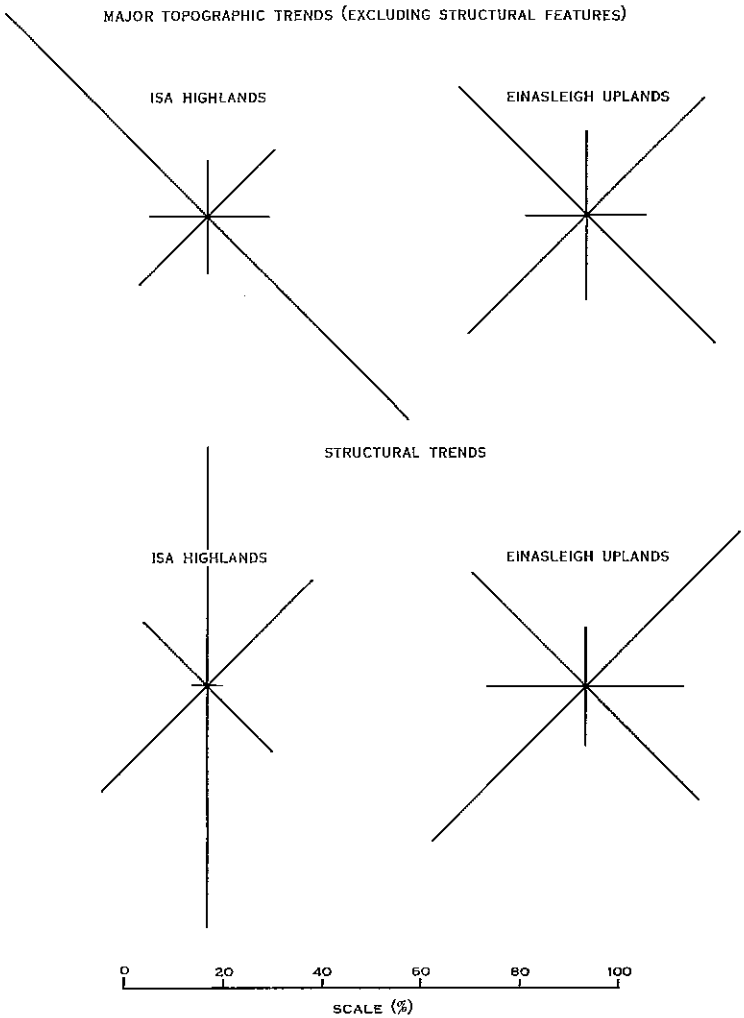

Fig. 8.—Relationship between topographic trends and structural trends, including joints and faults, based on percentage lengths in four directional sectors.

(iii) *Orogenesis and Epeirogenesis*.—The structures to which much of the relief of the study area is attributed date from several geological periods. Orogenesis occurred in the Isa highlands and in the western half of the Einasleigh uplands during the Precambrian, and near the eastern margin of the area during the late Palaeozoic. The vulcanicity evidenced in the Gregory and Newcastle Ranges is possibly related to these episodes of crustal deformation.

Since an early Mesozoic surface of erosion was warped down in the Carpentaria and Eromanga basins, allowing the incursion of late Mesozoic seas, this warping must have occurred in the middle Mesozoic.

The epeirogenic movements which initiated this incursion were guided by the older lineaments. Subsequently, a lateritized early Tertiary land surface was warped, and again the movements were guided by the ancient framework of lineaments, the Carpentaria and Eromanga basins being again depressed relative to adjacent structural divisions. Important subsidiary structures were, however, either developed or renewed at this time. The Kynuna plateau was raised relative both to the Gulf of Carpentaria, which was submerged, and to the Lake Eyre depression, which has suffered recurrent subsidence throughout the Cainozoic. The various structures, warped and faulted, of the Einasleigh uplands were also re-activated at this time, and extensive vulcanicity occurred on the eastern margin of the area in association with this epeirogenic activity.

Still later, possible warping occurred in the Donors plateau and also in the Croydon–Normanton area where it affected the terrestrial deposits of later Tertiary age included in the Lynd Formation (Laing and Power 1959; Allen, Cribb, and Isbell 1960). These movements are significant in that they may have initiated a shallow inundation of, and abrupt change in sedimentation on, the Wondoola plain during the Pleistocene.

The age of these latest movements may be early Quaternary: much hangs upon the precise age of the "Terrestrial Deposits" and of mammalian fossils found in the silts of the Wondoola plain. The well-preserved triangular facets and benches of the Einasleigh fault scarp on the eastern side of the Newcastle Ranges indicate that the earth movements here also cannot be of any great geological age.

Possibly the best evidence for neotectonism, however, is the Selwyn upwarp (Fig. 5), which forms the present watershed between the Gulf and inland drainage systems and represents a northward migration of the divide from the Kynuna plateau. The Selwyn upwarp obviously post-dates the early Tertiary, for the surface of this age on the Kynuna plateau had suffered virtual elimination before the upwarp developed. Furthermore, the major streams (Leichhardt, Flinders) which flow to the Gulf and drain the Carpentaria plains have recently changed from meandering to braiding, a change accompanied by channel incision and the abandonment of some courses. It is reasonable to suggest that a steepening of gradients is involved here, and thus that the Selwyn upwarp caused this change in habit. The change occurred after the Pleistocene silts of the Wondoola plain had been deposited (Bryan and Jones 1946, pp. 75–8). Since the lower sections of the braiding river plains are being further incised as a result of a late Pleistocene or Recent eustatic fall of sea level of some 20 ft, the Selwyn upwarp must have been active before these regressions.

(iv) *Lithology and Relief*.—The detailed sculpture of the land surface is intimately related to the differential weathering and erosion of the various rock types. Resistant quartzite and porphyry, for instance, tend to form upstanding masses; granite and limestone each develop a characteristic suite of land forms; siltstone and clay tend to offer little resistance and are eroded relatively rapidly to form lowlands and valleys.

TABLE 1

STRATIGRAPHIC UNITS OF THE LEICHHARDT–GILBERT AREA

(Modified after Prichard 1964)

Geological Unit	Lithology
CAINOZOIC	
Quaternary	
Alluvium	Fine- and coarse-textured alluvium
Littoral deposits	Saline muds and shell banks
Toomba and Kinrara Basalts	Scoriaceous lava flows
Tertiary to Quaternary	
"Terrestrial Deposits"*	Pebbly clays, conglomerate, sandstone, ferruginous siliceous grit
Basalt	Basalt flows
Glendower Formation	Conglomerate and sandstone
MESOZOIC	
Cretaceous	
Rolling Downs Group	Siltstone, shale, thin limestone beds
Triassic to Lower Cretaceous	
Various	Sandstone sequences with minor siltstone and conglomerate
PALAEOZOIC	
Carboniferous to Permian	
Sediments Gilberton Formation	Sandstone, minor siltstone
Croydon and Newcastle Range Volcanics	Porphyritic intermediate to acid volcanics
Siluro–Devonian	
Various	Siltstone, greywacke, limestone, including low-grade metamorphic phases
Cambrian	
Various	Siltstone, limestone, minor sandstone, conglomerate
UPPER PROTEROZOIC TO PALAEOZOIC	
Plutonic rocks	Granite, some granodiorite
Etheridge complex	Schist, gneiss, phyllite, slate, amphibolite, quartzite
PROTEROZOIC	
Conclurry complex	Schist, granite, gneiss, phyllite, slate, amphibolite, quartzite; includes granite where not mapped separately

* Included in the Lynd Formation of Laing and Power 1959; see also Allen, Cribb, and Isbell 1960.

The effect of lithology is considered in detail in the regional descriptions in Section III, but some idea of the range of rock types and their distribution may be gathered from Table 1, and from the small-scale geological map inset on the accompanying map sheet.

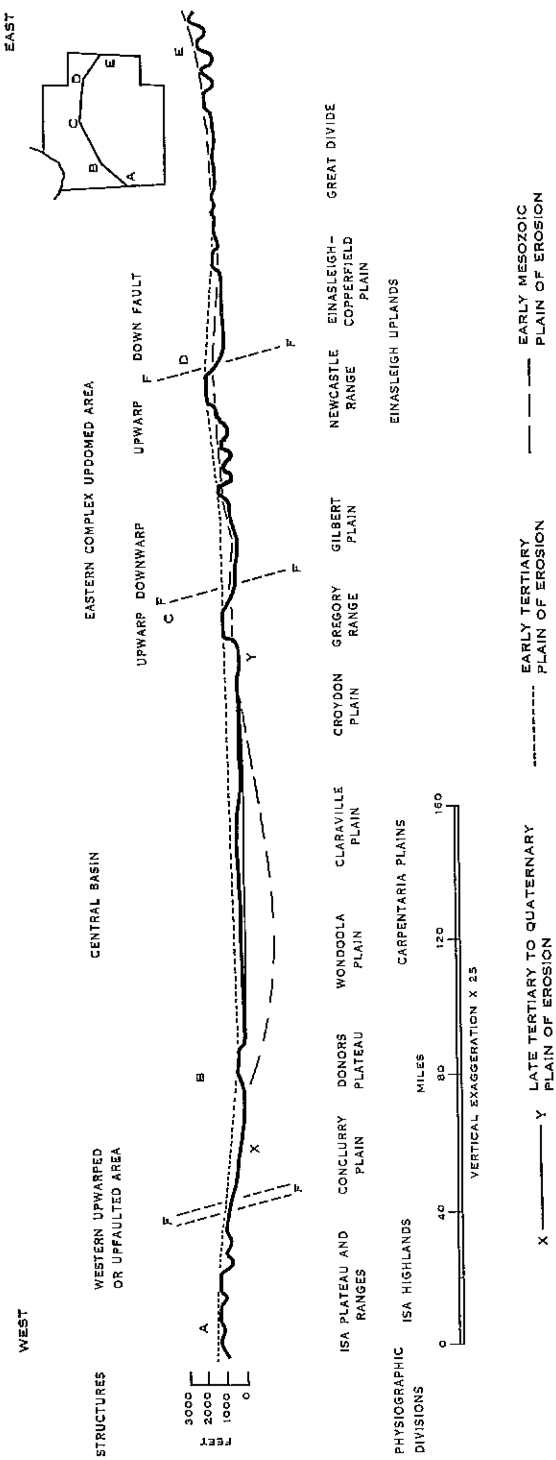

Fig. 9.—Section across the Leichhardt–Gilbert area showing the incidence of surfaces of erosion.

(v) *Laterite.*—One rock type not shown in Table 1 but which predates the "Terrestrial Deposits" and post-dates the Glendower Formation and is therefore of mid Tertiary age, is the laterite. This is part of a weathering profile developed on many stratigraphic units, though principally on the Cretaceous. On account of its geomorphological significance as a time marker, it is useful to determine its age range.

Lateritization has affected the Glendower Series, which rest upon Cretaceous strata in the Baronta scarp east of Hughenden; thus lateritization was proceeding at some time during the Tertiary. In the Carpentaria plains, Pleistocene silts are underlain at shallow depth by the "Terrestrial Deposits", which are mottled and which have been derived from erosion of the lateritized land surface. They therefore post-date lateritization. The age of the "Terrestrial Deposits" is not known precisely, but they may tentatively be assigned to the Pliocene or early Pleistocene. Since lateritization ceased earlier than this, it may be considered a mid Tertiary phenomenon.

(c) *Geological and Geomorphological History*

(i) *General.*—The present relief includes significant elements of earlier landscapes developed under geological and climatic conditions different from those obtaining now (Fig. 9). Thus, an understanding of present forms rests on a reconstruction of past events. Analysis of older land surfaces suggests that they have been affected by recurrent earth movements along ancient and well-established lineaments, acting consistently in the same sense. As the Leichhardt–Gilbert area encompasses parts of the three major structural and physiographic units of which Australia is built, namely western shield, central basin, and eastern highlands, the geological and geomorphological history of the area can conveniently be summarized under these heads (Fig. 10). Finally, not only does the reconstruction of land surfaces provide evidence for ancient earth movements, but analysis of present forms is suggestive of recent and continuing crustal activity.

(ii) *Orogeny and Sedimentation in the West.*—No more ancient rocks than the Proterozoic strata of the Cloncurry complex are known for certain in the area. The complex comprises sedimentary and volcanic and other igneous rocks which were weakly metamorphosed during late Proterozoic orogenesis in which the dominant pressure appears to have come from the east; consequently, the regional trend of the complex is meridional, a trend which finds strong expression in the grain of relief.

The distorted strata were thrust up and subjected to subaerial planation. During Cambrian times the sea occupied an area of unknown extent in the south-west of the Leichhardt–Gilbert area, but Cambrian sediments are preserved only in an infaulted block in the Burke River area, and as cappings of a few mesas, such as Mt. Bruce and Mt. Aplin, north-west of this graben (Öpik 1961).

(iii) *Inception of the Palaeozoic–Mesozoic Cycle of Erosion.*—No strata of ages intermediate between these Cambrian rocks and the Mesozoic sediments have been recognized, though rocks of Ordovician age are known from adjacent areas, and it appears that the period from the Silurian to the early Jurassic was one of non-deposition here. During this interval, the Cambrian strata were very largely stripped from the area.

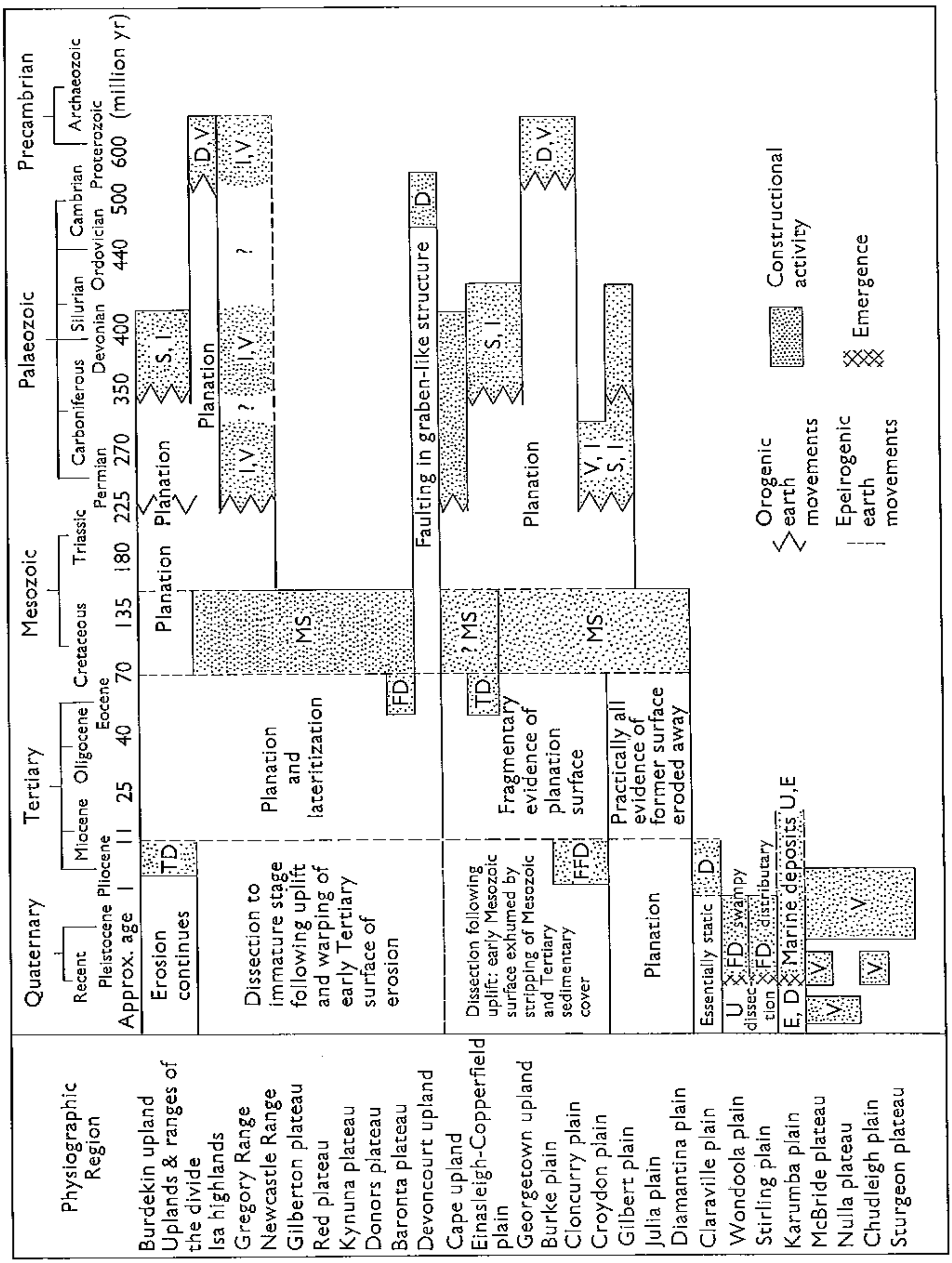

Fig. 10.—Summary of the geologic and geomorphic history of the Leichhardt–Gilbert area.

D, deposition
E, erosion
FD, fluvial deposits
FFD, fluvial fan deposits
I, igneous activity
MS, marine sedimentation
S, sedimentation
TD, terrestrial deposition
U, uplift
V, vulcanicity

The evidence of this Palaeozoic–Mesozoic erosional cycle is the striking unconformity between the Precambrian and the overlying Mesozoic sediments, which suggests that a stage of advanced planation was attained.

(iv) *Sedimentation and Orogeny in the East.*—It is thought that much of the detritus derived from the down-wearing of the two Precambrian blocks—the Isa block and the Georgetown massif—was carried eastwards and deposited in the Tasman geosyncline, a structure probably initiated by the same late Proterozoic orogenesis which caused folding and uplift in the present Isa highlands. The sediments have since been affected by two possible sets of orogenic movement with intrusion and low-grade regional metamorphism. In the east, volcanic extrusion accompanied all these movements, ranging from late Proterozoic through Palaeozoic time.

(v) *Extension of the Palaeozoic–Mesozoic Cycle.*—As sedimentation and orogeny were taking place in the east, planation continued in the west and extended eastwards. By early Mesozoic times the whole of the Leichhardt–Gilbert area was reduced to a plain which was of greater age in the west (Silurian to Triassic inclusive) than in the east (Triassic only) and which can hence be regarded as polycyclic. This widespread ancient surface is preserved beneath the Artesian Basin (Fig. 9).

(vi) *Mesozoic Sedimentation.*—The long Palaeozoic–Mesozoic cycle of erosion was terminated by earth movements which warped the plain surface and allowed the incursion of an epeiric Mesozoic sea in the Carpentaria and Eromanga basins.

In some localities, the warping which initiated the depositional period at first gave rise to separate small basins in which terrestrial sediments containing plant remains accumulated; such are the strata that occur at the margins of the Jurassic sedimentary basin and that form the outliers of Mt. Flattop and Mt. Dromedary in the Strathearn area. Soon, however, marine conditions prevailed throughout and sandstone, greywacke, shale, mudstone, limestone, and conglomerate were laid down. A widespread cover of Mesozoic sediments was formed and at the close of the era ranges of Palaeozoic rocks protruded only in the east of the Leichhardt–Gilbert area.

(vii) *Early Tertiary Planation.*—Uplift and warping in the late Cretaceous or early Tertiary initiated widespread subaerial erosion of the Mesozoic sediments, but in a few localities terrestrial deposition occurred as a result, for instance east of Hughenden. The Cretaceous shales, in particular, were susceptible to erosion, but the sandstones were more resistant; however, by the middle of the Tertiary much of the Leichhardt–Gilbert area had again been reduced to low relief and underwent extensive lateritization. The perfection of this early Tertiary surface is indicated by the flatness of plateau remnants.

The major drainage elements were initiated upon this surface in close relation to structures in the Cretaceous rocks. In a few areas the streams have eroded through these and have been superimposed discordantly on older structures. Examples of such superimposed drainage are the upper reaches of the Robertson River, the Broken and Clarke Rivers (White, Wyatt, and Bush 1960), and parts of the upper Burdekin (White and Wyatt 1960), though here volcanic activity has had some deranging influence.

(viii) *Late Tertiary–Quaternary Events*

(1) *Warping and Erosion*.—The early Tertiary plain was uplifted and warped in mid and late Tertiary times, and there was initiated a new planation which is still extending. The earth movements cannot be dated precisely, but the evidence suggests an approximate Miocene date for the inception of this new cycle.

As the streams began to adjust themselves to the lower base level, the new erosional surface began to extend inland along the river valleys. In the central part of the Artesian Basin, where easily eroded Cretaceous shale preponderates, it quickly developed into a plain of erosion lower than the early Tertiary surface.

At the upland margins of the basin and within the ranges, the Cretaceous and Cambrian strata were removed, exposing the early Mesozoic and pre-middle Cambrian surfaces. The upland plateau surfaces eroded across Palaeozoic and older strata are a reflection of their exhumation, in particular the even skyline of the Isa highlands.

On the unresistant Cretaceous outcrops of the Carpentaria plains and the inland plains the lowlands have been reduced by dissection along stream lines and washing of divides. Except for the common braided habit of the streams these plains have, over the greater part of the area, the form of typical Davisian peneplains. It should be borne in mind, however, that there is no indication of their past mode of development—only of their present form and sculpture. Where the plains extend onto granite and other crystalline rocks, or where the adjacent plateaux and uplands are constructed of or capped by resistant rocks, the plains take on different forms. Gone are the summit convexities and the deep soil cover; instead there are remarkably smooth, low-angle plains with few lines of concentrated drainage. They bear a thin discontinuous cover of detritus, appear to be moulded by rills and sheetwash, and join the backing scarps in an abrupt break of slope, the piedmont angle. The latter is truly angular only where developed on granite (Twidale 1956*e*), and is sharply concave upwards on other rocks such as amphibolite, or where the backing escarpment has a hard capping above less resistant rock. Thus in this area there is corroboration for Baulig's (1956) assertion that peneplains are characteristic of soft rocks and pediments of hard rocks.

(2) *Deposition*.—The rivers which carved the late Tertiary–Quaternary plain deposited some of their load extensively in their lower reaches and in small basins formed by warping in upland regions.

The deposits related to the late Tertiary–Quaternary cycle in the Burdekin upland and the Isa highlands consist of lateritic debris accumulated in shallow depressions in the warped early Tertiary surface. In the Carpentaria plains, the corresponding sediments are the "Terrestrial Deposits", those fluviatile sandy strata of the Claraville plain which accumulated on the downwarped lateritized surface as a major low-angle fan resulting from dissection of the same lateritized surface upslope. Concurrently, on the opposite, western side of the Carpentaria plains, coarser fan deposits were laid down as a result of the erosion of the upwarped Isa highlands.

In early Pleistocene times, outfall conditions changed, as a result either of increased rainfall, as postulated by Whitehouse (1940, pp. 63–4), or of a gentle upwarping behind the coast. Slow uplift there would impede outfall and cause the development of poorly drained swampy alluvial tracts, such as the Wondoola plain, on the inland side. To the north of the Claraville plain, the distributary Stirling plain was formed at the same time.

(3) *Neotectonism.*—The tectonic movements that affected the Leichhardt–Gilbert area during the late Tertiary–Quaternary have been mentioned previously, but their geomorphological effects may be considered in more detail under the headings of warping and faulting.

Warping.—A small late Pliocene or early Pleistocene upwarp trending SE.–NW. has affected the "Terrestrial Deposits" of the Claraville plain between Croydon and Normanton, causing a divergence of drainage, and the same movement may also have affected the Donors plateau, causing the widespread alluviation of the Wondoola plain.

Faulting.—Faulting on the east coast of Australia adjacent to the eastern borders of the Leichhardt–Gilbert area has been reviewed by Cotton (1949). Like Taylor (1911) and Stanley (1928), Cotton is emphatic in stating that NNW.–SSE. faulting has occurred and that the great gorges, such as the Herbert, are due to resulting rejuvenation which has affected all the streams flowing to the Pacific. The Herbert Falls and part of the gorge are within the Leichhardt–Gilbert area. Since the Herbert gorge is incised into the lateritic early Tertiary surface, this rejuvenation must have occurred in late Tertiary and Quaternary times.

The Einasleigh fault scarp on the east side of the Newcastle Range also probably formed at this time.

(4) *Vulcanicity.*—The earth movements that initiated the late Tertiary–Quaternary erosion cycle were associated with spasmodic vulcanicity of a multiple central-vent type in the east of the area* (Plate 8, Fig. 1). It is known from evidence of weathering and denudation that the vulcanicity was not continuous, and from the contrasted weathering and dissection of the basalts and their foci, distinct phases of eruption can be recognized. Within the McBride plateau, for instance, there are three basalts in the following succession:

Kinrara Basalt,
Newer McBride Basalt,
Older McBride Basalt.

In the Nulla plateau there are thought to be two basalts—the younger, Toomba Basalt, and the Nulla Basalt. In the Chudleigh plain there are two basalts, the newer and older Chudleigh, while in the Sturgeon plateau only one period of vulcanicity has been distinguished. The various basalts are correlated below, and ages have been tentatively assigned to them from a comparison with the weathering of Victorian and other flows:

Kinrara and Toomba Basalts—late Pleistocene to early Recent,
Newer McBride and Chudleigh Basalts—early to mid Pleistocene,
Older McBride and Chudleigh, Sturgeon, and Nulla Basalts—late Tertiary to early Pleistocene.

* For detailed discussion, see Twidale (1956*c*).

Thus a general south-to-north movement of vulcanicity is indicated, and the phenomena may perhaps be considered to be an after-effect of late Tertiary warping and to have been continuous from the inception of the movement almost to the present day. There are still active volcanoes further to the north, in New Guinea, but in north-west Queensland there is only scattered and minor solfataric activity.

The vulcanicity caused modifications of drainage which have been admirably described by Taylor (1911, p. 10), and which will be referred to in the regional accounts in Section III.

The most important effect of the basalt extrusion was a diversion of former Gulf drainage, e.g. the Upper Burdekin, to the Pacific.

(5) *Coastal Development.*—On the shore of the Gulf of Carpentaria, warping brought the lateritized early Tertiary surface within range of wave action. A low cliff was cut and in front of it a marine terrace was formed. A combination of low offshore gradients, ineffective wave action, and an ample supply of debris resulting from denudation inland favoured the development of constructional coastal forms (Twidale 1956*b*). Barrier beaches and islands were developed and driven inland.

Emergence of the order of 20 ft has since occurred, resulting in the dissection of the older marine terrace, the abandonment of higher beach ridges, and the formation of a lower, younger terrace.

Following this emergence, the lower reaches of valleys in the Carpentaria plains were incised into the wider, older valleys. The phenomenon is well marked on the Leichhardt, where the nick-point associated with the rejuvenation is represented by the Leichhardt Falls (Plate 6, Fig. 1), but it is also evident on the Flinders and Gilbert, although, because of weaker bed-rock, no falls or rapids have developed there.

(*d*) *River Patterns and Regimes*

(i) *Major Drainage Systems.*—By far the greater part of the Leichhardt–Gilbert area drains to the Gulf of Carpentaria, with small areas on the south draining inland to Lake Eyre and on the east to the Pacific (Fig. 7). The divides between these major systems are inconspicuous and mainly result from warping of the early Tertiary surface, with minor modifications due to later vulcanicity and warping. The centripetal drainage of the Carpentaria plains expresses the broad basin structure, and its asymmetry reflects that of the structural basin. In the upland areas structural control is closer and more complex, and has been generally treated above and in detail in the regional descriptions.

(ii) *River Regimes.*—The salient features of the climate of the Leichhardt–Gilbert area have been summarized elsewhere (Slatyer 1964); here it is necessary only to emphasize those significant to river regimes.

Although data are not available for all streams, the catchment area, mean annual rainfall, and estimated mean annual run-off of the principal river systems are given in Table 2. Climatic characteristics significant to drainage are the moderate to low annual rainfall, the strongly seasonal rainfall regime, the decrease of rainfall inland, and the high temperatures and high potential evaporation. As a result, streams are intermittent (Plate 9, Fig. 2).

Run-off is low (less than 4%), for rains occur principally in summer when temperatures and evaporation rates are high, but the rivers respond rapidly to rain because of lack of vegetation cover, and the bare, crusted soils. The rivers flowing to the Gulf run from areas of lower to areas of higher rainfall (see inset map of climate), thus increasing a tendency to seasonal flooding. The situation is further accentuated by the fact that in the Gulf of Carpentaria the higher tides are largely meteorological, such that the rain-bearing north-west winds also bring the highest tides; thus outfalls are seriously impeded, and the seasonal run-off from some 100,000 sq miles of north-west Queensland is checked, causing extensive flooding near the coast.

TABLE 2

DATA FOR PRINCIPAL RIVER SYSTEMS

(Largely after Nimmo 1948)

Stream System	Catchment Area (sq miles)	Mean Annual Rainfall		Estimated Mean Annual Run-off	
		(ac ft)	(in.)	(ac ft)	(in.)
Streams flowing to Gulf of Carpentaria					
Leichhardt	12,199	13,660,000	21·0	195,000	0·3
Morning Inlet	1,714	2,365,000	25·9	64,000	0·7
Flinders, Cloncurry, Saxby	41,604	43,500,000	19·6	550,000	0·25
Norman, Clara, Yappar	19,566	27,050,000	25·9	731,000	0·7
Gilbert, Einasleigh, Staaten*	28,032	46,600,000	31·1	2,392,000	1·6
Streams flowing to Pacific					
Herbert*	3,760	10,710,000	54·3	4,077,000	20·4
Burdekin*	50,489	68,620,000	25·5	4,617,000	1·7
Streams flowing to Lake Eyre					
Farrar, Diamantina†	46,367	27,800,000	11·25	—	—
Hamilton, Burke,† Georgina, Mulligan	56,793	30,000,000	9·9	—	—

* Much of the lower reaches of these rivers lies outside the Leichhardt–Gilbert area.

† Only a small portion of the headwaters of these streams is situated within the Leichhardt–Gilbert area.

(iii) *Channel Characteristics.*—Braiding occurs in some parts of every drainage system in north-west Queensland and is the outstanding characteristic of the rivers. On the lowlands, streams are commonly braided from inception, and in the uplands they may have several braiding channels long before the open plains are reached. Frequently, streams are both braided and meandering, when they are termed reticulate (Whitehouse 1944, pp. 189–91). Only in the steep and rocky headwaters and near the coast are the rivers not braided. Braiding is most fully developed on the open plains, where rivers achieve many channels and attain great widths (Fig. 11). In flood, the river occupies overflow channels called sloughs or chutes, such as the Alexandra River (Fig. 12), north of Kamileroi. This is a series of shallow, ill-defined channels which convey water from the Leichhardt River in a NNE. direction to the

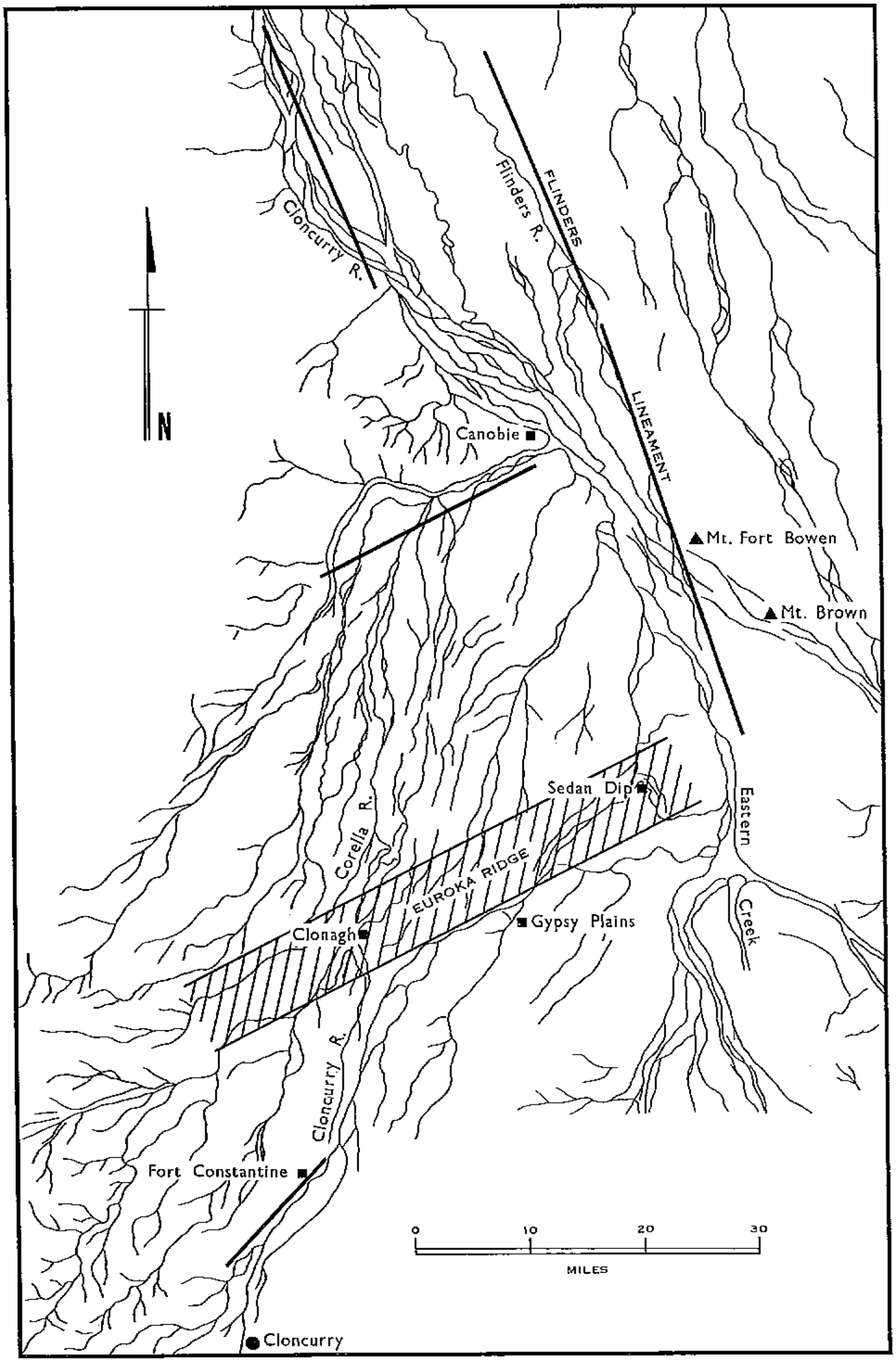

Fig. 11.—Internally braided drainage and structural lineaments in the Carpentaria plains.

Talawanta–Neumayr area, where the overflow is ponded to form a shallow ephemeral lake until the floods recede. Some of the water in the lake makes its way back to the

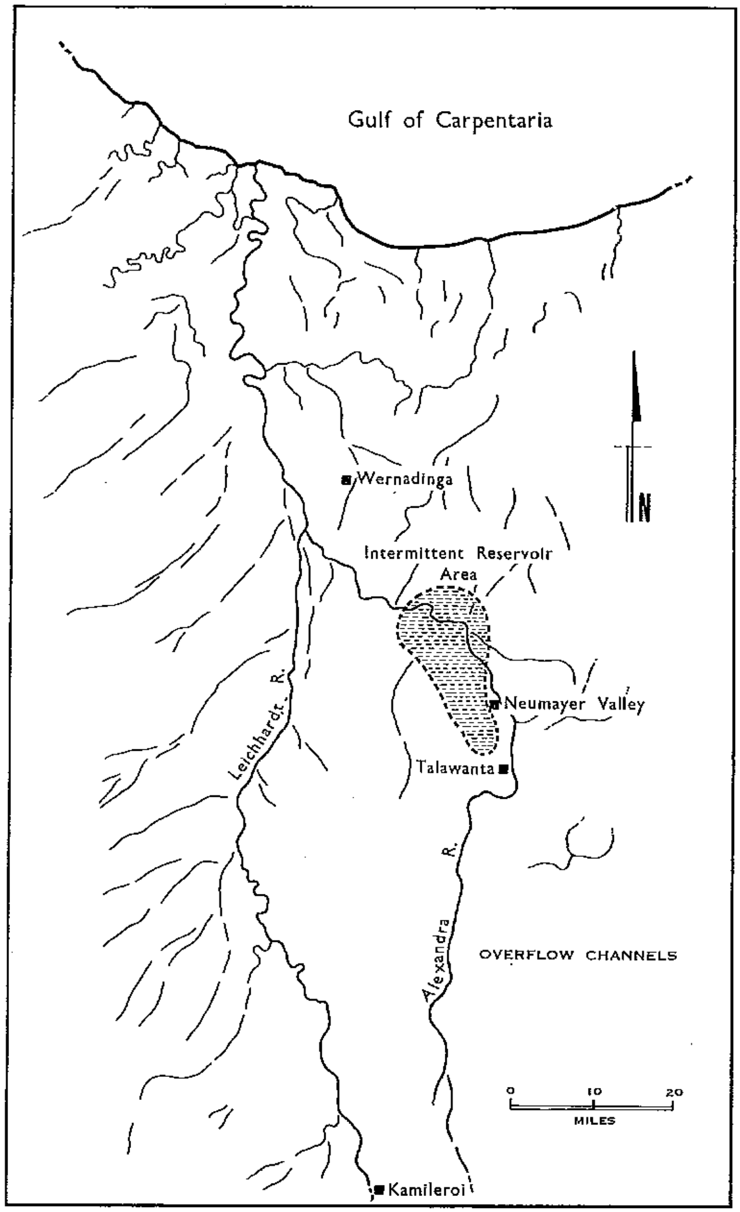

Fig. 12.—The Leichhardt River and its overflow channel, the Alexandra River.

main stream by way of a number of shallow channels which join the Leichhardt south of Wernadinga, but much is lost in evaporation as the lake degenerates into a series of swamps.

Some channels are braided on a grand scale, as where the Cloncurry River divides some 10 miles north of Fort Constantine (Fig. 11). The main branch proceeds north-east to be joined near Sedan Dip by the Williams and Gilliat, and then flows NNW. to mingle with the Flinders channels to the west of Mt. Fort Bowen; the minor distributary proceeds north to join the Corella near Clonagh, thence north-east to join the Cloncurry at Canobie, where the Cloncurry and the Flinders are branches of a single broad system. The distance between division and junction is 60 miles.

Most of the braided sectors are long, extending from far into the hill country to within 40 miles of the coast, where the several channels coalesce in a single channel which follows a relatively straight course for a few miles until laciniate meanders develop (Melton 1936). These, in turn, give way to meanders that are unusually sinuous and in places surprisingly angular (Plate 7, Fig. 1).

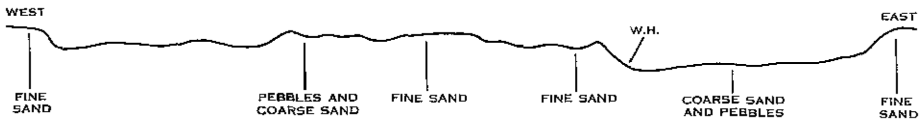

Fig. 13.—Braiding rivers of the Carpentaria plains: section across the Einasleigh River at Talaroo. *W.H.*, waterhole.

Each river is to some extent individual in its patterns. For instance, between its emergence from the hills and the coastal zone, the Gilbert has a broad, long distributary sector in which, however, many of the individual distributary channels have developed laciniate meanders. The Leichhardt River, in all but its lowest reaches, has more rock exposed in its bed in the plain sector than any other major river in the area, and its braided zone is of less than average width. The major streams of the basalt regions in the east commonly have gorges, and their channels, save at tributary junctions, are constricted and not braided. Rivers such as the Williams and McKinlay that rise on the rolling relief of the Julia plain exhibit braided patterns practically from their sources.

All, however, conform to a general pattern, and in ideal sequence the following sectors can be discerned: a hill sector of structurally guided, ungraded, and unbraided channels; a long braided sector; a hinterland sector of laciniate meanders; and a coastal sector of extreme and angular sinuosity.

There is an ordered sequence of channel cross-section which correlates with the downstream sequence outlined above. Typical cross-sections of the Einasleigh River (Fig. 13) and of the Leichhardt River at several points along its course (Fig. 14) are illustrated. Two types of braided section have been noted: the first type comprises interwoven channels cut deeply into alluvium and formed by distributing floodwaters; the second type is those which have formed by subdivision of a single channel through the development of depositional islands. The second type is extremely common and also occurs within major channels of the first type. The middle Flinders, the Gilliat–McKinlay–Williams system, and the Corella–Dugald system provide examples (Fig. 11). The composite channels are very wide, though shallow. The debris islands are commonly steep-sided and well vegetated, and in the larger rivers they stand high above the river bed.

(iv) *Significance of Braiding*.—Braiding has usually been considered characteristic of heavily laden streams, but more recently it has been viewed as one of several possible equilibrium forms of a river channel and not necessarily a result of "overloading" (Leopold and Wolman 1957). Whether a river meanders or braids depends on a complex of variable factors (discharge, volume of sediment load, channel width, channel depth, roughness of channel, slope, and velocity), the precise interrelationships of which are not understood. As a result of their observations, Leopold and Wolman conclude that:

(1) When slope decreases, then, for the same discharge, meandering and not braiding will develop. Braided sectors are steeper than meandering ones.

(2) Similarly, when slope increases still further above a critical limit for the same discharge, a braided habit can give way to meandering.

(3) In flume experiments of braiding development, shoals tended to grow initially in the centre of the channel. They grew to water level because the central zone remained the primary area of deposition even when the water became extremely shallow due to the growth of the shoals. Its growth involved local sorting, and it comprised the coarser debris of the load.

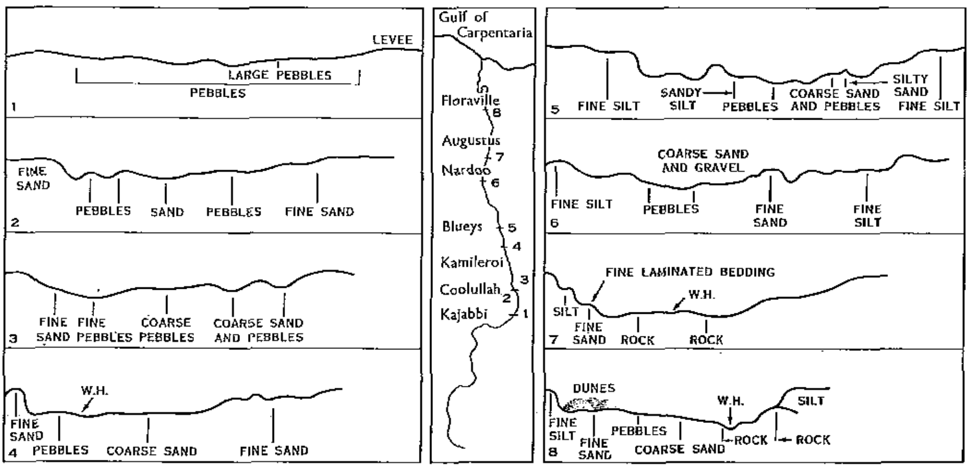

Fig. 14.—Braiding rivers of the Carpentaria plains: selected cross-sections of the Leichhardt River. *W.H.*, waterhole.

These conclusions are pertinent to an understanding of the rivers of north-west Queensland. There is evidence that meanders were once more common in what are now braided sectors. In the Pleistocene alluvia adjacent to the Flinders at Wondoola, for instance, aerial photographs show that there were scrolls and laciniate meanders. Similarly, adjacent to the Leichhardt between Kamileroi and Augustus Downs, there are covered plains (Melton 1936) with well-defined sandy levees and sinuous silty back-slope depressions. The present braided rivers have cut into these older depositional patterns. The change in habit, following Leopold and Wolman (1957), may have resulted from an increase in river gradient, which could be attributed either to a fall in base level downstream or to general uplift to the south. As suggested earlier, movement of the Selwyn upwarp appears to have been responsible.

Where a river is divided into a number of channels, the two major courses are always the outer ones (Figs. 13 and 14). Leighly (1934) has described two major zones of turbulence in rivers, each located between bank and mid-stream. Between, *in the centre of the channel*, is a quiet zone where deposition can take place. This can explain the patterns observed by Leopold and Wolman (1957). Coarser material accumulates and a shoal grows upwards to be exposed at low water and become stabilized by vegetation. Accumulation continues at the downstream end or tail of the debris island, for it is here that the newest, unstabilized debris is most commonly found. Islands can develop in other ways, e.g. as a result of obstacles, and islands can also be subdivided, but deposition in the centre of the stream combined with erosion in the marginal zones of turbulence tends to make the two largest channels migrate laterally and, in so doing, cause the braid complex to be widened.

Particular circumstances operating in north-west Queensland may have caused an unusual profusion of braided channels. First, even shallow shoals are exposed for long periods, when they can be colonized and stabilized by plants. Second, the intermittent regime results in excessive alluviation—compared with permanent streams—so that there is always an abundance of material to be moulded into shoals. Third, the brief but often heavy discharges may tend to the development of a trough-shaped channel cross-section (Mackin 1948).

III. Regional Descriptions

In this Section detailed descriptions are presented of the 28 physiographic regions into which the Leichhardt–Gilbert area has been subdivided. Constant reference should be made to Figure 4 and to the accompanying geomorphological map.

(*a*) *Isa Highlands* (*7300 sq miles*)

The Isa highlands occupy the west and south-west of the area. They comprise a series of predominantly N.–S.-trending ridges and hills which exceed 1650 ft in places, but which average between 1200 and 1500 ft above sea level (Plate 1, Fig. 1). As well as small plateau remnants, there is a marked accordance of crests, and the division has clearly evolved as a major plateau which has since been largely dissected.

(i) *Geology*.—The highlands correspond with the Isa block and consist of Proterozoic metamorphic and igneous rocks of the Cloncurry complex; granite, quartzite, gneiss, schist, amphibolite, phyllite, limestone, and shale are the most common rock types. Many strata are highly contorted and steeply inclined. The region is delineated by NNW.–SSE. trends of very ancient origin, but within the tectonic block there are important N.–S. and E.–W. trends which find physiographic expression. Faults of widely varying strikes are common (Carter and Öpik 1959).

Gently dipping or horizontal conglomerate and arkose of Jurassic or Cretaceous age (Öpik, personal communication) are "sporadically distributed over the Cloncurry district" (Anon. 1936, p. 50). They rest unconformably on the Proterozoic metamorphics and give rise to the small isolated mesas which protrude above a generally even skyline (Plate 1, Fig. 2).

(ii) *Drainage and Land Forms.*—There are two terrain types: a narrowly dissected plateau and areas of more advanced dissection with limited plains.

(1) *Narrowly Dissected Plateau.*—This runs northwards from Mt. Isa and forms the backbone of the Isa highlands. The most common land forms are long flat-topped ridges and plateau remnants topped by low mesas. The plateau surfaces are best preserved on resistant quartzitic rocks and are particularly prominent in the north. Relief amplitude ranges between 500 ft near major rivers and 20 ft on major divides.

The plateau surface bevels the various strata. In places it is secondarily silicified, and ferruginous gravels occur in some depressed areas on it, but the surface cannot be described as lateritized. However, Öpik (personal communication) reports lateritized subhorizontal Cretaceous strata above the Precambrian to the west of the Leichhardt–Gilbert area and Stewart (1954) has mapped lateritic plateaux above the general level of the highlands in the adjacent Barkly region.

The pattern and density of drainage vary considerably. Major strike streams such as the Leichhardt follow prominent structural lines in contorted members of the Cloncurry complex, whilst other major streams, after following such trends for some distance, abruptly turn across the strike in deep gorges through resistant barriers. Where the rivers flow over resistant rocks there are strong river curves resembling the ingrown meanders of Rich (1914). Rectangular drainage patterns are common on quartzite, and in granite areas there are fine angular patterns in which the streams are guided by rhomboidal joint systems.

Drainage density ranges from intense in granitic areas (Plate 4, Fig. 1) to a virtual absence of streams on the small quartzite plateaux.

Where the plateau has been dissected the hill slopes are of the faceted type with steep upper bluffs and straight debris slopes (Wood 1942; King 1953). Not all slope units are everywhere present and there is considerable variation in the relative development of units.

Below the debris slope, and often extending far up towards the bluff, are smooth surfaces which possess few lines of concentrated drainage and which are concave, 1–2° in the lower sectors and 3–4° in the upper, though attaining 10–15° in some localities in the south-west of the division; they occur as low-angle cones around granite inselbergs, or below the scarps of plateaux and ridges; they are erosional surfaces cut in bed-rock, though often with a discontinuous veneer of alluvial–colluvial debris. In some cases, as near Naraku, there is a truly angular break of slope, the piedmont angle, between them and the backing scarp (Plate 4, Fig. 2), and here especially the term pediment would seem to be warranted (Twidale 1956*e*).

Overhangs occur at the junction of the bluff and debris slope as a result of cavernous weathering. Whatever the cause of such weathering, it is the chief means by which the plateau, mesa, or butte is reduced. Weathered joint blocks are undermined and ultimately roll down-slope, overturning as they do so.

(2) *Areas of More Advanced Dissection.*—These are usually marginal to the narrowly dissected plateaux and represent a more advanced erosional stage coincident with outcrops of less resistant rock such as granite, shale, phyllite, amphibolite, and gneiss. All remnants of the plateau surface have here disappeared and the only sign of its previous existence is an accordance of hill and ridge crests (Plate 2, Fig. 1). Valleys are more extensive, pediments are well represented, and steeply sloping, coalescent rocky plains occur in many localities, for instance along the Cloncurry–Duchess road.

Cuestas and hogbacks are frequently encountered, the former in association with more gently inclined strata, the latter with steeply inclined beds and especially with dykes and fault dykes. Tors are characteristic in granite areas and "tombstone" weathering is common on amphibolite and amphibolite–schist. At still greater distances from the narrowly dissected plateau, there are areas of isolated hills and ridges separated by rolling irregular rocky country.

There are fewer and larger streams than in the narrowly dissected areas, but the same drainage patterns occur.

(iii) *Genesis.*—The evolution of the Isa highlands has been simple in outline but complex in detail (Plate 3, Fig. 2). The region underwent planation, and in view of the mid or late Mesozoic age of the rock forming mesas above this surface this first planation must have occurred in the early Mesozoic; however, it probably also incorporates elements of a pre-Middle Cambrian surface, since residuals of this age, such as Mt. Aplin, also occur above it locally (Plate 2, Fig. 2; Plate 3, Fig. 1). During the Cretaceous this plain was wholly buried. The Mesozoic cover was then planed and lateritized during the early Tertiary. The ancient pre-Middle Cambrian and early Mesozoic surfaces of erosion were later exhumed as the early Tertiary plain was itself dissected during the late Tertiary–Quaternary cycle.

(*b*) *Carpentaria Plains*

This division is a broad corridor, some 150 miles wide, extending between the Isa highlands and the Einasleigh uplands and drained to the Gulf of Carpentaria by the main rivers of the area, including the Leichhardt, Flinders, and Gilbert. It coincides with a complex basin of subsidence (Fig. 6) and is floored with Cretaceous rocks, but there has been extensive deposition during later Tertiary and Quaternary times. The characteristic land forms are plains and undulating or broadly rolling surfaces resulting from the shallow dissection of former plains. Altitude ranges from sea level to over 700 ft at the divide with the interior drainage in the south, and relief amplitude is low, with a maximum of 150 ft. Subdivision into physical regions is based primarily on contrasts between erosional plains, depositional plains, and residuals of a dissected older surface.

(i) *Cloncurry Plain (3550 sq miles).*—The Cloncurry plain extends to the east of the Isa highlands as an irregular bed-rock plain ranging from about 300 ft in the north to about 700 ft above sea level in the south, and with a local relief of 100–150 ft.

(1) *Geology.*—Igneous and metamorphic rocks of the Cloncurry complex predominate, but in the east the plain is developed on Cretaceous and younger rocks.

The Cretaceous strata feather out against the Precambrian with no perceptible break of slope, despite differences of lithology. At Mt. Flattop and near Boomera and Strathearn there are plateau remnants of weathered Cretaceous sandstone and conglomerate (the equivalent of the Polland Waterhole Shale of Carter and Öpik (1959)). Scattered over the plain are remnants of a late Tertiary (Pliocene) colluvial fan in which coarse debris predominates, whilst younger alluvium is found in river valleys.

(2) *Drainage and Land Forms.*—The plain is irregularly undulating or broadly rolling with occasional isolated hills and ridges which become more numerous closer to the main front of the Isa highlands. Where granite crops out, the plain consists of numerous coalescent pediments above which stand small rocks and inselbergs (Plate 4, Fig. 2).

The drainage consists of widely spaced large streams in broad shallow valleys. Control of drainage by structure is generally not marked, though a subrectangular pattern can sometimes be discerned in granitic areas of above average relief.

(ii) *Croydon Plain (1400 sq miles).*—This is a piedmont plain 300–500 ft above sea level and is similar to the Cloncurry plain; there is thus no need to describe it at length. It can be termed an irregular plain, developed largely on granitic rocks but also extensively formed on Cretaceous sandstone in the south. Pediments are present, especially on granitic rocks, but they are not so well developed here as in the Cloncurry plain. There are isolated hills, commonly of porphyry, and sandstone mesas.

(iii) *Donors Plateau (2500 sq miles).*—The Donors plateau corresponds to the lateritic "Gulf Region" of Whitehouse (1941, p. 3); it is not continuous, but occurs in closely adjoining areas between the coast and the Dugald River (Fig. 4). The detailed description which follows refers to the largest of these areas, namely that north and north-west of Donors Hill homestead.

(1) *Geology.*—The plateau is developed upon greywacke and siltstone considered to be of Lower Cretaceous age (Glaessner, personal communication). Structurally, it is a low dome within which are several minor flexures. The doming occurred in the Miocene, but it is possible that the movement was renewed in late Pliocene or Quaternary time.

(2) *Drainage and Land Forms.*—The dome has been narrowly dissected and an examination of the pattern of dissection suggests that the relief is primitive, the higher parts being directly attributable to upward flexures while valleys and basins are coincident with negative structures.

The plateau has been formed by doming and narrow dissection of the lateritized early Tertiary surface of erosion. Low plateaux and occasional mesas and buttes are the commonest land forms; but where denudation is advanced a plain of erosion of late Tertiary–Quaternary age occurs between the plateau remnants. A radial drainage joins streams flowing north-west and north-east to the Leichhardt and Flinders Rivers respectively.

Features similar to those described occur on outliers of the Donors plateau near Wurung and Normanton, the only notable difference being that a ferruginous horizon is extensive in these two areas, whereas mottled and pallid zone material predominates elsewhere.

(iv) *Julia Plain* (*20,800 sq miles*).—This plain of erosion has a considerable extent in the south, south-west, and north of the area.

(1) *Geology*.—It is developed upon the Cretaceous Rolling Downs Group, which comprises shale with intercalated beds, lenses, and concretions of limestone and greywacke. The strata dip gently towards the centre of the structural basin, with additional regional fall to the north. On both eastern and western margins the Cretaceous strata are masked by the "Terrestrial Deposits", which comprise boulders and gravels in a matrix of clays derived from the Isa highlands on the west, and sands and clays derived from the Gilberton plateau to the east.

(2) *Drainage and Land Forms*.—The drainage is centripetal towards the axis of the Carpentaria plains. Several streams are believed to follow lines of structural weakness; the middle Flinders, for instance, is remarkably straight and probably follows a major lineament induced in the sediments from the underlying basement. In the south-west especially, there is an asymmetrical tributary drainage in which the more numerous eastern tributaries are longer than their western counterparts; this is attributed to uniclinal shifting in the gently inclined strata.

All stream channels of the Julia plain are braided practically from their inception; some of these braided channels are entrenched into Cretaceous strata.

The unresistant nature of the rocks upon which it is developed no doubt accounts for the facility with which the plain has been eroded. The occasional thin limestone beds and lenses are expressed as low, gentle cuestas, whilst thicker beds of limestone form low but prominent plateaux, e.g. at Koondi homestead in the south-west of the plain. East of Hughenden and near Corfield the surface of the plain is thickly strewn with silicified and ferruginized gravel; the Corfield gravel is situated on a low rise which may be a relic of the lateritic surface, but that to the east of Hughenden is undoubtedly lag from an early Tertiary rudaceous and arenaceous cover which has since been removed. Where the marginal "Terrestrial Deposits" have survived erosion, as to the north of Richmond, small depositional plains of late Tertiary age are preserved. Bar-plains (Melton 1936) of various sizes occur near the rivers.

The great extent and perfection of the plain, with its predominant convex interfluves, suggest that it is a Davisian peneplain.

(v) *Claraville Plain* (*22,000 sq miles*).—The flat, sandy Claraville plain occupies the eastern part of the Carpentaria plains, falling from 600 ft in the east to about 200 ft above sea level in the west.

(1) *Geology*.—In the east, close to the uplands, the plain is largely developed upon Lower Cretaceous sandstone. Over the remainder, outcrops of an indurated silicified argillaceous and mottled sandstone of possible Pliocene age, the "Terrestrial Deposits" (see also Allen, Cribb, and Isbell 1960), are exposed in river sections, and there is little doubt that it is on this thin formation that the plain is mostly developed.

Near the western margin there are Middle Cretaceous limestones; conglomerates have been reported in the area, and near the eastern margin, especially in the north, granites are known to occur (Maitland 1898).

Although the "Terrestrial Deposits" are flat-lying, the drainage patterns suggest that the strata have been affected by a gentle upwarp of late Pliocene or Quaternary age between Croydon and Normanton; the stream channels, though maintaining the parallel pattern so common in the Claraville plain, flow to the south-west and north-west, and not, as is generally the case, to the WNW.

(2) *Drainage and Land Forms*.—The Claraville plain is almost flat, with a relief amplitude not exceeding 5 ft. The plain is depositional over the greater part of its area, but near the eastern margin and in the north the region includes erosional plains developed on sandstone.

The minor drainage is generally diffuse, and though it forms a close parallel pattern on air photographs it is commonly not discernible on the ground. The major channels are the Clara, Norman, and Yappar Rivers and Belmore Creek; nowhere are these deeply incised.

Zones of intermittent through-drainage are marked by low levees and floodplains, and there are many small, periodically wet, depressions. These ephemeral swamps may be due to levee damming or to collapse due to solution of underlying limestones, or they may be related to "cone" structures in the underlying lateritized surface downwarped beneath the Claraville plain, similar to those observed in the laterite of the Kynuna plateau (see below) (Whitehouse 1940, pp. 10–12).

(vi) *Wondoola Plain (12,400 sq miles)*.—The extensive Wondoola plain occupies the axis of the Carpentaria corridor and is of considerable geomorphological interest despite its monotonous flatness.

(1) *Geology*.—The plain has a cover of heavy pedocalcic soils which are developed in silts with a variable but always moderate amount of quartz grit. Apparently the source rocks are Cretaceous shale, greywacke, and limestone which crop out in the south, for the main drainage originates in this area. Perhaps the outstanding characteristic of the silts and of the derived soils is their uniformity. The soil and the silt layer are only between 6 and 8 ft thick—as indicated by auger holes, by observations in earth tanks, and by numerous sandy inliers which show that sandy deposits underlie the silts at shallow depth.

The silts have been dated as Pleistocene* from vertebrate remains near Leichhardt Falls and at Floraville, in the north-west of the area, and nearby at Riversleigh (Bryan and Jones 1946, pp. 75–7; Woods 1960, pp. 401–2).

Inliers of lightly metamorphosed Precambrian sediments protrude abruptly from the black soil plains as the low hills of Mt. Fort Bowen and Mt. Brown. Their low grade of metamorphism suggests that the sediments belong to the Etheridge complex.

* A jawbone of *Euowenia* sp. collected in 1926 from silts near the Leichhardt Falls and supplied to me by the Queensland Museum, courtesy Dr. J. T. Woods, gave a date "greater than 33,550 years B.P. with 95% certainty" (Geochron Labs. Inc. Sample No. GX0306); hence the silts are at least of Pleistocene age.

(2) *Drainage and Land Forms.*—The plain rises from about 50 ft above sea level in the north to about 350 ft in the south in a distance of 170 miles, a gradient of less than 2 ft per mile, and the general flatness is enhanced by the predominant grassland vegetation (Plate 5, Fig. 2). The only discernible relief is that due to localized dissection along incised stream channels, though pronounced gilgai micro-relief covers large areas.

The main streams are roughly parallel and drain northwards with the regional slope. In the north, the river valleys are countersunk into broader older valleys, and in these lower areas sedentary soils occur on plains of erosion developed on Cretaceous strata which generally underlie the alluvial cover and which have here been exposed by stream incision. Near major rivers which head in quartzitic rocks, sandy levees occur in covered plains (Melton 1936), in contrast to the modern bar plains. In the middle Leichhardt valley these ancient levees have been abandoned and are perched above present base level, and accordingly may be considered Pleistocene or early Recent. However, in the vicinity of Sedan Dip the levees occur where streams from the hills debouch onto the black soil plains, and in this area the covered plain is of Recent age.

With the exception of the Leichhardt and Flinders Rivers and their major tributaries, the drainage lines are broad shallow depressions without distinct channels. Some depressions drain to a stream, but many lead to enclosed basins. The sparseness of streams is due to the prevalent low gradients, to rapid initial percolation into dry black soils, and to impedance of drainage by gilgais, with the formation of small shallow swamps after rains. Save in the vicinity of major streams the plain is poorly drained, and it appears that much of the rainfall enters the numerous swamp depressions, whence it is gradually evaporated.

(vii) *Stirling Plain (1900 sq miles).*—The Stirling plain is a distributary alluvial plain in the lower reaches of the Gilbert River. The northern limit lies outside the surveyed area, where the Gilbert channels appear to merge and mingle with those of the Mitchell River; the southern limit is the Claraville plain.

(1) *Geology.*—The plain is developed upon alluvia of two apparent ages, both of which overlie and hence post-date the sands of the Claraville plain into which they have been countersunk. The older, silty alluvium is considered to be Pleistocene, deposited at the same time as the silts of the Wondoola plain, and the younger sandy alluvium, of relatively minor extent, to be of Recent age. The latter is deposited within channels excavated in the former.

(2) *Drainage and Land Forms.*—There are many stream channels with small levees and extensive flood-plains. Some seem to be abandoned channels, but those which are utilized at the present time are characterized by slight incision and by the possession of laciniate meander plains. Covered plains associated with distributary drainage systems occur on the older alluvium and extend over the greater part of the Stirling plain.

(viii) *Karumba Plain* (2100 sq miles).*—This is the coastal part of the Carpentaria plains, a zone about 30 miles wide which continues east and west beyond the limits of the surveyed area.

* For fuller account see Twidale (1956*b*).

(1) *Geology.*—In places the inland boundary is a low sea cliff eroded in lateritized Cretaceous strata of the Donors plateau. Therefore the muds and shelly beach rock of which the plain is partly built were deposited after marine erosion of the weathered early Tertiary surface and are of later Tertiary or Quaternary age. They are relatively unconsolidated and horizontally disposed. At Karumba the beach rock is 70 ft thick and rests directly upon the late Tertiary sandstone of the Lynd Formation (Laing and Power 1960), which in turn overlies the laterite. Over most of the region, however, the beach rock has been eroded and buried beneath estuarine gypseous mud.

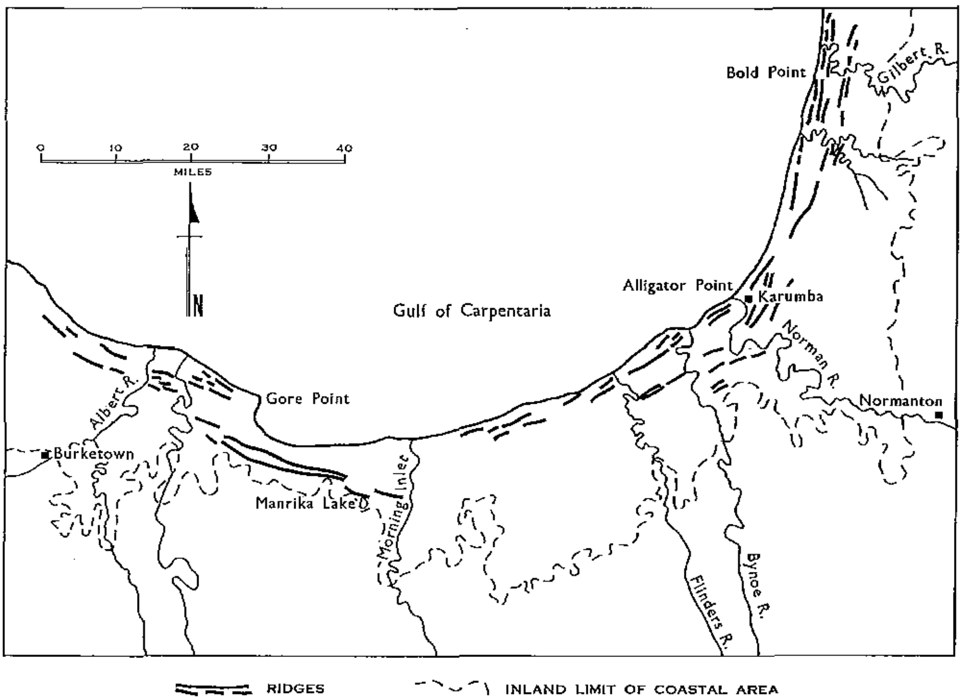

Fig. 15.—Features of the Karumba plain.

(2) *Drainage and Land Forms.*—The Karumba plain is a strip of varying width which extends for short distances up the valleys breaching the lateritized plateau (Fig. 15). In detail it is complex, being largely occupied by mud flats but also containing beach ridges and low plateau remnants of beach rock (Plate 6, Fig. 2).

Whitehouse (1944, pp. 185–9) has discussed in some detail the unusual drainage patterns of the tidal salt flats. Meanders of great sinuosity and occasionally of marked angularity are developed. On meander loops, what Whitehouse has termed a "centrifugal pattern" is formed by subsidiary tidal creeks which may be single or branching (Plate 7, Fig. 1). It seems that the main factors in the evolution of these patterns are the periodic flooding of the flats, the extremely soft nature of the clay; and the very low gradients.

Extending in a series of discontinuous and imperfect arcs are a number of subparallel sandy ridges which extend the whole length of the shore. The maximum number of arcs is five—three on the dissected beach rock plateau, well seen to the east of Karumba, and two on the mud flats (Fig. 16), but the five do not occur in any one section. Several of the ridges are composite features, comprising as many as five or six closely spaced minor ridges. The inner slopes of the ridges are slightly undulate,* while the seaward-facing slopes are straight, indicating that the ridges are remnants of barrier beaches and islands (Shepard 1952).

Like the beach-rock plateaux, the ridges are composed principally of marine shells and sand which are progressively more weathered from the coast inland.

The ridges exert some influence upon drainage, for quite frequently a stream runs parallel to the coast behind a sand ridge until it reaches a gap through which it makes its way to the sea. The plateau remnants of beach rock are best preserved where protected to seaward by one of the ridges.

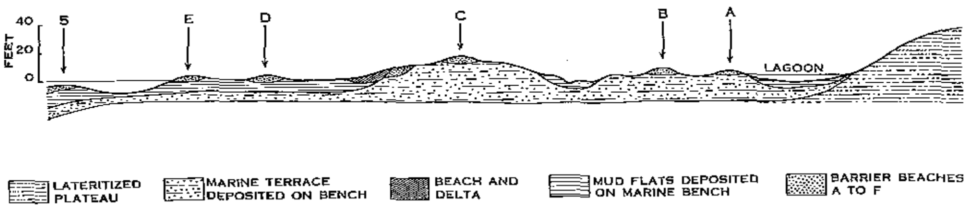

Fig. 16.—Section through the Karumba plain.

There are only slight differences in elevation within the group of ridges on the flats on the one hand and within the group on the plateaux on the other, but the ridges on the flats are approximately 20 ft lower than those on the plateaux.

In places lagoons are impounded between beach ridges and the alluvial plain, or against the colluvial margins of the beach-rock plateaux.

Old dunes are found in places along the inland side of the littoral zone, but are not an important feature of the region. They are of indefinite shape and varied alignment and consist of deep, undifferentiated sand carrying a dune scrub. There is some drifting sand in the area, particularly on the beach-rock plateaux, and here sand ridges accumulating behind vegetation have a consistent SW.–NE. trend.

(3) *Tides and Offshore Gradients*.—Very little information is available concerning the tides and currents of the Gulf of Carpentaria, and that the present chart of the Gulf is essentially the one produced by Matthew Flinders in 1802–3 epitomizes our present lack of knowledge. At Karumba the tidal range is of the order of 18 ft, with an "observed maximum of twenty-two feet" (Whitehouse 1944, p. 185). Local information suggests that the higher tides are largely meteorological, produced by strong north-westerly winds; the period of the north-west monsoon is thus not only the time of heavy rains but also of high tides, and consequent upon this combination of factors, the area suffers severe seasonal flooding. The rivers entering the Gulf from the survey area alone drain about 100,000 sq miles, hence run-off is considerable and

* The indentations on the backslope are due to erosion by water percolating through the loose upper material, and to debris being thrown up the backslope by waves refracted and reflected in backing lagoons.

the amount of work achieved is increased by the flood conditions that frequently obtain. A great volume of debris is transported to the coast, there to be deposited in the shallow gulf. This is therefore an aggrading coastline characterized by low offshore gradients: about 65 miles offshore the sea is only some 80 ft deep.

(ix) *Genesis of the Carpentaria Plains.*—The Carpentaria plains are the result of a long and complex denudational history. At the margins of the plains there is evidence that the early Mesozoic erosion surface, upon which the basin sediments that underlie the plains were deposited, has been exhumed to form part of the present land surface (Fig. 9). In the Cloncurry plain, for example, there is a distinct accordance of ridge crests, the crest line rising gradually from east to west (Fig. 17). That the soft

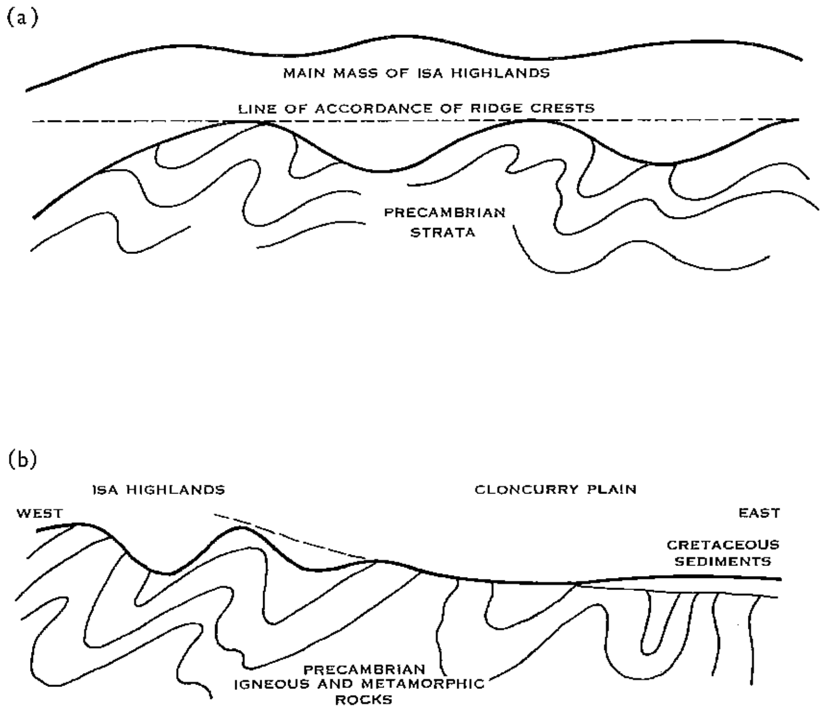

Fig. 17.—Postulated incidence of the early Mesozoic surface of erosion on the Cloncurry plain, (*a*) from the east and (*b*) from the south.

Cretaceous shale and limestone feather out against the resistant Precambrian strata, with no topographic break between the two, is difficult to comprehend unless the surface on the Precambrian rocks is essentially that upon which the Mesozoic sediments were laid down. This exhumed plain has itself suffered considerable erosion since re-exposure.

This ancient land surface was buried beneath Mesozoic sediments which suffered planation and lateritization in the early Tertiary. Later, probably in Miocene times, the surface suffered considerable warping and some faulting, followed by renewed dissection. The dissection of the weathered Tertiary land surface marked the onset of a new cycle of erosion; once the rivers had penetrated the lateritic duricrust they were able to erode rapidly in the underlying Cretaceous sediments, and the extensive Julia plain was developed. Remnants of the lateritic surface survive on resistant sandstones, for example in the Donors plateau. The dissection of the weathered early Tertiary surface caused vast volumes of debris, gravelly and bouldery in the west, sandy and argillaceous in the east, to be deposited at the margins of the plains in late Tertiary times (Fig. 6). The eastern outwash fan in particular was extensive and not only do the fan deposits underlie the Claraville plain, but also the eastern part, at least, of the Wondoola plain.

The Pleistocene silts of the Wondoola plain were deposited by streams flowing at low gradients, and aerial photographs show former stream lines which display excellent meanders. On account of the extraordinary uniformity of the soils, and presumably therefore of the parent silts, it is necessary to postulate shallow swamp conditions for their accumulation; this is consistent with the contained mammalian fossils.

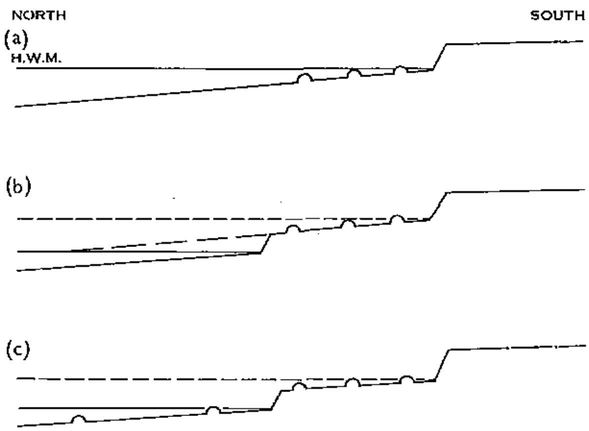

Fig. 18.—Stages in the evolution of the Karumba plain. (*a*) Following emergence and cliff formation, marine bench carved and debris deposited on terrace and three barriers and bars formed. (*b*) Emergence of about 20 ft, terrace dissected. (*c*) Further barriers and bars develop on mud-strewn lower bench.

At the same time as the Wondoola silts were being deposited in the west, the silty older alluvia of the Stirling plain were being laid down as a huge distributary plain in the north-east. Both the Wondoola and Stirling plains have since been dissected, though erosion has not progressed far from the major streams. This latest rejuvenation results in part from late Quaternary tectonism, and partly from the fall in sea level evidenced in the coastal zone.

The forms of the Karumba plain are in all probability Quaternary. The coast is aggrading, but is of compound type as there is clear evidence of emergence. The argument that the higher barrier ridges were formed at high tides of the present sea level is untenable, as the lower ridges could hardly have survived if this were the case. The topographic separation of the barriers into two groups is interpreted as evidence of an emergence of about 20 ft (Fig. 18). No deformation is discernible, and a eustatic lowering of sea level is therefore probably involved.

A Recent age for the emergent beach at Karumba is shown by a date of 3320±125 years from coquinite (beach rock) there.* If eustatic, this emergence may be related to a Recent fall of sea level of 6 m claimed by Daly (1934) and hence possibly with the post-glacial climatic optimum and the post-Flandrian regression of 4000–5000 B.C. (Valentin 1954). The marine shells in the Karumba beach rock are all of modern type.

(c) *Inland Plains*

The inland plains are that part of the lowland corridor which drains southwards to Lake Eyre.

(i) *Burke Plain (3000 sq miles)*.—Essentially similar to the Cloncurry plain already described, the Burke plain is differentiated from its northern counterpart mainly by virtue of its inland drainage.

(1) *Geology*.—Precambrian igneous and metamorphic rocks of the Cloncurry complex crop out through most of the Burke plain, but Mesozoic and Cambrian rocks occur as mesa cappings, e.g. Mt. Aplin (Plate 2, Fig. 2), Mt. Burnie, and Mt. Bruce. South of Selwyn there are outcrops of a heterogeneous series of siliceous and ferruginous grits, breccias, and sandstone believed to have been laid down in local depressions in late Tertiary times.

(2) *Drainage and Land Forms*.—The Burke plain is an irregular plain of erosion on which low hills and ridges are quite common. There are fine examples of inselberg and pediment landscapes, notable for the sharp break of slope between hill and plain. However, considerable tracts are occupied by plateaux at two levels. The higher ones are capped by mottled Mesozoic siltstone with large iron concretions; the others have almost level summits which bevel the contorted Precambrian strata. This lower summit surface is seen in places to emerge from beneath Mesozoic rocks and is thus identified as the early Mesozoic land surface stripped of its sedimentary cover. The exhumed surface attains up to 100 ft above the present plains of erosion, but in many areas is close to or coincident with the modern plain. Thrust-faulting affects both Precambrian and Mesozoic strata about 30 miles SSE. of Selwyn. On the divide between the interior and gulf drainages there is a marked discrepancy between the levels of the erosional plains related to each drainage system, with the Burke plain at a lower level than the Carpentaria plains.

The two main streams are the Burke and the Wills, which flow southwards to join the Georgina. Drainage patterns are generally trellis or rectangular, being guided by joints and other planes in the granite and metamorphic rocks; dense pinnate patterns are developed on granite plains of low relief.

* Geochron Labs. Inc. Sample No. GX 0305; sample supplied through the efforts of D. Traves, Geological Survey of Queensland, and Professor Dorothy Hill, University of Queensland.

(ii) *Kynuna Plateau (1500 sq miles)*

(1) *Geology.*—A portion of the Kynuna plateau occurs on the southern margin of the survey area. It is a narrowly dissected lateritized remnant developed upon mottled Cretaceous siltstone and greywacke, with its top a little more than 1000 ft above sea level (Plate 5, Fig. 1). A ferruginous horizon has been noted by Whitehouse (1940, pp. 10–12), who also first described curious "conical shaft" structures in mottled material.

(2) *Drainage and Land Forms.*—The drainage is radial and the various streams join the Diamantina, which flows in an arc around the northern periphery of the plateau.

Plateaux with marginal mesas and buttes constitute the major land forms. The scarp slopes are faceted, with bluffs and debris slopes especially well represented and with cavernous weathering well developed at the junction of bluff and debris slope.

The Ayrshire hills, an isolated lateritic remnant situated a few miles to the east, are similar to Kynuna plateau.

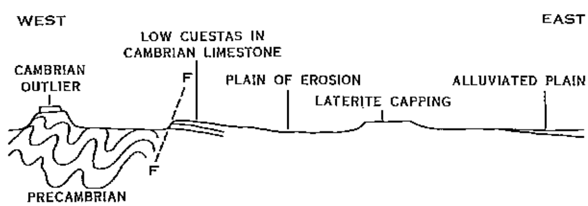

Fig. 19.—Schematic section through the Devoncourt upland, showing major land form elements.

(iii) *Devoncourt Upland (1400 sq miles)*

(1) *Geology.*—The region is developed upon sediments of Cambrian age, including sandstone, siltstone, silicified breccia, and limestone, the latter predominating. The sediments are subhorizontal and gently warped. They are the only extensive Cambrian sediments within the Leichhardt–Gilbert area and owe their preservation to downfaulting, for they occur in a graben (Öpik 1961).

(2) *Drainage and Land Forms.*—The trunk stream is the Burke, which flows almost due south, but surface streams are few, as is to be expected in an area in which considerable thicknesses of limestone are present. Much of the drainage is radial off low lateritic plateau remnants, while the Burke appears to flow in a synclinal depression, the tributaries draining the flanks of the structure.

Near the Burke River, a plain, part erosional and part depositional, has developed (Fig. 19), and similar smaller plains have been formed along many of the larger streams. A narrow plain of erosion on Cambrian rocks has also developed on the margins of the downfaulted block. However, low hills and plateaux displaying "bastion" forms (Öpik 1961) occur over a large part of the area. Few steep slopes exist, but these include stepped scarps with structural benches on limestone. The plateaux, which frequently possess a ferruginous and siliceous cap, stand between 50 and 100 ft above the general level of the plain. They are commonly considerably dissected, and only low hills with accordant crests remain where this dissection is advanced.

(iv) *Diamantina Plain (5300 sq miles)*.—The Diamantina plain is similar to the Julia plain and is distinguished from it here only because its drainage belongs to the inland system. The region is a rolling plain developed upon Cretaceous shale, greywacke, and limestone.

(v) *Genesis of the Inland Plains*.—The evolution of the division is similar to that of the neighbouring Carpentaria plains. In the Burke plain there are remnants of pre-Middle Cambrian and early Mesozoic erosional plains; there are widespread and numerous residuals of the formerly extensive weathered early Tertiary surface of erosion in the Burke plain, Devoncourt upland, and Kynuna plateau, particularly in the latter; and there is a younger plain eroded below.

The curious arcuate course of the Diamantina River has been explained in terms of late Pleistocene or Recent warping (Taylor 1911) which beheaded the upper reaches of the gulf drainage and caused gulf drainage from the northern part of the Kynuna plateau to be diverted into a depression between the plateau and the upwarp, and thence eastwards into the Diamantina.

(*d*) *Einasleigh Uplands*

This division is a westerly projection of the highlands of eastern Australia. The uplands exceed 3000 ft locally and coincide with tectonically delineated, uplifted blocks of a wide range of Precambrian and Palaeozoic rocks. In the east of the division there has been Tertiary and Quaternary vulcanicity which has deranged the generally radial drainage pattern and has given rise to high basalt plains and plateaux. It is a vast, dissected plateau, with lowlands limited to the major river valleys. The constituent physical regions are mainly separated on the basis of structure and relief.

(i) *Gregory Range (1900 sq miles)*.—The Gregory Range extends from a few miles north of Croydon for a considerable distance south-south-eastwards until it merges with the Gilberton plateau. It exceeds 600 ft above sea level in the north and 1500 ft in the south, standing between 300 and 1000 ft above the plains to the west and rising from them by a steep scarp.

(1) *Geology*.—Subhorizontal mottled sandstone and siltstone of late Mesozoic age cap the range and are increasingly prominent to the south, where they become continuous in the Gilberton plateau. The capping is much dissected and over the greater part of the range the underlying porphyry, granite, and Precambrian strata of the Georgetown massif are exposed.

The range is thought to be primarily due to late Tertiary upwarping along the regionally dominant NNW.–SSE. trend. The warp is asymmetrical, and on the very steep western limb there are a number of small strike faults with downthrow to the west. The eastern limb slopes gently down as part of the Gilbert River downwarp. A secondary cause of the relief is the resistance of the porphyry, of which it is largely built (Plate 7, Fig. 2).

(2) *Drainage and Land Forms.*—The drainage forms an incomplete and elongate radial pattern; the main streams are all consequent, flowing north-eastwards on the eastern limb, northwards on the short north-facing slope, and south-westwards on the western slope. On the latter, falls and rapids are common features because of faulting. Adaptations to detailed structure are common on the porphyry, and many areas have a distinctly angular drainage pattern, the streams following prominent joints and small faults with trends usually NNW.–SSE., NE.–SW., and NW.–SE.

The highest parts of the range occur where crestal survivals of Cretaceous sedimentary rocks build small mesas, but over the area as a whole high ground coincides with outcrops of porphyry. This forms the steep western scarp and the high erosional plain with bare rounded or broadly rolling forms on the gently inclined top and eastern slope. Where granite crops out there are hummocky bouldery hills and rock plains with tors and whalebacks.

(ii) *Newcastle Range (2250 sq miles).*—The Newcastle Range is similar to the Gregory Range but is higher, ranging between 800 ft above sea level in the north and 2500 ft in the south. It projects between 300 and 1000 ft above the Einasleigh valley in an abrupt eastern scarp which is probably a fault or fault-line scarp, for it has excellent triangular facets. Stepped benches separated by very sharp breaks of slope also point to recurrent earth movements. The western scarp, though steep, is less precipitous than that on the east. This may also be a fault scarp, in which case the Newcastle Range would be a horst; however, it is more likely to be primarily due to differential erosion against the resistant porphyry forming the range. The sandstone locally capping the range may be late Palaeozoic or Mesozoic (O. A. Jones, personal communication).

(iii) *Gilberton Plateau (5850 sq miles)*

(1) *Geology.*—In the Gilberton plateau the dissected cappings of the Gregory and Newcastle Ranges become continuous. The subhorizontal Lower Cretaceous sandstone and siltstone overlie near-vertical Precambrian and Palaeozoic metasediments and igneous rocks which occur as basal beds and which crop out on the eastern margin of the region. The Mesozoic sandstone is mottled near the surface and the siltstone is deeply weathered, with lateritic red earth soils. In the east, lateritic debris accumulated in downwarped basins of the plateau in late Tertiary time.

Tectonically the plateau is an elongate dome, the "Gilberton knot", from which upwarped fingers radiate (Fig. 5) as, for example, the Gregory and Newcastle Ranges. Many east–west faults are known to occur on the dome, especially near the western margin of the plateau.

(2) *Drainage and Land Forms.*—The region is a narrowly dissected plateau of which the original level surface largely remains to form the largest landscape element. The valleys are narrow and are bounded by faceted sandstone escarpments. Where granitic rocks are exposed beneath the sandstone, tors and pediments are well developed. In some areas, for instance between Forsayth and Gilberton, striking weathered forms which have been described as "beehives" (Twidale 1956*d*) occur in cross-bedded sandstone (Plate 10, Fig. 1).

A few mesas protrude above the general level of the high plateau surface north of the Stawell River, about 25 miles north of Coalbrook homestead, as monadnocks on the weathered early Tertiary surface which constitutes the main plateau summit.

On its eastern side the plateau is bounded by a steep, dissected scarp, but to the west the plateau surface on weathered sandstone slopes gently down and passes beneath the sands and clays of the Claraville plain.

The sandstone is pervious and streams are few; they form a radial pattern off the dome, the major streams being consequent and occupying subsidiary downwarps. These major streams are deeply incised, and several flowing westwards, for instance the Norman (Fig. 20), have been guided by the prominent east–west faults already mentioned.

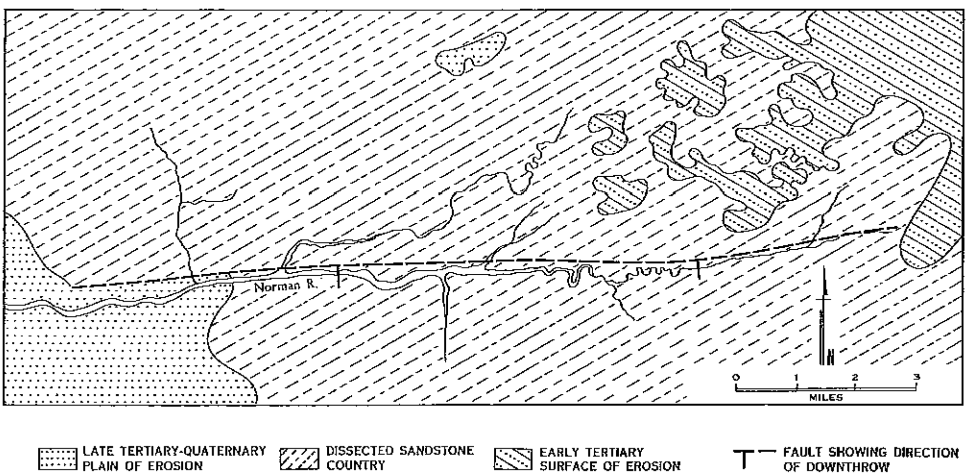

Fig. 20.—Sketch map, drawn from air photography of the fault-guided course of the upper Norman River on the west side of the Gilberton plateau.

In many of the major valleys there has been extensive deposition of sandy alluvia, but the minor streams flow in steep-sided rocky gorges. On the Great Dividing Range, in the east of the region and at about 2900 ft above sea level, several lakes occur in the downwarped basins of lateritic deposition already referred to; the origin of these lakes, of which Lakes Louisa, Pelican, and Agnes may be cited, is complex, though warping, or damming by basalt flows of the Chudleigh plain, may be involved.

(iv) *Red Plateau (3600 sq miles)*.—The Red plateau is similar to the Gilberton plateau in that it is narrowly dissected and developed upon Mesozoic sandstone and siltstone. It is little known, being very rough country and difficult to penetrate, and no land traverses were made through this region.

(1) *Geology*.—Sandstone and mottled siltstone of Lower Cretaceous age crop out over most of the area. There is a greater proportion of siltstone than in the Gilberton plateau and in some localities these have given rise to "downs" soils.

(2) *Drainage and Land Forms.*—The Red plateau is drained by north-westerly-flowing streams, of which the Lynd and the Tate are the most important. The sub-parallel drainage is consequent upon the warped early Tertiary surface and flows to the Gulf of Carpentaria. Many of the upper tributaries display rectangular patterns controlled by similar jointing in the sandstone. Because of the prevalence of impervious siltstone, the drainage is of moderate intensity. The rivers have carved deep gorges in which exposures of mottled white siltstone are common, and which are wider than in the Gilberton plateau. Small plateau remnants with mesas and buttes are the usual land forms, with plateau surfaces not exceeding 500 ft above the plains. In the valleys of major rivers and on the margins, especially the western margin, plains of erosion have developed upon sandstone and there has been some alluviation adjacent to the major streams.

(v) *Gilbert Plain (1150 sq miles).*—The Gilbert plain is situated astride the upper and middle reaches of the Gilbert River.

(1) *Geology.*—Geologically the region is complex, and air photographs show remarkable sigmoidal folds aligned on east–west axes in Precambrian metasediments of the Georgetown massif. Slate and phyllite are common, and there is a marked unconformity between these highly inclined strata and the subhorizontal Mesozoic sandstone above. Quartz veins intrude the metamorphic rocks, and scattered outcrops of porphyry are common.

(2) *Drainage and Land Forms.*—The physiography of the region is also complex. Irregular plains constitute the largest terrain type, but sandstone mesas and low rugged hills cover a considerable area.

On the plains, streams are relatively sparse and in places display a rectangular pattern adjusted to structures in the metasediments. Elsewhere, the intensity of drainage is greater, particularly in the small areas of soft pelitic metasediments which are frequently revealed in the cores of anticlines: here an extraordinarily dense subangular drainage pattern has developed.

The plains lie between 500 and 700 ft above sea level and the mesas and hills stand up to 500 ft higher. Throughout the region, the quartz veins form prominent features of the landscape, either as small cuestas or as hogbacks according to their dips.

There has been considerable alluviation along the Gilbert River and its main tributaries, for instance the Langdon. This has been caused firstly by simultaneous flooding in the main stream and the tributary, causing back-ponding and the formation of temporary lakes. Secondly, the Gilbert has extensive levees of two and possibly three ages (the oldest and highest consists of red sand and the other two are of brownish yellow sand) which cause impedance of drainage behind them. There are numerous levee-dammed lagoons and lakes, not only in the Gilbert but also in the Langdon and other tributary valleys, and Langlo Lake is the largest of these. Thirdly, alluviation has occurred on a large scale headwards of rock bars, mainly of porphyry, several of which occur on the Gilbert River.

(vi) *Georgetown Upland (1750 sq miles)*

(1) *Geology.*—Over the greater part of its area this upland is developed upon Precambrian granitic rocks, though basic metamorphic rocks such as amphibolite occur in the east, near the Newcastle Range. Small outliers of thin subhorizontal Cretaceous sandstone occur at various levels over the whole area.

(2) *Drainage and Land Forms.*—There are two major drainage systems, the Gilbert in the west and the Etheridge in the east. All the major streams are thought to be consequent upon warping of the early Tertiary land surface, and probably follow synclinal depressions.

The major streams flow north-westwards. Some subangular patterns are discernible in tributary systems, possibly related to rectangular jointing in the granitic rocks, but generally the drainage pattern shows no such regularity except in hilly country, where the more youthful drainage shows some adjustment to structure.

The upland extends between 500 ft above sea level in the west and about 1300 ft in the east. It is an undulating or rolling irregular high plain consisting of coalesced pediments above which stand isolated block-strewn hummocks, hills, mesas, and ridges, and below which narrow V-shaped valleys have been incised. The interfluve crests display a remarkable accordance but are topped by sandstone mesas and buttes in several localities. An outstanding feature of the upland plain is the preponderance of convex slopes, even on valley-floor side strips, interfluves, and pediments.

The relief increases in the east, in a subregion which is not delineated in Figure 4 but which may be termed the Forsayth foothills.

(vii) *Einasleigh–Copperfield Plain (2150 sq miles).*—This is a plain of irregular, low relief with isolated hills and ridges, situated at between 1200 and 1600 ft in the west and rising to heights in excess of 2000 ft in the east.

(1) *Geology.*—The region contains a variety of metamorphic and igneous rocks amongst which granite and amphibolite predominate. Basalt occupies several sectors of the valley of the Einasleigh River and also occurs at a high topographic level in two places.

(2) *Drainage and Land Forms.*—The plain is drained northwards by the Einasleigh and Copperfield Rivers. Drainage density is low and tributary streams display rectangular patterns. Where the main valleys are occupied by basalt, there are stony plains with "stony rises" (Skeats and James 1937), and modifications of drainage are common. The more significant types of drainage diversion are mentioned below, in the description of the volcanic region of the McBride plateau. The Einasleigh and Copperfield Rivers flow in relatively shallow valleys until they reach Einasleigh, where they join and plunge abruptly over a fall into a gorge which is extremely narrow at first, but which widens downstream. The fall originated at the front of a basalt flow and is now working back up the valley.

Broadly and gently undulating country with mainly convex slopes extends over wide areas, especially on granite. Occasional low hills and ridges and isolated mesas of basalt or of sandstone and siltstone break the monotony of the plain, and more prominent hills are formed by porphyry dykes and hummocky granite outcrops with tors and joint blocks. In some of the granitic hill country, as near Lyndhurst, the hill crests are commonly flat and reach a fairly uniform level of 200 ft above the plain, though low hummocks and tors protrude above this.

In the east the plain is bordered by the Great Dividing Range, a low watershed indistinguishable from several others; in the west, the plain abuts against the Newcastle Range.

(viii) *Uplands and Ranges of the Divide (2650 sq miles)*.—This region comprises those high plains and ridges situated on and slightly to the east of the Great Dividing Range, at 2000 ft and more above sea level.

(1) *Geology*.—Strongly folded Palaeozoic rocks, amongst which Silurian and Devonian strata have been identified and which include probable Permian strata, crop out over most of the region. A prominent structural feature is the complex series of steep-flanked domes and basins elongated along NE.–SW. axes. Siltstone, greywacke, and limestone are the main sedimentary rocks present, and weakly metamorphosed representatives of some of these also occur. Granite and granitic rocks are common, while patches of basalt, inclusions from adjacent regions, are also common on the southern margin.

Along the Hann Highway there are outcrops of siliceous and ferruginous grit, breccia, and sandstone which are thought to be accumulations of lateritic debris formed in lakes or internal drainage basins. These are the Cheviot Beds, and rocks of possibly similar age and origin have been described from the Isa highlands just south of Selwyn. Since the rocks are considered to be derived from laterite they cannot be older than mid Tertiary.

(2) *Drainage and Land Forms*—The high plain with its broad low interfluves is broken by narrow but deep V-shaped valleys of which the Broken and Clarke Rivers and Yates Creek are the main examples. Ridges trending NE.–SW. protrude above the general level where Siluro–Devonian sediments crop out, and here the relief is of the order of 500 ft, and even greater near major rivers.

The drainage also shows a strong NE.–SW. alignment, particularly in the trellis patterns of the ridge country.

There are small but striking areas of limestone, displaying lack of surface drainage, swallow holes, collapse features, *Rillenkarren* (Plate 10, Fig. 2), and other typical karst forms.

(ix) *Burdekin Upland (3400 sq miles)*.—This region consists of a plateau and extensive plains between 1500 and 1900 ft above sea level.

(1) *Geology*.—The plateau is developed upon sandstone of Upper Devonian and lower Tertiary age. The boundary between the two is not known and the Tertiary strata may be only a veneer. Various contorted and inclined sedimentary, igneous, and metamorphic rocks are revealed beneath the flat-lying sandstones in valleys and perched plains.

(2) *Drainage and Land Forms*.—The highest parts of the Burdekin upland comprise narrowly dissected, gently undulating or rolling sandstone plateaux with faceted escarpments. These have few streams, and such as are present have worked

back from the margins. Where the sandstones have been removed, perched plains have been formed as extensive uneven surfaces with isolated ridges and hills. The streams of the region are ungraded and conform to no particular pattern, though some accommodation to structure is discernible locally. There has been some alluviation near the main rivers, particularly in the Burdekin valley above Valley of Lagoons homestead and near the western margins against the McBride volcanic province.

The Burdekin, the principal river, here follows the basalt margin in its upper reaches and flows south-westwards to near Greenvale and Wyandotte, where it makes a turn through almost a right angle because of obstruction by a lava flow.

The Clarke, a major tributary of the Burdekin, drains much of the south of the region. Like its trunk stream, it closely follows the margin of a basaltic province (in this instance the northern edge of the Nulla plateau), and like the Burdekin below its diversion, the Clarke River flows in a deep winding gorge.

The north of the area is drained by the Herbert River system, the main valley of which is eroded in granitic rocks with fine tors. About 12 miles south of Cashmere homestead the river makes a turn through more than 90°, changing from its N.–S. course to a direction slightly north of east, and this is considered to be yet another case of diversion by a lava flow. Just below this bend are the spectacular Herbert Falls, which are about 350 ft high. Above the falls the river pursues a meandering course in a wide shallow valley, while below them it flows in a deep V-shaped gorge with many discordant tributaries. There is no structural reason for the falls and they are apparently a nick-point caused by a relative uplift at the coast (Cotton 1949) and working headwards up the river.

(x) *McBride Plateau* (2000 sq miles)*

(1) *Geology*.—The province (Fig. 21) is composed of successive sheets of vesicular and amygdaloidal olivine basalt. That there were long periods of weathering between some of the major flows is shown by sections such as that 1½ miles south of Rosella Plains homestead, where fresh basalt is underlain by a deeply weathered flow. Evidence of erosion between flows is present to the south-west of Mt. McBride, where a very late extrusion flows down valleys eroded in an earlier basalt, towards the Burdekin valley near Valley of Lagoons and Reedy Brook homesteads.

(2) *Drainage and Land Forms*.—Essentially, the region consists of a great topographic and structural dome which on the Hann Highway rises from about 2000 ft above sea level at the margin to about 3000 ft at the crest.

The basalt dome comprises a series of stepped plains separated by scarps which are the consolidated fronts of lava flows. The scarps may attain 50 ft, but are more commonly of the order of 20–30 ft high. The lava plains are uneven, with low stony ridges or rises, some exhibiting collapse structures similar to those described by Skeats and James (1937). Soil cover is restricted to black swampy soils in depressions between the rises. Caverns are numerous everywhere, but especially so in the newer basalt between Mt. McBride and the Burdekin valley. This area is occupied entirely

* For a fuller account of this and the other volcanic regions see Twidale (1956*c*).

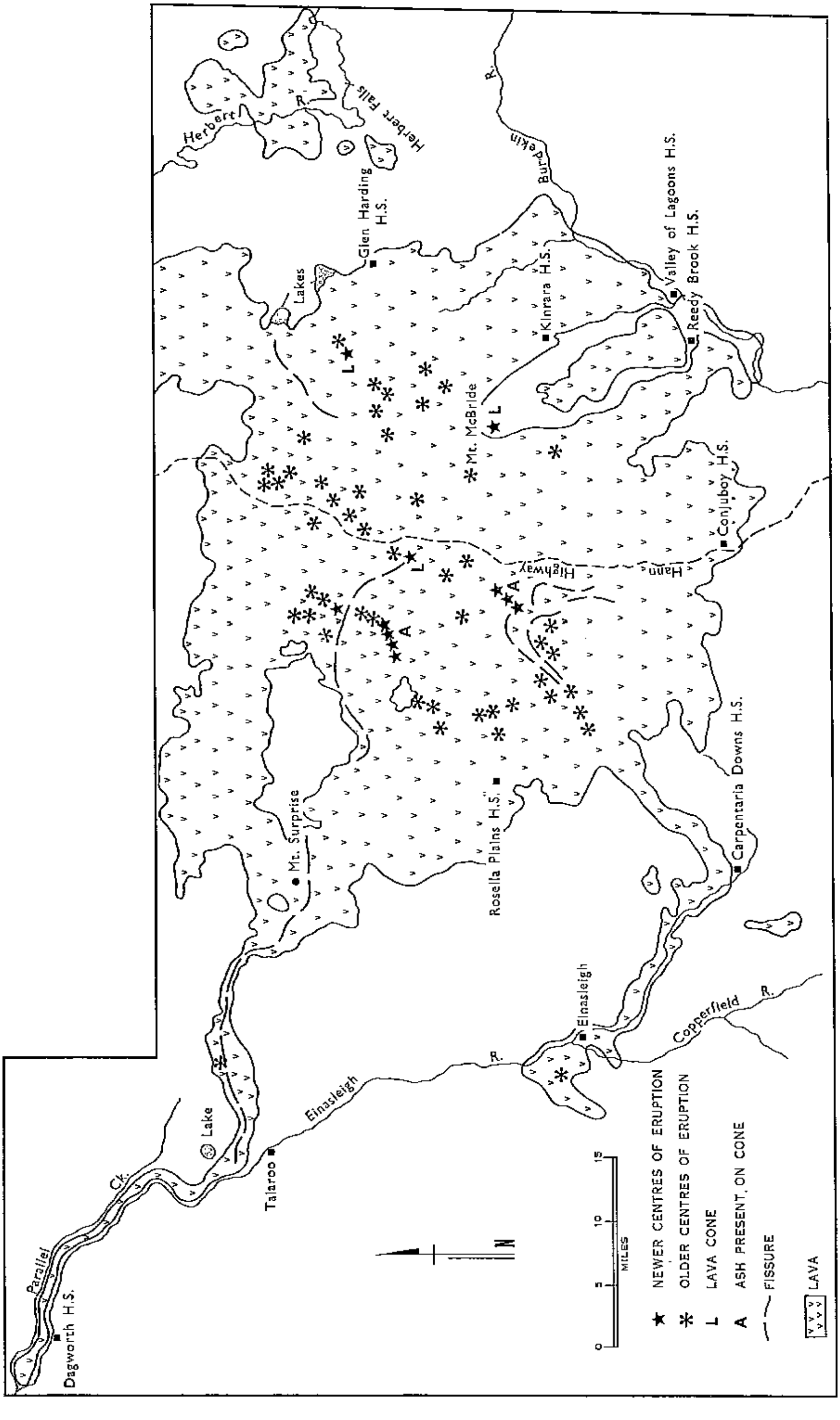

Fig. 21.—The McBride plateau volcanic province.

by rocky outcrops of scoriaceous lava displaying excellent aa and pahoehoe structures. Lava pavements have formed where this relatively fresh lava reaches the Burdekin valley at Reedy Brook and Valley of Lagoons.

Numerous old centres of eruption, some of which were located by Taylor (1911), occur on parts of the dome (Plate 8, Fig. 1) and are indicated in Figure 21, where a distinction is made between weathered, eroded, presumably older cones and the more complete newer ones. About 60 centres of eruption have been recognized. With two possible exceptions the foci lie within an ellipse astride the Hann Highway, its major axis trending NE.–SW. The alignment of fissures and cones here is parallel to the regional structural trends of the Siluro–Devonian strata (Broken River Series) further south in the Burdekin upland. In detail, several alignments of foci can be distinguished, notably the clear NE.–SW. arc some 23 miles ESE. of Mt. Surprise and the arcuate fissure, some 25 miles long and with a centre of eruption at the SE. end, in the same general area (Fig. 21).

Most of the older centres of eruption are marked by lava cones, but there are scoria cones and some diatremes, occasionally occupied by lakes; coulées and adventive cones also occur (Plate 8, Fig. 1). The newer centres are diatremes with well-preserved craters.

On the north, east, and west sides of the dome the drainage is consequent and radial, and to the south the radial drainage is joined at acute angles by streams from the Great Dividing Range. Some streams are fed by springs that emerge from between lava flows, and these tend to run parallel with the structural scarps and to flow at an obtuse angle to the radial consequent streams, making a concentric pattern around the crest of the dome. Where streams leave the basalt, or where they penetrate it and reach the underlying strata, marked incision has taken place.

Some of the major valleys on the dissected periphery of the dome are occupied by tongues of basalt, e.g. the Einasleigh valley between Carpentaria Downs homestead and Einasleigh, and between Talaroo Crossing and Dagworth homestead (Fig. 21).

Drainage diversion by basalt flows has occurred around the periphery of the basalt dome, principally in the Einasleigh and Burdekin valleys, and several flow-dammed lakes have formed, for instance north of Talaroo Crossing and in the Glen Harding area. Between the Crossing and Dagworth homestead a tongue of basalt flowed from centres in the Mt. Surprise–Brooklands area along a pre-basalt valley, causing inversion of relief and drainage diversion; instead of the river occupying the position now occupied by the basalt tongue, there are now two lateral channels occupied by the Einasleigh River and Parallel Creek. South of Einasleigh as far as Carpentaria Downs, the Einasleigh River is divided into many channels due to diversions by basalt flows.

(xi) *Nulla Plateau (2600 sq miles)*.—The Nulla plateau (Fig. 22) has much in common with the McBride plateau further north; it has the overall form of a low dome composed of a large number of successive flows, and the typical land forms are lava benches with lava cones and with flow-front scarps. There are fewer recognizable centres of eruption than in the McBride plateau (7 as opposed to 60), a contrast thought to indicate a slightly greater age of the basalt here. The characteristic stream line of the basalt areas is a shallow, boulder-strewn waterway, but there has been considerable dissection of the periphery of the lava dome and the formation of deep gorges, as for example on the northern margin leading down to the Clarke River. In these peripheral areas there have been drainage diversion and alluviation as in the McBride plateau. Newer basalt to the east-north-east of Lolworth homestead and north of Toomba homestead is bounded by the irregular scarp known as the

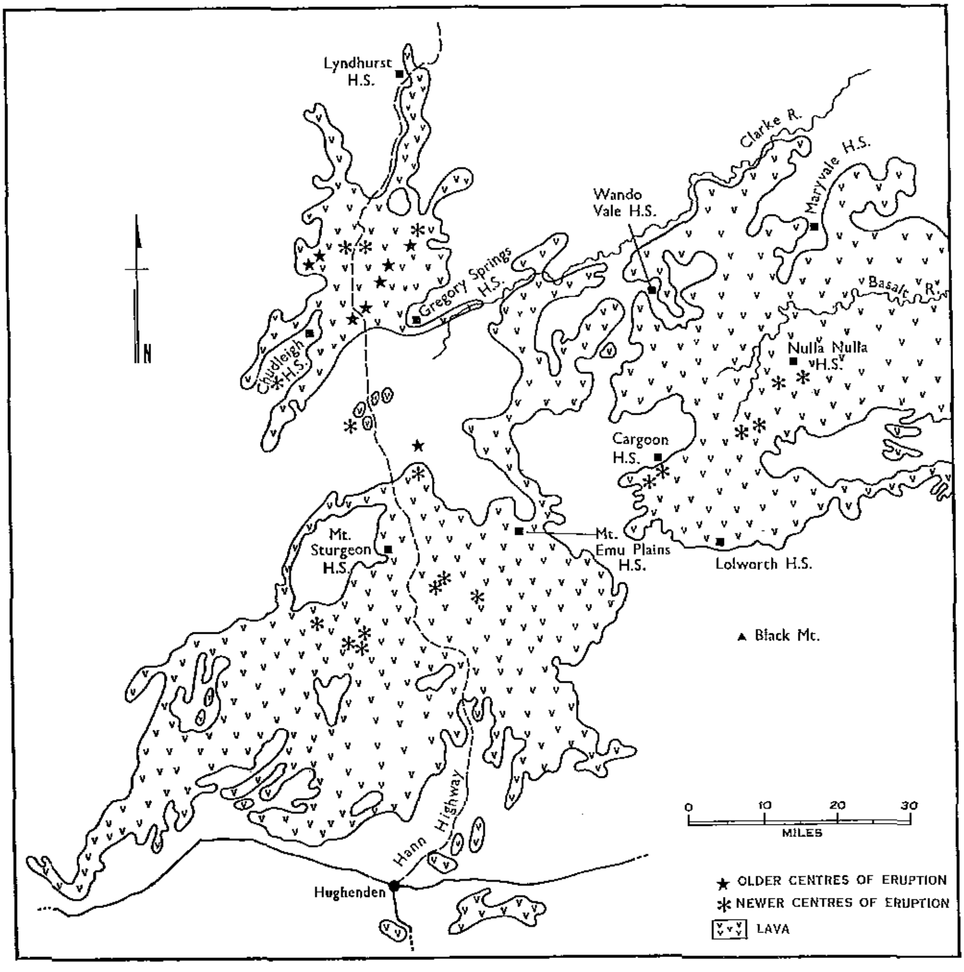

Fig. 22.—Nulla, Chudleigh, and Sturgeon volcanic provinces.

"Great Basalt Wall", which is merely the consolidated and cooled front of a lava flow. This basalt is extremely vesicular and clinkery, and displays well-developed pahoehoe or ropy structure; it is riddled with caverns and other collapse forms and stands as a low plateau some 50–100 ft above the plain.

(xii) *Chudleigh Plain (500 sq miles).*—This region differs from the other basaltic provinces of the survey area in that it is essentially a valley flow confined by higher country, and the main lava flow tongues down valleys eroded in Palaeozoic igneous and metamorphic rocks. The landscape consists of low stony rises with occasional scoria cones and lava cones which break the general plain surface. Twelve centres of eruption, seven of them quite new, have been located within this small area, six of them apparently occurring along a NE.–SW. line (Fig. 22). Marginal drainage impedance is common.

(xiii) *Sturgeon Plateau (2400 sq miles)*.—In general the land forms here are similar to those described for the McBride province, the flow-scarp features being especially prominent. Again, there is a general dome-like form (Fig. 22), and once again the dome is composed of successive lava flows. On Porcupine Creek about 6 miles south of the Whitecliff Gorge crossing, for example, four structural benches related to successive lava flows can be observed (Plate 9, Fig. 1). Marked peripheral dissection is characteristic, and the maximum dissection of the basalt sheets has been achieved where the underlying rock is the soft shale of the Cretaceous Rolling Downs Group.

Many of the gorges are over 200 ft deep and several have fine ingrown meanders and high-level perched and abandoned meander cut-offs, as on Spring Lawn Creek at Bonderoo. In the south, many parts of the basalt plateau have been isolated as basalt-capped mesas and residuals standing above the plain level, e.g. Mt. Walker, Mt. Mowbray, Mt. Castor, and Mt. Arthur. Here also, there has been much slumping of basalt on scarps due to undercutting in the soft underlying shale.

Near Mt. Sturgeon homestead there are many interesting features, including exposure of the base of the basalt where it rests on (?)Tertiary siltstone (Plate 8, Fig. 2), "toes" (Cotton 1944, pp. 116–7), and impressions of wood enfolded in the lava.

Only nine centres of eruption have been identified in this region and all of them are old, being well weathered and much dissected, e.g. Mt. Emu, Mt. James, and Mt. Sturgeon.

(xiv) *Cape Upland (1500 sq miles)*.—The Cape upland consists of an irregular plain of erosion about 1200 ft above sea level, with a series of parallel ridges and hills some 500 ft high.

(1) *Geology*.—The region is developed on metamorphic rocks—gneiss, granitic rocks, and amphibolite—of the Etheridge complex, with a strong NW.–SE. trend. This trend is reflected in the grain of the country and especially in the hill country. In the south-east of the upland there are valley deposits consisting of mottled siliceous sands which are very similar to the late Tertiary deposits of the Claraville plain. Black Mountain is a volcanic plug, predominantly basaltic, about 65 miles ENE. of Hughenden.

(2) *Drainage and Land Forms*.—The main streams, including the Cape River, flow east-south-eastwards. In the hill country there is trellis drainage, and drainage patterns are angular where granite hills occur. On the plains the patterns are indistinct, though some elements of rectangularity remain, and the density of drainage is much less than in the hilly areas.

The hilly country is of two types, the first protruding above the general level of the plain and the second resulting from the dissection of the plain (Fig. 23). In the latter type, ridge and hill crests are accordant, and in some places fragments of the former plain surface are observable on air photographs, especially on igneous rocks. It appears to emerge from beneath the Cretaceous sandstone to the west and is hence equated with the early Mesozoic surface.

The plain is irregular, for lowland streams are incised to about 30 ft, and low stony hills and hummocks are common. Where granite occurs, there are tors and whalebacks.

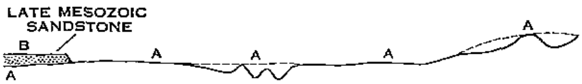

Fig. 23.—Disposition of the early Mesozoic and early Tertiary erosion surfaces in the Cape upland. *A*, warped Mesozoic plain of erosion; *B*, early Tertiary lateritized plain of erosion.

(xv) *Baronta Plateau (1550 sq miles)*.—The Baronta plateau is a high, even plain of low relief extending from about 1100 ft above sea level in the west to about 1800 ft at Burra on the Great Dividing Range, but falling again to approximately 1500 ft towards Pentland. It is bounded on the west by the low Baronta scarp.

(1) *Geology*.—Over the greater portion of the plateau, Lower Cretaceous sandstone crops out. South of Glendower homestead, deeply weathered late Tertiary olivine basalt is found, and on the western margin are exposed terrestrial conglomerates and sandstones which may form a veneer over much of the western part of the plateau. These terrestrial deposits are the Glendower Formation (Whitehouse 1940, pp. 57–61); they are fluviatile and were deposited under conditions of strong flow, possibly as a result of uplift to the east, which is the source area of many of the contained conglomeratic fragments. The formation is exposed in the Baronta scarp, and a composite section can be derived (Fig. 24).

The Glendower Formation is massively jointed and subhorizontally bedded and preserves a lateritic profile with well-developed ferruginous and mottled zones. Since lateritization is thought to have occurred not later than the mid Tertiary, it is evident that the Glendower Formation is older; but it overlies shales of Upper Cretaceous age and must thus be considered early Tertiary. It may have been deposited soon after the post-Cretaceous uplift and warping that caused the initiation of the early Tertiary cycle of erosion.

The fragments contained in the conglomerate include silcrete ("billy"), and Whitehouse (1940, p. 60) considered this to be indicative of two ages of laterite, but silcrete can develop in a number of ways and is not necessarily related to lateritization.

(2) *Drainage and Land Forms*.—Except at the dissected margins, broad low undulations are the only relief. Rivers are few, and the main drainage, of which

Torrens Creek is the most prominent stream, is southerly. Silty alluvium derived from basalt has filled those valleys heading against the basaltic Sturgeon plateau to the north. Pans are scattered on the high plain.

On the north-western periphery the sandstone has been much dissected by northward-flowing streams and has been formed into hilly terrain with deep valleys bounded by precipitous cliffs displaying structural benches. Accumulations of colluvium on some of the benches may be derived from weathering of bluffs, but the possibility that they are alluvial debris deposited at former higher river levels cannot be ignored.

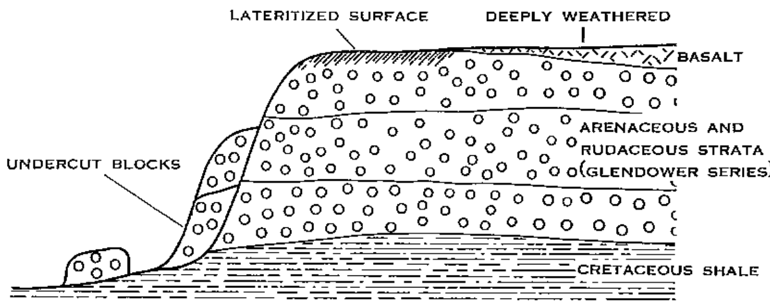

Fig. 24.—Diagrammatic section through the Baronta scarp near Glendower homestead.

Weathering along joints in the sandstone is prominent near the western escarpment and in river bluffs, and cambering has been observed in the Baronta scarp.

(xvi) *Genesis of the Einasleigh Uplands.*—Throughout the Einasleigh uplands there is evidence of three major surfaces of erosion. The oldest is that upon which the late Mesozoic sandstone and other sediments were laid down. It is developed upon a variety of rock types, but is best preserved on porphyry in the Gregory and Newcastle Ranges. The Mesozoic sediments were in turn eroded to a plain and weathered during the early Tertiary, and in middle or late Tertiary time this surface was disrupted by warping with minor faulting, and a new cycle was initiated. The sandstone was stripped from many areas and only in the Gilberton plateau do extensive continuous outcrops remain. The rejuvenated streams exhumed parts of the early Mesozoic surface, but they also destroyed it over wide areas, for they have eroded it in forming the youngest, late Tertiary–Quaternary plains and valley floors.

Near the Great Dividing Range the late Tertiary saw the onset of vulcanicity of multiple-vent type (Tyrrell 1937) which may have been related to the movements causing the disruption of the early Tertiary surface. The main phases of vulcanism post-date the period of lateritization, for no basalts display such weathering. There were, however, several periods of lava flow separated by weathering and erosion.

In limited areas, especially near Toomba, the basalt is less weathered, and hence much younger than the bulk of the volcanic rocks. There is no direct evidence of the age or ages of the vulcanicity, but on the evidence of weathering and erosion it may be described as late Tertiary and Quaternary. There is some indication that the vulcanicity may have migrated from south to north, where there is still some solfataric activity, for the southern volcanic provinces are more weathered and dissected than the northern.

IV. Acknowledgments

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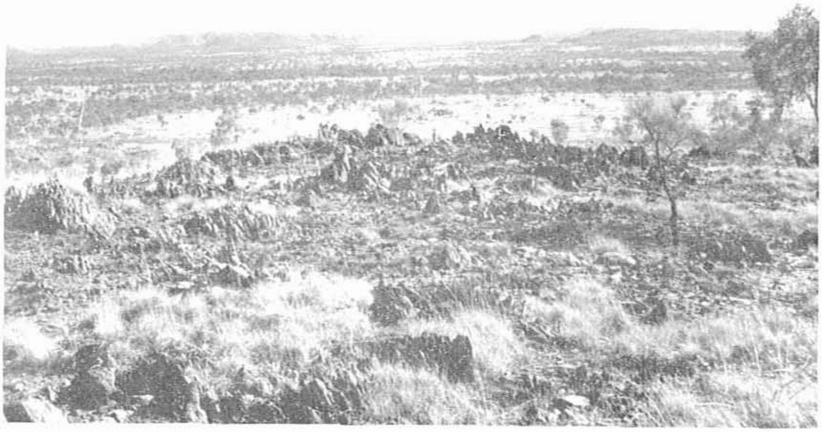

Fig. 1.—The Isa highlands, here pictured 20 miles south of Mt. Isa, commonly exceed 1500 ft above sea level and retain their plateau character over considerable areas, but broad valleys of irregular relief tongue into the uplands. The vertically cleaved mica-schists in the foreground are representative of the rocks across which the plateau surface is eroded.

Fig. 2.—The narrowly dissected parts of the Isa highlands are rugged, with small plateau remnants. In the centre of this view, some 25 miles west of Cloncurry, a mesa, probably of subhorizontal Cretaceous strata, protrudes above the general plateau level formed on truncated Precambrian rocks.

Fig. 1.—On the margins of the Isa highlands and along major rivers, little of the erosional plateau surface remains and the country is typically hilly and rough as shown here between Mt. Isa and Cloncurry.

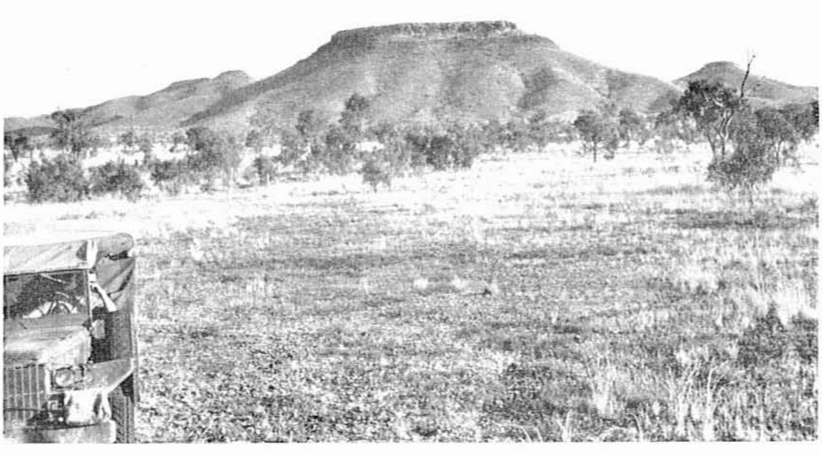

Fig. 2.—Cambrian rocks are preserved in a graben near the Burke River in the south-west of the Leichhardt–Gilbert area, but small outliers cap mesas as at Mt. Aplin, some 20 miles south of Duchess. The Cambrian sequence here comprises a siliceous breccia, siltstone, and sandstone, resting upon Precambrian granite.

Fig. 1.—Where the Cambrian rocks have been stripped, a plain of pre-Middle Cambrian age has been exhumed. This was subjected to lateritization in the early Tertiary and has subsequently been dissected, but it is preserved on mesas and plateaux such as these east and north-east of Mt. Aplin.

Fig. 2.—The complex geologic and geomorphic history of the Leichhardt–Gilbert area is reflected in this picture in the south of the Isa highlands. *A–B–C* is part of the early Mesozoic erosion surface, expressed topographically as a bench and continued as an unconformity between Mesozoic siltstone and Precambrian schist. The mesa, *D*, bears the lateritic capping of the early Tertiary land surface, whilst *E* is the extending head of the youngest, late Tertiary–Quaternary surface.

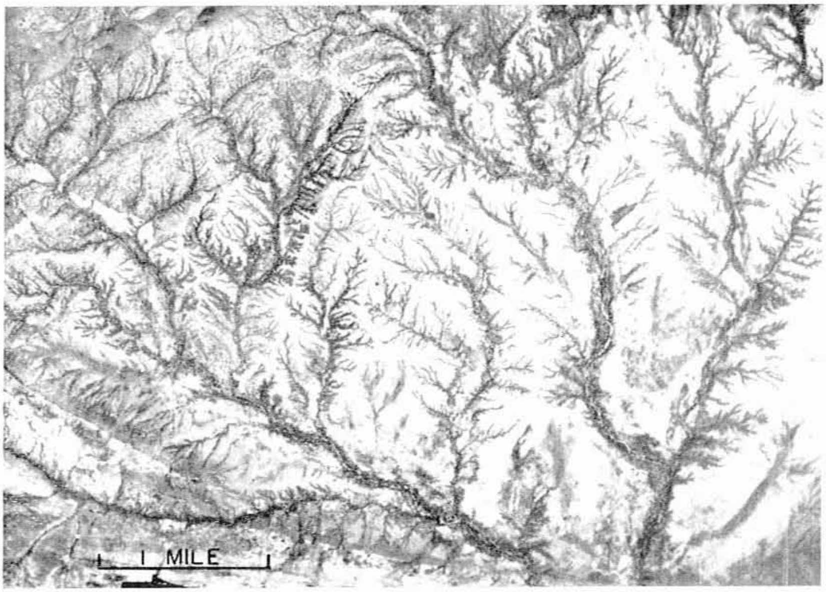

Fig. 1.—Drainage patterns in the Isa highlands are generally trellised, but there are many local adaptations to structure. Density of streams also varies considerably. Amongst the most spectacular are these pinnate patterns developed in granitic rocks 15 miles north-east of Duchess. (Reproduction courtesy Director of National Mapping, Department of National Development, Canberra.)

Fig. 2.—Granitic pediments and inselbergs are common in the Isa highlands and in the Einasleigh uplands. The pediments are smooth with few stream channels. The granite is extensively exposed near the hills and is nowhere more than a few feet below the sandy alluvium of the lower areas. The hills rise abruptly from the plains and the piedmont angle may be truly angular, as shown here at Naraku, 45 miles north-east of Cloncurry.

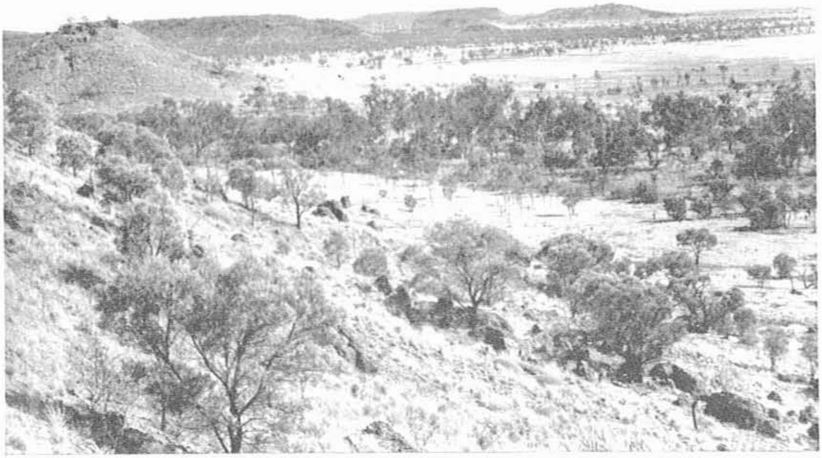

Fig. 1.—Remnants of the early Tertiary lateritized surface of erosion occur as plateaux and mesas within the Carpentaria and inland plains. The Kynuna plateau, part of the northern margin of which is shown here, is such a remnant located on the former divide between the gulf and interior drainage.

Fig. 2.—In Pleistocene times the Flinders, Leichhardt, and other rivers deposited a sheet of silty alluvium over broad areas of the Carpentaria plains. The Wondoola plain is typical of the extraordinarily flat surfaces formed, and its featurelessness is enhanced by the grassland vegetation. Gilgai puffs and depressions form the only relief.

Fig. 1.—The rivers flowing to the gulf have been rejuvenated and have cut down to a new lower base level. The Leichhardt Falls is a nick-point marking the inland progress of this rejuvenation. Here the river tumbles 40 ft over lateritized Cretaceous sediments and enters its tidal reach.

Fig. 2.—The gulf coast, with its gentle offshore gradients and large river mouths, is one of aggradation, with groups of beach ridges and large mud flats which are traversed by the rivers in fantastic meanders. These features are well developed between Nicholson River and Parker Point, just west of the Leichhardt–Gilbert area. (Reproduction courtesy Director of National Mapping, Department of National Development, Canberra.)

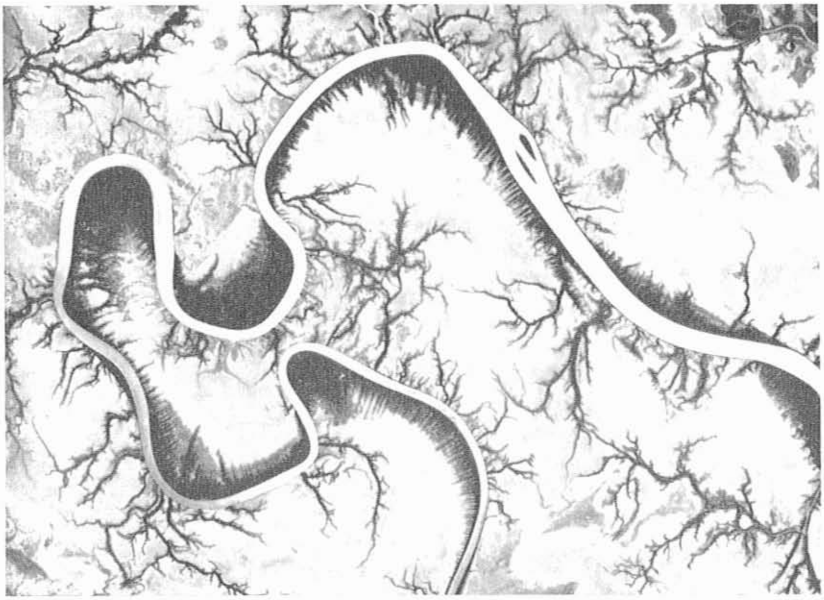

Fig. 1.—River meanders through coastal mud flats 20 miles ENE. of Burketown. Note the two types of secondary drainage, namely dendritic streams and short parallel gutters draining river banks on the inside of bends. (Reproduction courtesy Director of National Mapping, Department of National Development, Canberra.)

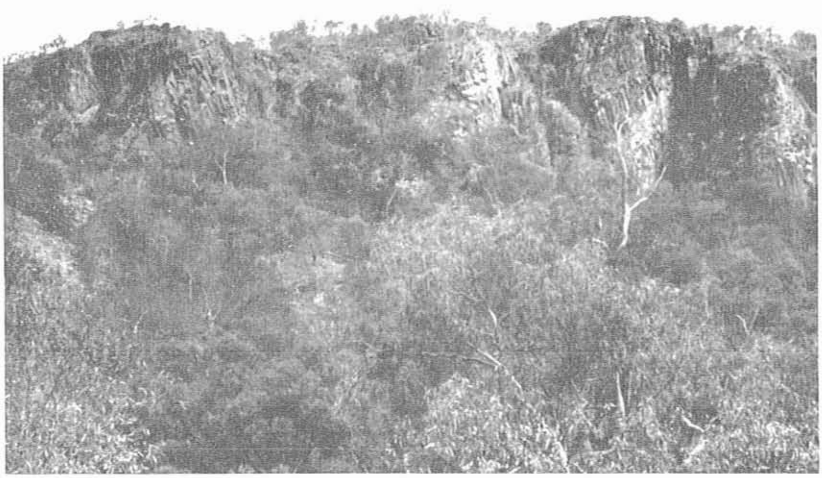

Fig. 2.—The resistant Croydon Volcanics form prominent, massive relief in the Einasleigh uplands, and its volcanic nature is reflected in columnar jointing in a valley near Einasleigh. However, the vulcanicity extended over an immense period, for evidence suggests that the felsite is Proterozoic near Croydon, Devonian further east, and Permian north-east of Einasleigh.

Fig. 1.—Extensive basaltic lava plateaux and plains formed in late Tertiary and Quaternary vulcanicity in the east of the Leichhardt–Gilbert area. Eruption was of the central-vent type and many of the centres are still visible despite their age. This aerial view of Mt. Tabletop, near Rosella plains in the McBride plateau, shows a main cone of Mauna Loa type with four adventive cones on the north-east flank and another opening on the south-east. (Reproduction courtesy Director of National Mapping, Department of National Development, Canberra.)

Fig. 2.—Lava flows blanketed rocks of many types, valleys were filled, and streams diverted. This siltstone exposed beneath the basalt near Mt. Sturgeon homestead has been baked to a depth of 3 in. at the contact.

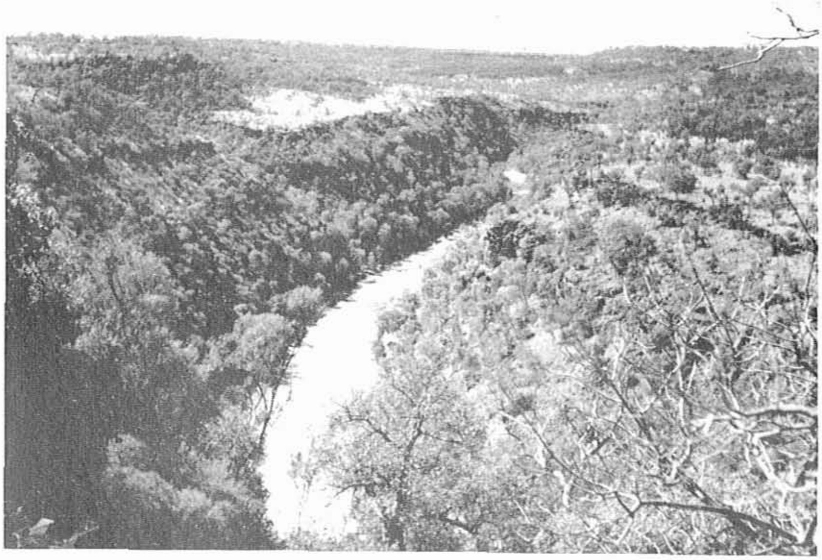

Fig. 1.—The basalt plateaux are deeply dissected at their margins and successive lava flows are revealed in the gorge walls. Structural benches are caused by differential erosion of layered flows in the 200-ft Porcupine or Galah gorge, 30 miles north of Hughenden.

Fig. 2.—The rivers of the Leichhardt–Gilbert area flow intermittently, but when they do flow they often flood. The sandy bed of the Einasleigh River, here pictured near Abingdon homestead, is typical of the dry season, but the stranded tree trunk is a reminder of the volume of water carried in flood.

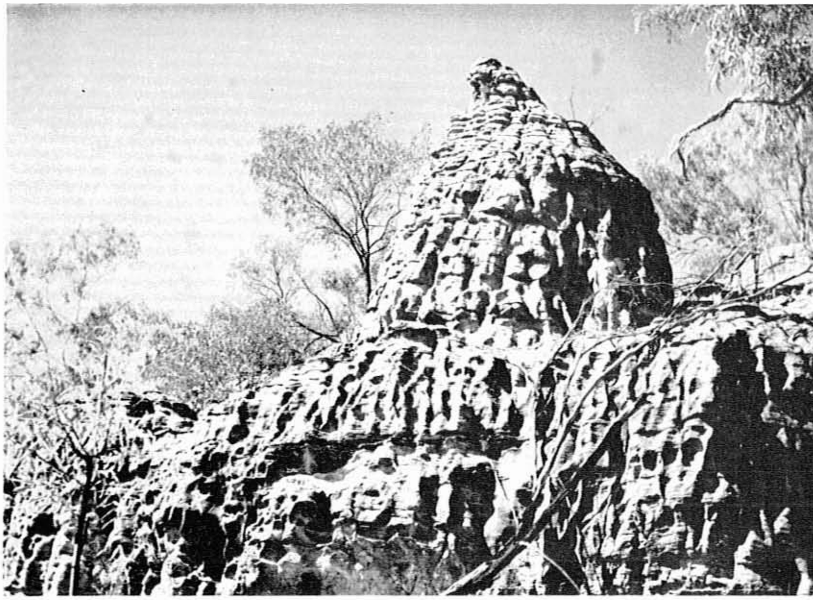

Fig. 1.—Lithology is expressed in land forms at many scales in the prevailing dry climate. Honeycomb weathering and "beehive forms" (Twidale 1956*d*) are here displayed in Cretaceous sandstone in the Einasleigh uplands 30 miles south of Forsayth.

Fig. 2.—Another characteristic suite of land forms occurs in limestone. These *Rillenkarren* are found on deeply dipping strata of Siluro-Devonian age 20 miles NNW. of Wando Vale homestead.