Lands of the Adelaide–Alligator Area, Northern Territory

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PART I. INTRODUCTION

By R. E. O'Ferrall*

I. General

The history of this survey goes back to 1945, when the Commonwealth Government established a committee to plan the coordinated development of northern Australia. The committee recommended that reconnaissance surveys should be undertaken in this part of the continent and that priority should be given to the Katherine–Darwin region. In 1946 the field work was begun, and in 1947 an advance report was distributed, subsequently revised, and published by CSIRO (Christian and Stewart 1953).

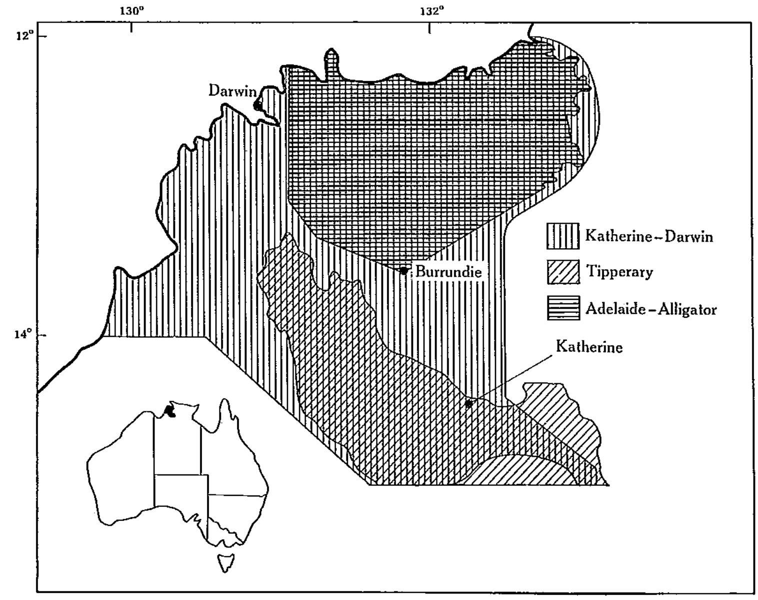

Fig. 1.—Location of Katherine–Darwin, Tipperary, and Adelaide–Alligator areas.

It was obvious that more detailed surveys would be necessary as the region developed. The first of these, of the original Tipperary land system, has been completed (Speck *et al.* 1965). The present survey is the second and deals with the north-eastern third of the Katherine–Darwin region. The location of these three survey areas is shown in Figure 1.

Publications consulted during the compilation of this Part, and which give a general background to conditions in the area, are by Bauer (1964), Bureau of Agricultural Economics (1964), Christian and Stewart (1953), Commonwealth of Australia (1958), Hill (1964), and the Northern Territory Administration, Agricultural Branch (1965).

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II. Survey Procedure

Like similar reconnaissance surveys done by the Division of Land Research, this one of the Adelaide–Alligator area is a broad study of the natural features and resources and a classification of the land according to land systems (areas each with its own characteristic combination of topography, soils, and vegetation, and consequently with its own agricultural potential). The survey technique also is similar, being based upon the interpretation of aerial photographs in which each land system is reflected by its own individual pattern. The mapping and description of the land systems are done by a scientific team of three—a geomorphologist, a pedologist, and an ecologist—who work throughout in close cooperation.

Before going into the field, the team mapped the land systems tentatively by delineating and, as far as possible, classifying the apparently different types of country through stereoscopic study of the aerial photographs, run by run. The boundaries were then transferred from the aerial photographs to photo-mosaics to give the rudiments of a land system map. For future study in the field, sample areas were selected in representative parts of each pattern, their number varying according to the size and complexity of the pattern.

The team used a helicopter in the field, which speeded the work and made possible an even scatter of samples over this inaccessible area. Field work began towards the middle of July 1965 and lasted for 6 weeks.

In the final period of laboratory work, the team members remapped and described the area in the light of their additional information. The land system map is at a scale of 1:250,000, and maps at 1:500,000 show the geomorphology, soils, vegetation, and pasture lands.

III. Size and Location of the Area

The area comprises just under 9600 sq miles of country south-east of Darwin, as shown on an inset to the land system map.

The western boundary of the area is a straight line running north–south along long. 131°03′E. from the coast near Fright Point until it intersects the Adelaide River. Burrundie siding on the north Australian railway is the southernmost point of the area, from where the boundary runs in a straight line in a north-easterly direction to a point at lat. 12°47′S., long. 132°46′E. at the edge of the Arnhem Land plateau. The boundary then follows the escarpment northward to the coast at lat. 12°07′S., long. 132°43′E. on the north-eastern bank of the estuary of the East Alligator River. Off-shore islands are excluded.

Place names mentioned in the text are shown in Figure 2.

Although Darwin is about 15 miles west of the survey area it is historically and geographically closely connected with it. It is therefore considered in some detail in this section.

IV. History

The Northern Territory, in particular its northern coastal region, has proved to be one of the most difficult areas of Australia to settle.

By 1823, both the administration in Sydney and the Colonial Office in London had recognized the need to establish some form of permanent settlement in this area to buffer the threat of the Dutch and Portuguese, who were active in the East Indies at the time. French explorers, Malay fishermen, and Javanese also frequently used the Timor Sea.

The northern coastline west of the Coburg Peninsula was first explored in detail by King between 1818 and 1822. As he was operating by ship, he experienced few of the climatic hardships that were later to prove the largest single factor in delaying northern development.

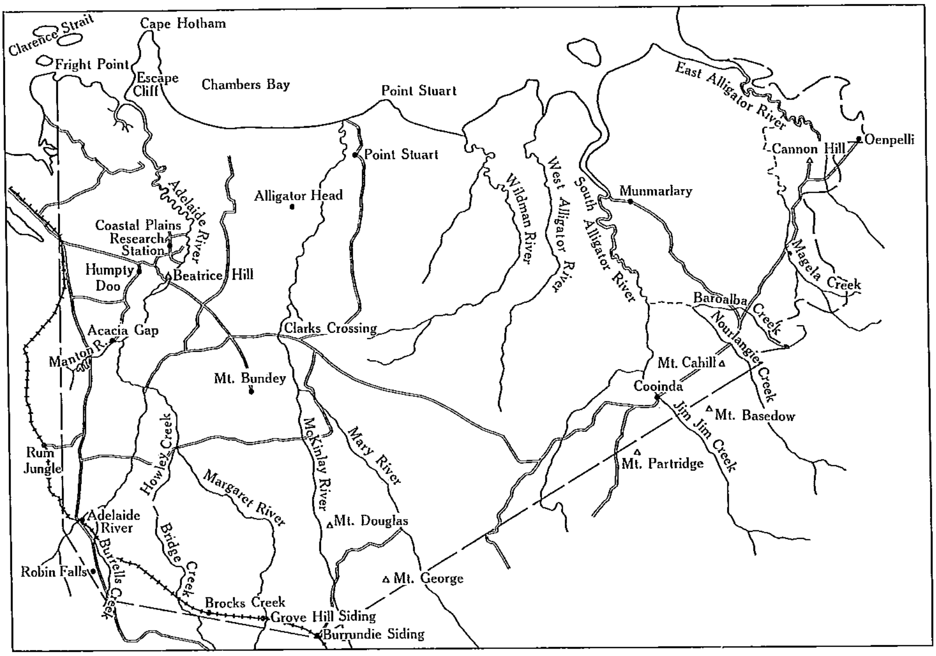

Fig. 2.—Place names.

The first attempted settlement was made beside a small stream on the Melville Island side of Apsley Strait late in 1824. The settlement was called Fort Dundas. The reason for siting it on Melville Island and not on the mainland appears to have been based on an idea that some form of trade could be established with the Malays who frequented the area in their fishing boats. This plan was a failure, however, and the rigours of isolation and the unexpected harshness of the seasonal tropical climate forced the abandonment of Fort Dundas in 1829.

The second settlement was made at Raffles Bay in 1827, and the third at Port Essington on the Coburg Peninsula in 1838 (this site was the only one recommended by King). Both were established for the same trade reasons as Fort Dundas, and they too were abandoned within 10 years.

Of more direct interest to the actual survey area are the voyages of the *Beagle* (under Wickham and Stokes). Operating from Port Essington between 1839 and 1841, she explored the coast of Chambers Bay and further west. During the course of these trips, Port Darwin and the Adelaide River were discovered. The Adelaide was explored upstream for 80 miles, high praise being given to what appeared to be fertile plains. Had they been seen in the wet season, no doubt there would have been far less enthusiasm displayed.

Soon after this, in 1844, Dr. Ludwig Leichhardt struggled down to the coastal plains after a difficult journey up the Roper River and over the Arnhem Land plateau. He travelled along the East Alligator River, recording favourable comments about the country through which he passed.

Later, after four unsuccessful and arduous attempts, Stuart in 1862 reached the Mary River after having traversed the continent from south to north. He explored the area as he travelled northwards down the river, eventually reaching the coast at Point Stuart, recording high praise for the region (no doubt biased by the comparatively dry and poor country through which he had previously travelled). Stuart's good reports did much to publicize the area at the time.

In 1864, soon after South Australia took over administration of the Northern Territory, a party under B. T. Finniss chose an area at Escape Cliffs, near the mouth of the Adelaide River, as the site for a capital. The settlement soon began to decline, and Finniss's relief on a charge of dereliction of duty, followed by the appointment of Manton as Government Resident in 1865, did nothing to improve the situation. One of the severest critics of the Escape Cliffs settlement was McKinlay, although his own abortive and expensive expedition to the East Alligator River achieved virtually nothing of significance. An explorer of considerable repute, he had been sent north by the South Australian government in 1866 to report on the region to the east of the Adelaide River. Escape Cliffs was finally abandoned in 1867.

It was not until 1869 that Goyder eventually chose Point Darwin as the site for what was hoped this time would be a permanent capital. Under his initial leadership the settlement grew and became well established. Once a capital had been secured, the area underwent a comparatively rapid change. This was most noticeable between 1869 and 1889.

During this period gold was discovered (Goyder had initiated the search for this metal), the overland telegraph was constructed, and the foundation of the present land tenure system was established when agriculture and grazing were commenced.

Oenpelli, in the east of the survey area, was occupied intermittently by Europeans from 1906. The mission station was founded there in 1925, and more recently the road across the survey area was built to serve the mission.

V. Communications

The first really important achievement in communications marked the beginning of northern development and aroused world-wide interest. This was the completion of the overland telegraph. The work was begun from Darwin and Adelaide in 1870, and the two lines were joined near the centre of the continent in 1872. Thereafter the track from Darwin to Adelaide came into regular use in carrying supplies to the maintenance crews, but even so the area developed slowly until World War II brought about a sudden improvement in communications, and a general focusing of attention on the north. Telephone and telegraph communications in the survey area are still confined to a few places along the western boundary, but the old track was improved and became an important link with the south during World War II, and has remained so. Named the Stuart Highway, it is a sealed all-weather road as far as Alice Springs, running north–south just inside the western boundary of the survey area. The only other such roads in the area are the 22-mile access road to the Coastal Plains Research Station at Middle Point, a section of the road to Batchelor, and the 9-mile road to Fountain Head, which continues unsealed to Mount Harris.

Branching east from the Stuart Highway are various small tracks and three other rather important roads. The principal one leaves the highway 47 miles from Darwin, traversing the survey area and terminating at the Oenpelli Mission. The second runs from the township of Adelaide River and joins the Oenpelli road 5 miles to the east of Clarks Crossing on the Mary River. The remaining road runs from Pine Creek, entering the survey area near Mount Partridge and linking up near Jim Jim Creek.

These three roads and the access tracks that branch off them to pastoral leases and abattoirs are impassable in the wet season (November–April) and are poor even in the dry season. Their standard, however, is gradually being improved by some re-routing and by continual grading throughout the dry season. New roads are under consideration, but full-scale construction has not yet begun. They would mainly serve the buffalo industry, but in its present uncertain state there is some doubt whether new roads will be economically justified. An important new link to the Mount Bundey ore field is under construction from Humpty Doo, with the Adelaide River bridged near Beatrice Hill.

Supplying Darwin from the south as far as Larrimah is the north Australian railway, which was built in 1887–89. It runs through the south-western corner of the area.

The port of Darwin handles a considerable amount of shipping, both coastal and overseas. The Oenpelli Mission Station was originally supplied by a shallow-draught launch which for many years carried supplies between Darwin and the mission, landing its cargo at a point on the East Alligator River adjacent to the mission. Before the construction of suitable roads through the area, a launch service used to operate from Darwin to Chambers Bay.

Airstrips have recently been constructed and light aircraft, both chartered and privately owned, are running a year-round service to the various properties. In the wet season, supply work and all essential transport become entirely a function of these air services. Direct communication is maintained daily with the properties by a transceiver radio service, through a regional "mother" station in Darwin.

VI. Supplies

Coastal tankers supply Darwin with petroleum products for the entire north-western sector of the Northern Territory, and freighters bring a continual supply of foodstuffs (mostly non-perishable) and other essential supplies. Heavy road transport on the Stuart Highway brings in a variety of lighter freight and perishable foodstuffs from South Australia and Queensland. Some supplies from the south as far as Larrimah (the terminus) are carried by the north Australian railway.

Darwin depends heavily on these lines of communication, and although fruit, vegetables, poultry, beef, milk, and eggs are produced locally, they contribute little towards its needs. In any case not much of this produce comes from the survey area except meat, most of which is exported—the beef mainly for the hamburger trade and the buffalo meat mainly for pets' meat. Fresh beef comes in from South Australia and Western Australia. Almost all the fruit and eggs come from Brisbane. Local vegetables are at times fairly plentiful but fluctuate widely, and overall supplies are quite inadequate. A good deal of fish is caught locally, but even this is supplemented by supplies from the south and overseas. Pure fresh milk is used for mixing with various forms of preserved milk and is difficult to obtain.

This low production is ascribed in the annual reports of the Northern Territory Administration to poor soils, high cost of fertilizer, lower market prices, better incomes from other activities, pests and diseases, and waterlogging.

In 1960 a retail market was established to encourage local production. It is still maintained but has changed in character, and is now a wholesale market dealing with produce from outside as well as inside the Northern Territory.

VII. Population and Activities

The population of the Adelaide–Alligator area experiences a marked seasonality. However, even at its highest level in the dry season, it could still only be described as sparse.

Between November and April, the European population is noticeably greater. This is principally the result of an influx of workers connected with the buffalo industry (i.e. shooters, butchers, meat inspectors, and labourers).

At the onset of the wet season, this temporary population withdraws either to Darwin or to southern States.

Within the survey area the only township is Adelaide River, situated in the south-west at the junction of the Stuart Highway and the north Australian railway. This town was established as a mining centre, and during World War II was the site of a large army supply base. Mining has since ceased, and the population of the town is now approximately 160.

In the extreme south of the survey area the main population centre is the government battery at Mount Wells, employing some 20 men. Smaller numbers are employed at Jessops Mine, and on railway maintenance at Burrundie siding. The remaining European population is distributed amongst the large pastoral leases, eight abattoirs, two safari camps, three hotels, and the several small tin and gold mines in the south of the area.

There is no accurate figure available for the Aboriginal population. Many are employed at the pastoral properties and mission, and a considerable number work for the various abattoirs.

There are few, if any, Asians within the survey area today. Although many were originally employed during the gold rushes of the nineteenth century, the remainder of these have long since withdrawn to Darwin.

The main primary industry is cattle ranching for beef production. The industry depends almost entirely on the native grasses, with improved pastures and supplementary feed contributing only very little to the animals' requirements.

VIII. Rural Research

Various rural research projects are being conducted within, and adjacent to, the survey area by both CSIRO and the Primary Industries Branch of the Northern

Territory Administration (N.T.A.). The general background to these research activities can be conveniently obtained from the report of the Commonwealth of Australia (1958) and Commonwealth of Australia, Department of Territories (1960) (Forster Committee Report). More up-to-date information is contained in recent annual reports of the Animal Industry Branch, N.T.A., Agricultural Branch, N.T.A., and Coastal Plains Research Station, CSIRO.

The Coastal Plains Research Station is situated near Humpty Doo about 43 miles from Darwin, and is under the joint control of CSIRO and N.T.A. CSIRO officers are mainly concerned with rice breeding, agronomy, physiology, and soil chemistry, while N.T.A. officers maintain pasture experiments primarily with legumes. The entomologist and plant pathologist of the Scientific Services Section, N.T.A., participate in experimental work and provide constant checks on crop condition.

The Beatrice Hill Animal Husbandry Research Station (N.T.A.) on the Adelaide River plains about 14 miles south of the Coastal Plains Research Station is concerned with improved pasture establishment with grasses (mainly para grass, *Brachiaria mutica*) and legumes. Breeding units have been established here using Santa Gertrudis and Brahman stock.

The Upper Adelaide River Experimental Station covers nearly 500 acres of land between the Stuart Highway 60 miles from Darwin and the Adelaide River. In association with a number of pilot farms, research work was originally designed to study rice agronomy of the river plains and range pasture improvement on higher land near the Stuart Highway. Work at present is mainly concerned with utilization of both improved and rangeland pastures. West of the surveyed area, but typical of considerable areas within the Adelaide–Alligator region, the Berrimah Experiment Farm, 8 miles from Darwin, has been concerned with pasture forage crops and vegetable and cashew nut production. Much of the vegetable research has recently been transferred to Lake Deane, about 45 miles south of Darwin.

In addition to these stations numbers of small trials are carried out yearly by the Primary Industries Branch, N.T.A., in test sites within the survey area.

Soil surveys by Scientific Services Section of the Primary Industries Branch (formerly Agricultural Branch) have investigated in detail the solonetzic soils of the major riverine plains of the Adelaide–Alligator area and the estuarine clay soils of the Adelaide River plains. Work is currently being directed to detailed soils maps of the Daly River plains. This work involves large amounts of analytical data of soil chemical content, which are provided also by the Scientific Services Section.

The Land Resources Section of the Primary Industries Branch conducts detailed ecological surveys to prepare land unit maps. This work forms a natural complement to land system studies and most detailed work by the section has been concentrated in the Tipperary area following the publication by CSIRO of the relevant survey report (Speck *et al.* 1965).

The Water Resources Branch has been carrying out investigations into the development and control of water resources since 1955. A series of stream gauges and measuring devices, both permanent and temporary, has been set up along streams and over the coastal plains. Information from these, and various other field measurements of stream velocities and depths, are used to determine the relation between water levels and stream discharge throughout the year, and to assess future storage potential. Investigation and development of underground water resources are also being carried out by this branch. Currently the branch is undertaking detailed level surveys in conjunction with research by CSIRO on the soil types and their distribution and relation to drainage factors at the Coastal Plains Research Station. Records of the branch are mainly in the form of unpublished reports and maps.

IX. The Buffalo

The water buffalo (*Bubalus bubalis*) has been intensively studied by Tulloch.* It is found on and adjacent to the coastal plains, and is of major importance to the area at the present time. The original beasts were introduced from Timor to the Melville Island settlement of Fort Dundas in 1826. Buffalo were later landed on the mainland at Raffles Bay and Port Essington. The animals eventually ran wild and, aided by several early imports of less than 50 beasts, they have grown in number to approximately 150,000. The figure remains reasonably constant from year to year, natural increase being offset by shooting (bulls over 3 years of age only), disease, and competition for the limited supplies of feed during the later part of the dry season.

There was a marked increase in buffalo numbers following the decline of the market for hides. Unrestricted and widespread shooting, which had become common, ceased in 1956 when the value of hides fell to uneconomical levels. Shooting for the abattoirs today is more or less controlled, although a decrease in numbers appears evident once again. There has been a general plan put forward which aims at the gradual eradication of the buffalo from certain areas, and its replacement with beef cattle. The plan envisages the withdrawal of the buffalo to approximately 4000 sq miles of the area and the introduction of beef cattle to approximately 2750 sq miles of the choicer areas remaining. While some of the pastoral lessees of the region support this plan, others believe that under controlled management the buffalo has greater potential.

It was generally noted throughout the Buffalo Protection Area (6680 sq miles of the coastal plain and adjacent Koolpinyah land system) that the buffalo was able to maintain condition on a variety of feed, including many water plants. On the other hand, the cattle in the area had a more restricted diet and generally appeared to be in inferior condition.

Bovine tuberculosis is widespread among the buffalo (Northern Territory Administration, Animal Industry Branch 1965).

X. Acknowledgments

Grateful acknowledgment is made to Messrs. D. Tulloch, S. Baseden, J. Martin, and their staff of the N.T.A. Agricultural Branch, and Messrs. P. R. Dunn and J. Hays of the Bureau of Mineral Resources, for assistance and advice; Messrs. R. N. Eden, D. Purich, F. Eggington, W. Morton, and D. Kingston of the N.T.A. Water Resources Branch, for maps of the area, access to unpublished records, and helpful discussions; the Commonwealth Department of Works, for information on roads and tracks; Mr. and Mrs. T. Opitz, of Cooinda, and Mr. K. L. Johnston, of Point Stuart, for providing base camp sites; the pastoral property lessees of the area,

* Annual reports, Northern Territory Administration.

in particular Mr. J. Lord of Munmarlary, for assistance, hospitality, and information; and the two pilots and their mechanics of Helicopair Ltd., on whose skill the field work was largely dependent.

Plate 2, Figure 1 of Plate 3, and Plate 8 were made available by courtesy of the Director, Division of National Mapping, Department of National Development, Canberra.

The work of the staff of the Division of Land Research in the field and during the compilation of the report is gratefully acknowledged.

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Addendum

Since this Part was written the Mount Bundey road has been opened, providing an all-weather link to the iron ore mines. The improved access to the Mary River and the Oenpelli road via the Mount Bundey road and improvements to the Oenpelli–Jim Jim road have resulted in a marked increase in tourist traffic in the surveyed area. The old access route to the Mary River via the 47-mile road on the Stuart Highway is now little used.

Several roads have been formed for dry-season access to the buffalo areas on the plains north of Point Stuart (Jimmys Creek abattoirs) and Munmarlary stations.

Buffalo shooting for the export meat trade reached a peak in 1966 but the imposition of a quota system to prevent excessive shooting has resulted in lower returns and greater stability in the industry. Several properties are now engaged in pasture improvement programmes using Townsville lucerne, and some areas of pangola grass (*Digitaria decumbens*) and para grass (*Brachiaria mutica*) are promising.

Pastoral leases have been granted for three properties formerly under occupational development licences and these and other properties are now experimenting with buffalo domestication programmes. The new property boundaries for these leases were determined by using the land systems mapped by this survey.

PART II. SUMMARY DESCRIPTION OF THE ADELAIDE–ALLIGATOR AREA

By R. Story*

For the simplification needed in this generalized sketch, the area is considered not in terms of the 23 land systems but in terms of the 6 different types of country which have been used as a basis for grouping the land systems on the map. This descriptive part is preceded by an outline of the main features of the environment and followed by a note on land use and capabilities.

I. Main Features of the Environment

(*a*) *Climate*

The rainfall of the area is strongly seasonal. It is negligible between April and October, then builds up steeply to a high monthly average with a peak of over 10 in. in January or February, and drops after March even more steeply than it rises. The difference in rainfall between the wettest and driest parts of the area is a relatively small 12 in. (from 48 to 60 in.), the increase, both in amount and reliability, being towards the north.

In contrast to the seasonal fluctuation of the rainfall, temperatures are relatively even. On a fortnightly basis at Humpty Doo the mean maximum varies by 8·6 degF (96·6–88·0°F), the mean minimum by 16·2 degF (75·8–59·6°F). This gives an annual range for the mean of 37·0 degF. Temperatures are highest in November. In terms of human comfort, the winters are pleasantly warm, with rare cold mornings when pullovers and coats are needed, but the summers, although not a great deal hotter, are oppressive because of high humidity.

The highest evaporation is 9 in. a month, towards the end of the dry season.

(*b*) *Geology*

The geological history of the survey area may be summarized as follows.

(i) *Lower Proterozoic.*—Deposition of gravels, sands, and silts on the Archaean basement rocks forming the Pine Creek Geosyncline. Regional metamorphism, folding, and faulting. Major intrusions of granite. Uplift, metamorphism, erosion.

(ii) *Upper Proterozoic.*—Subsidence and marine transgression. Deposition of sands and gravels.

(iii) *Palaeozoic.*—Episodic upwarping and erosion; gentle uplift, prolonged tectonic stability, peneplanation giving rise to the sub-Cretaceous surface.

(iv) *Mesozoic.*—Downwarping. Deposition of freshwater sands and gravels. Marine transgression; deposition of marine sands and silts.

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(v) *Cainozoic.*—Marine regression. Erosion. Deep weathering and formation of lateritized Bradshaw surface. Erosion and partial burial of underlying rocks with Late Cainozoic sediments. Formation of Koolpinyah surface. Episodic erosion and deep weathering accompanied by fluctuating Pleistocene sea levels.

(*c*) *Geomorphology*

(i) *Land-forming Processes.*—The intense and heavy seasonal rainfall results in rapid run-off and erosion. Slopes over 5% are generally stony (Plate 1, Fig. 1), and gullies are locally common on the slopes and flats. The rainfall regime has resulted also in a fluctuating but generally high water-table, which, with the high average temperatures, has enabled rapid chemical weathering to take place, with lateritization and softening of the rocks (Plate 1, Fig. 2). Of the laterite known in the area, it is estimated that roughly 45% is disintegrating, 30% forming, and 25% stable.

(ii) *Drainage.*—There are six main river systems. The Adelaide, Mary, South Alligator, and East Alligator rise in the dissected foothills, where they follow the strike vales. On the Koolpinyah surface the valleys widen out, often into extensive alluvial flats with levees on the river banks and low gravelly scattered rises elsewhere. Here two more rivers originate, the Wildman and West Alligator. All meander in their lower reaches, sometimes in a confused and irregular way, with recent changes in course apparent (Plate 2, Fig. 1). The influence of the salt water, because of the 26-ft tide, extends as far as 30 miles inland.

(iii) *Evolution of the Landscape.*—What is known as either the "Bradshaw" or the "Tennant Creek" surface is a very gently tilted surface cut across the Upper Jurassic or Lower Cretaceous Mullaman Beds. It is probably of early Miocene age. Little of it remains in the area—the 800-ft plateau south of Adelaide River and the cliffs at Cape Hotham and Fright Point are examples. It was eroded by north-flowing streams after slow uplift later in the Miocene, and it was this process that uncovered the Lower Proterozoic strike ridges and granites. When uplift ceased, rising base levels and slower streams caused the progressive accumulation of debris to the north, with burial or partial burial of the hills and the formation of a gently undulating plain running east–west across the centre. This process continued into Quaternary times, and was accompanied by sporadic lateritization. The present topography depends greatly on the amount of stripping of the Late Tertiary cover (Plate 2, Fig. 2). It has been almost complete along the margins of the dissected foothills, partial further north and to the east, and relatively slight in the west and north-west, because of gentle slopes and permeable soils, which have minimized erosion. At least two phases of Quaternary stripping and alluviation are apparent. The earlier phase seems related to the numerous internal drainage depressions, which are often aligned north–south with a roughly dendritic pattern; this suggests that they are former spillways eroded in the lateritized lowlands (Plate 3, Fig. 1). The later phase is associated with a general decline in stream competence, which could stem either from climatic change or from a slowing down of stream flow through coastal emergence. There is evidence that both have occurred.

(*d*) *Soils*

These have been classified firstly according to agronomic characters, namely texture and stoniness, then according to depth, colour, horizonation, pH, drainage, and parent material. It was not found necessary to use all these characters each time a soil was classified, or to use them always in the same order.

In the text, the soils have been grouped according to the main geographic regions. Soil descriptions are grouped according to the intrinsic characters used in the factual key of Northcote (1965). Gradational, texture-contrast, and uniform soils are common in the area.

Gradational soils occur on the flat or dissected Koolpinyah surface and on the alluvial flats of the larger rivers. All are non-calcareous and most are sandy or earthy, and on the lateritic plains often stony as well.

Texture-contrast soils are on colluvial foot slopes, the alluvial flats of the larger rivers, and the lateritic plains.

Of the uniform soils, those of coarse or medium texture are on recent alluvium, foot slopes bordering sandstone hills, and next to the Koolpinyah surface, and those that are fine textured (most of them cracking clays) are on the coastal plains (Plate 3, Fig. 2).

A catenary relationship is widespread, generally with coarse gravelly soils on the upper slopes, sandy leached soils on the middle slopes, and texture-contrast soils on the lower slopes and alluvial flats, those on the alluvial flats often having a columnar structure in the B horizon. These differences correspond fairly closely with differences in the vegetation (Plate 2, Fig. 2).

(*e*) *Vegetation*

In the text the vegetation has been divided into 15 types, but for mapping purposes and the purposes of this summary the smaller types have been disregarded or combined, to give a total of 8.

Tall open forest (15%) is dominated by *E. miniata* and *E. tetrodonta*, together or separately, averaging over 40 ft in height. Visibility at eye level is up to 100 yd but varies greatly according to the number of non-eucalypts below the canopy, which form a distinct 12-ft layer of palms, small trees, and tall shrubs, comprising about 20 species. Small shrubs are uncommon, grasses are abundant. They are mostly tall annuals, but patchy and variable. This type is found on the level sandy plains of the Koolpinyah surface (Plate 4, Fig. 1).

Woodland (30%) is the vegetation of the slopes adjoining the Koolpinyah surface, and of the dissected foothills. The trees are more widely spaced than those of the tall open forest, and are smaller, ranging from 20 to 40 ft (Plate 4, Fig. 2). Eucalypts are usually again dominant but are in greater variety, and many are deciduous. The same palms, non-eucalypt small trees, and tall shrubs are common below them. Grasses are mainly tall and mid-height, with perennials predominating.

Stunted woodland (5%) is floristically similar to woodland, but characteristically dwarfed and crooked. It is found on stony low rounded hills in the south-west.

Scrub (8%) is dense and low (about 25 ft) and dominated by non-eucalypts, commonly *Melaleuca*, *Pandanus*, *Grevillea*, and *Acacia*. Shrubs are common and the ground cover is patchy and variable, often of short grasses and sedges and other non-grasses. Scrub is found on sandy or gravelly slopes bordering many parts of the coastal plains or downslope from the woodland (Plate 5, Fig. 1).

Paperbark forest (5%) covers large areas in the coastal plains, sometimes where the ground is waterlogged for most of the year and sometimes where it is relatively dry. It is of *Melaleuca leucadendron*. It occurs also as a gallery forest along many of the creeks, but there it is mixed with other evergreen non-eucalypt trees (Plate 5, Fig. 2).

Mangrove scrub and samphire (2%) are made up respectively of several species of mangrove and of *Arthrocnemum*, all on the estuarine plains.

Grassland and savannah (19%) form a mosaic of communities that are seldom separable at the scale of mapping used in this report (Plate 6, Fig. 1). The trees are widely scattered and characteristically comprise *E. papuana*, *E. polycarpa*, *E. alba*, *E. latifolia*, *E. clavigera*, *E. apodophylla*, *Pandanus*, and *Melaleuca*. The grasses on the whole are perennial mid-height, and commonly *Themeda* and *Eriachne*.

Sedge land and herbaceous swamp vegetation (16%) occur respectively on the higher and lower areas of the coastal plains that are not occupied by paperbark. The sedges are small (2 ft or smaller), the herbaceous swamp vegetation is a mixture of sedges, water-lilies, water-weeds, grasses, and algae (Plate 6, Fig. 2).

(*f*) *Underground Water*

Because of the low relief, mostly permeable soils, and high rainfall, underground water is plentiful. For the area covered by the Pine Creek 4-mile sheet, Malone (1962*a*) states, "In general, a flow of about 1000 gallons per hour could be expected from any bore sunk in the area, provided it was not sited in granite or in a bad topographic position." This holds good also for the Darwin sheet where "the bore records indicate that water may be obtained in almost any part of the sheet area at less than 250 feet" (Malone 1962*b*), and for the Alligator River sheet where "in the dry season good fresh water should be available anywhere within 20 feet of the surface of the laterite and not deeper than 100 feet almost anywhere in the Precambrian rocks" (Dunn 1962).

(*g*) *Floodwater*

Flooding over most of the alluvial flats occurs regularly every rainy season. The following extract from an unpublished report by P. Purich of the Water Resources Branch, N.T.A., summarizes the position with regard to flooding in Cyperus, Copeman, and Pinwinkle land systems: "The results of this study show that in most cases the flooding is extensive, deep and prolonged. It highlights areas that are not worthy of further consideration and other areas that appear favourable for more investigation. It did show that there is a serious water problem to overcome if developmental work is considered, and that, although the land is apparently attractive, it is a misconception because of the high cost of drainage works that would be needed to bring it into production. Naturally other factors enter into production but this study is concerned with the water problem only."

Forbes, also in an unpublished report (Water Resources Branch, N.T.A., Technical Report No. 1963/4), deals with salinity forecasting in uncontrolled tidal rivers.

II. Main Types of Country

(*a*) *Dissected Foothills*

These are related to the rocks of the Pine Creek Geosyncline, which occupy two sedimentary troughs, one in the south-west of the area and a smaller one to the east. The rocks in both are folded into strike ridges that run generally north–south. In the remote past they were planed down and deeply weathered to form a fairly level surface. Little remains of the original surface, most having been eroded, with the resultant debris relateritized or scattered. The underlying strike is now again manifest, the strike ridges being 200–300 ft high and up to 700 ft above sea level, and separated by alluvial flats (Plate 7, Fig. 1). Relief and altitude become less towards the north, where tongues of the Koolpinyah surface occupy the spaces between the ridges.

Level sites (remnant lateritic caps) have stony red soils with high infiltration and wastage rates, but on slopes greater than 3–5% there is little soil, and even on the more gentle slopes the soils are usually skeletal. Although derived from a variety of parent materials, they are predominantly fine textured.

The vegetation is woodland, with some stunted woodland on stony skeletal soils on low rounded hills. On the alluvial flats it is grassland or savannah. This type of country comprises three land systems differing in the steepness of the slopes and the proportion of associated alluvium. Baker is most rugged, and contains least alluvium. Bend often adjoins Baker, from which it may receive alluvium, so that it has more than Rumwaggon. Rumwaggon is an intergrade towards Flatwood, but has less than 50% alluvium.

(*b*) *Escarpment of the Buldiva Plateau*

This is only of academic interest in the survey area, for most of the formation is outside with its westernmost cliffs forming the area's eastern boundary (Plate 7, Fig. 2). It rises to about 600 ft above the plains. A few erosional outliers in the area itself form flat-topped hills with sandy basal wash slopes. The soils are skeletal.

The vegetation is very varied. Some semi-deciduous non-eucalypt forest occurs on rocky erosional remnants and in the gorges and usually some form of open eucalypt woodland on the less precipitous slopes. The plateau itself is under spinifex grassland, sometimes with scattered eucalypts to form a savannah. Buldiva land system is the only one represented.

(*c*) *Granite Hills and Lowlands*

Although these intrusions form only 2% of the area they are economically important, for they are richly mineralized in the contact aureoles. Where the underlying structure is covered by a deep weathering profile the landscape is of rolling to undulating lowlands with scattered tors, but where the deep weathering profile has been eroded away steep rugged hills occur. The granite country is mainly in the south-west (four isolated patches, each of 20 sq miles or so) with smaller patches near the centre and in the extreme west. The soils range from skeletal on the rugged hills to moderately deep or deep sandy acid gradational soils on gentle crests, with free drainage. On alluvial flats and on foot slopes they are texture-contrast, acid or neutral, with a soft or loose sandy surface.

The predominant vegetation is eucalypt woodland, usually a rather tall and dense form dominated by *E. miniata,* and with an admixture of non-eucalypt trees in the more rugged parts and in the shelter of granite tors. Tall and mid-height grasses form the ground cover, with slightly more perennials than annuals.

The two constituent land systems are Cully and Currency, respectively rugged and rolling or undulating.

(*d*) *Koolpinyah Surface*

This is the largest natural region, covering more than 40% of the survey area. The surface is level to rolling or dissected and forms a broad belt extending from the Buldiva plateau in the east to the Lower Proterozoic ridges of the west. It consists of up to 100 ft of varied fine and coarse sediments overlying Lower Cretaceous rocks in the north-west and Lower Proterozoic rocks elsewhere, and is polygenetic, having had a complex Late Tertiary and Pleistocene erosional history. In places the surface is level and sandy, elsewhere it is gravelly, consisting of reworked lateritic detritus derived by erosion from the older, more level, relatively intact portions of the original Late Tertiary weathered surface. For simplicity, the term Koolpinyah surface has been extended to include both the initial surface and its erosional derivatives, grouped as a single landscape entity.

The extreme winter drought causes desiccation and makes the soil vulnerable to the effects of the intense summer rainfall. This regime brings about the removal of fine material and the consequent development of coarse gravelly or sandy soils, which are extremely leached on the lower slopes or where the water-table is high. As a rule they are deep and uniform or gradational. Three subdivisions are recognized.

(i) *Soils of the Undissected Koolpinyah Surface.*—These are usually on level sites, and are sandy or loamy red soils, freely drained, acid or neutral, and uniform or gradational.

(ii) *Soils of the Marginal Slopes.*—In general the soils are deep, acid or neutral, and have free drainage at least at the surface. They are sandy yellow and grey soils, usually on slopes a little over 3%. Here the thin surface leachate of the first group becomes incorporated into a pale sandy A horizon, often melanized in the top 6 in.

(iii) *Relic Soils.*—These occur on the surface and on the slopes. They are gravelly, either through removal of the finer material or through the disintegration of laterite outcrops.

The level to rolling parts are very uniformly under tall open forest. In the dissected areas the dominant vegetation is woodland or scrub, usually on the upper and lower slopes respectively (Plate 4; Plate 5, Fig. 1).

There are nine constituent land systems. Kay and Queue are level, with gravelly and sandy soils respectively. In Krokane about half the area is level and half under billabongs, which are rather shallow but abrupt and definite depressions flooded to varying depths in the wet season. Kysto is slightly and evenly eroded to the point where the strike of the underlying rocks is reflected in the vegetation, sometimes also with an associated ridge and swale topography. Keating is slightly and unevenly eroded, with large patches of the Koolpinyah surface and intervening gentle indefinite hollows. Keefers Hut represents a later stage in erosion, with dissected rolling country between the (20%) Koolpinyah remnants. In Jay, erosion has proceeded further still, and the country is of rounded low hills with remnants of the Koolpinyah surface on the tops. Kosher is similar, but borders the coastal plains and as a rule has little internal dissection and no remnants of the Koolpinyah surface. Knifehandle is of shallow valleys and wash slopes.

(*e*) *Alluvial Plains*

Two main types of alluvium are recognized, one connected with present-day streams and one laid down by streams that have since vanished.

The more recent of the two types forms plains along the middle sectors of the larger rivers, which are incised into them (Plate 6, Fig. 1). The plains have a very gradual fall (roughly 1 in 2500) and eventually grade into the coastal plains. Their level surface is broken by low gravelly rises and slightly raised patches of old alluvium, often lateritized. In the east, where it is derived from the sandstone of the Buldiva plateau, the alluvium is mainly sandy, but in the west, where it is from a wide variety of parent materials, it is of finer texture. In both areas it is about 30 ft deep. The vegetation is savannah (usually on alluvial brown loams or stratified soils) or grassland (usually on solodized solonetz soils). Two problems make subdivision difficult for mapping purposes, one is the small size and patchiness of these two communities over much of their range, and the other is the many intergrades which are neither one thing nor the other. The composition of the grassland has without doubt been greatly changed by the buffalo which graze these flats in preference to the surrounding higher ground.

The alluvial plains have been subdivided into four land systems. The eastern sandy alluvium has been classified as Effington. The western finer alluvium comprises three land systems, Fabian (flat, mainly treeless), Flatwood (flat, mainly wooded), and McKinlay (channels, levees, swales, sand-bars, flood-plains, mainly wooded).

(*f*) *Coastal Plains*

Along the coastal margin of the area are large flat ill-drained plains of estuarine mud and clay which extend over and blanket the alluvial flood-plains. They are flooded annually (in parts permanently) and are covered by several feet of freshwater clay. Apparently they are the infilled estuaries of north-flowing rivers drowned by the last Pleistocene rise in sea level. Relic dunes occur locally, the result of emergence and indicating former coastlines (Plate 8, Fig. 1).

The soils are dense heavy cracking clays which shrink in the dry season into polygons up to 12 in. across, with cracks up to 6 in. wide. Less cracking takes place in swampy places and on the inland margins of the plains where more sand is present in the clay. A thin transition zone often separates the A horizon from mainly grey saline estuarine muds, in places sandy or with deposits of gypsum, carbonate, or peat.

The buffaloes are even more numerous here than on the alluvial plains, and obviously have an important influence on the vegetation, drainage, and soils (Plate 8, Fig. 2).

Four land systems have been recognized. Copeman is low, swampy for most of the year, and under herbaceous swamp vegetation. Pinwinkle is also low and swampy but under paperbark forest. Cyperus is a little higher and mostly under sedges. Littoral is seaward of them all, flooded at times by the tides, and under samphire or mangrove scrub.

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PART III. LAND SYSTEMS OF THE ADELAIDE–ALLIGATOR AREA

By M. A. J. Williams,* A. D. L. Hooper,† and R. Story‡

I. General

The area is subdivided into 23 land systems, which are types of country each with its own recurring pattern of land forms, soils, and vegetation (Christian and Stewart 1953§). They are products not only of these natural features, but also of the team's approach and of the scale of working. They are described in the tabulated section that follows, distinguished by code names and listed alphabetically. They are subdivided into land units, which may be similarly defined but are too small for mapping at the scale used in this report.

Each tabular description is headed by a generalized section that gives a short description of the land system as a whole. This has a block diagram below it, to give an idealized picture of the land system and to show the geological structure.

The numbers on the block diagrams refer to the land units into which each land system is divided. They are arranged in decreasing order of size.

The areas of the land systems were calculated by means of a dot grid, and rounded to the nearest 5 sq miles, and those of the land units were done subjectively from the aerial photographs and from field experience.

More detailed information on the natural features of the environment is given in Parts IV–IX.

II. Comparison with the Land Systems of the Katherine–Darwin Survey

This section lists the land systems of the Katherine–Darwin survey in the order used by Christian and Stewart (1953) and correlates them with those of this Adelaide–Alligator survey.

Charles Point, Koolpinyah (Katherine–Darwin): Jay, Kay, Keating, Keefers Hut, Knifehandle, Kosher, Krokane, Kysto, Queue (Adelaide–Alligator).—The two Katherine–Darwin land systems differ proportionately from each other but have closely similar constituents. For this reason, the nine new Adelaide–Alligator land systems that resulted from the subdivision are distributed independently of the boundary line between the original two. The "key" characters that separate the nine are mainly topographical, e.g. the amount of erosion and its form.

Bynoe, Mullaman (Katherine–Darwin).—These are not represented in the Adelaide–Alligator area.

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§ Christian, C. S., and Stewart, G. A. (1953).—General report on survey of Katherine–Darwin region, 1946. CSIRO Aust. Land Res. Ser. No. 1.

Brocks Creek Ridge, Brocks Creek Foothill, Brocks Creek Undulating (Katherine–Darwin): Baker, Bend, Rumwaggon (Adelaide–Alligator).—These two groups of three are roughly equivalent each to each, i.e. Brocks Creek Ridge to Baker, and so on. They are listed here in descending order of relief. The larger-scale mapping that was done on the Adelaide–Alligator survey made possible the separation of many small areas that could not be catered for at the scale of the Katherine–Darwin survey, consequently Baker, Bend, and Rumwaggon are more fragmented than their Katherine–Darwin equivalents. The range of relief, too, is greater in the Katherine–Darwin area because of the inclusion of more mountainous country in the south-east, outside the Adelaide–Alligator area.

Batchelor (Katherine–Darwin).—There is no single equivalent in the Adelaide–Alligator area. Batchelor, to quote the Katherine–Darwin report, "is a variable area in which several of the major land systems are intimately intermixed, and of which the separate units are too small or too irregular to be mapped separately by a reconnaissance survey". The more detailed mapping of the Adelaide–Alligator survey was able, however, to cope with the separation to some extent. The constituent Adelaide–Alligator land systems are Bend, Rumwaggon, Baker, Keefers Hut, and Flatwood.

Cullen (Katherine–Darwin): Currency, Cully (Adelaide–Alligator).—These land systems in both surveys refer to granite country, subdivided in the Adelaide–Alligator area into rugged (Currency) and undulating (Cully).

Buldiva (Katherine–Darwin): Buldiva (Adelaide–Alligator).—These are identical, but the Katherine–Darwin area includes much more of this land system than does the Adelaide–Alligator.

Volcanics, Tipperary, Litchfield, Elliott, Moyle (Katherine–Darwin).—These are not represented in the Adelaide–Alligator area.

Marrakai (Katherine–Darwin): Fabian, Flatwood (Adelaide–Alligator).—The two subdivisions in the Adelaide–Alligator are treeless and wooded respectively; Marrakai includes them both. Marrakai also includes some parts of Effington land system, but most parts were too small for mapping at the Katherine–Darwin scale.

Finniss (Katherine–Darwin).—This is not represented in the Adelaide–Alligator area.

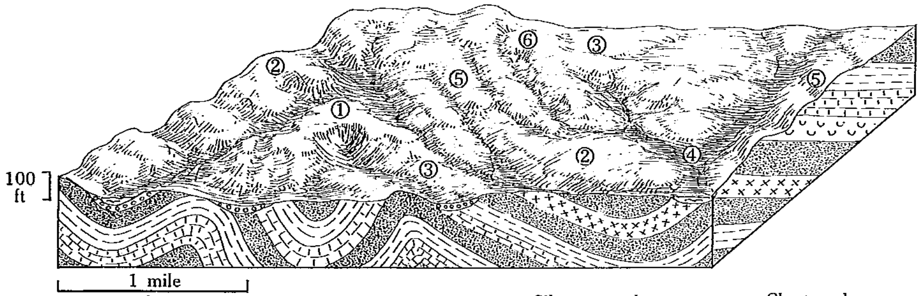
Sub-coastal Plain (Katherine–Darwin): Cyperus, Copeman, Pinwinkle (Adelaide–Alligator).—Except for limitations imposed by the scale, the mapping of the three Adelaide–Alligator land systems coincides with that of the sub-coastal Plain. The subdivisions were made to cater for paperbark forest (Pinwinkle), treeless areas more or less permanently swampy (Copeman), and treeless areas relatively well drained (Cyperus).

Littoral (Katherine–Darwin): Littoral (Adelaide–Alligator).—This is the same land system in both survey areas, but as it extends westwards from Darwin the original is somewhat larger.

The Brocks Creek Foothill–Marrakai complex of the Katherine–Darwin survey is mapped according to its separate constituents in the Adelaide–Alligator survey, mainly Bend, Rumwaggon, Fabian, and Flatwood land systems.

Baker Land System (965 sq miles, 51 observations)

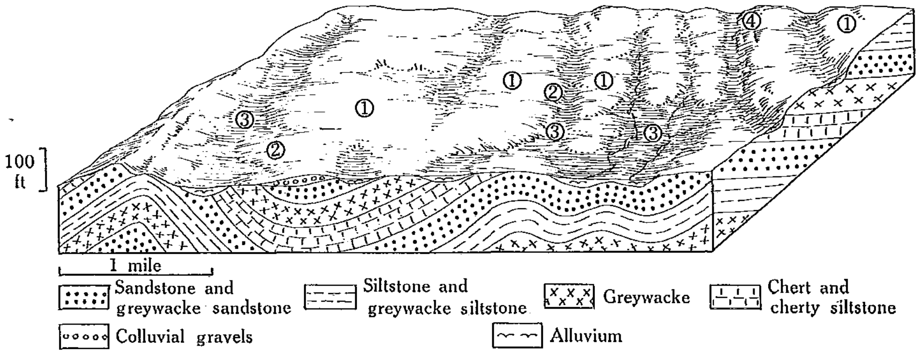
Dissected uplands and isolated strike ridges of greywacke, sandstone, and siltstone mainly in the south and west of the area; skeletal soils and outcrop with minor sandy red and yellow gradational soils; woodland (evergreen or semi-deciduous eucalypt).



Unit	Area and Distribution	Geomorphology	Soils	Vegetation
1	35% Throughout	Sandstone, greywacke, greywacke sandstone and siltstone, and quartzite hills and strike ridges: 50–200 ft high, slopes to 60%, stony to rocky, much outcrop; gullying, diffuse wash	Skeletal soils and outcrop	Woodland, height 30 ft, visibility 200 yd, eucalypts over tall or mid-height grass (*E. dichromophloia*, *E. miniata*, *E. bleeseri*, *E. tectifica*, *E. terminalis*, *Livistona*, *Petalostigma*, *Cochlospermum*, *Ampelocissus*, *Terminalia ferdinandiana*, *Grevillea heliosperma*, *Heteropogon triticeus*, annual *Sorghum*, *Themeda*, *Chrysopogon*)
2	30% Throughout	Siltstone and weathered sandstone hills: 40–70 ft high, gentle convex summits or narrow strike crests with up to 25% outcrop, linear to convex hill slopes to 30%, even stony to gravelly regolith up to 2 ft deep; minor gullying, diffuse wash	Skeletal soils and outcrop, rare red sandy Cahill soils, and shallow Munmarlary yellow-red sand to clay; gradational soils associated with lateritized outcrop	
3	15% Throughout	Colluvial wash slopes at foot of units 1, 2, and 6: linear to gently concave, up to 600 yd wide, slopes to 5%; up to 5 ft of sandy to silty colluvium with ½ in. even veneer of fine gravel and siltstone flakes over bevelled rock; minor laterite benches 2 ft high, 20 yd wide, 10 ft above unit 4; scalding, minor gullying	Skeletal soils, shallow grey Cullen soils, and rare Cahill soils as in unit 2	
4	10% Throughout	Alluvial flats: less than 200 yd wide, slopes to 2%, channels up to 30 ft wide, ill defined or incised through 4–5 ft sandy or loamy alluvium into rock; local outcrops, river laterite	Skeletal soils (colluvium), with minor Elliott (yellow sand to clay, hard-setting)	Flats grassland or open savannah (*Eriachne burkittii*, *Themeda*, scattered *E. alba*, *E. polycarpa*); channels sometimes fringed with *Pandanus* and non-eucalypts
5	5% Mary–McKinlay area	Chert and cherty siltstone hills: 70–100 ft high; convex summits above 20–30% linear slopes; 6–12 in. angular scree up to 2 ft deep; rare outcrop; dissection by closely spaced, sharply incised, V-shaped gullies up to 60 ft deep, 150 ft apart, with side slopes to 50%	Skeletal soils	Woodland, height 25 ft, visibility 250 yd, eucalypts over tall or mid-height grass (*E. alba*, *E. dichromophloia*, *E. clavigera*, *E. tectifica*, *Xanthostemon*, *Cochlospermum*, *Petalostigma*, *Grevillea heliosperma*, *Heteropogon triticeus*, annual *Sorghum*, *Themeda*, *Chrysopogon*)
6	5% Chiefly in south and south-west	Hills of varied lithologies, especially dolerites and amphibolites: 50–150 ft high, smoothly convex, bevelled or irregular summits, benched, linear or convex slopes up to 40%; stony to rocky; frequent outcrop; gullying, sheet wash, eluviation, and basal sapping	Skeletal soils, stony krasnozems on amphibolite (not described), and Cahill soils as in units 2 and 3	As for unit 1

Bend Land System (825 sq miles, 70 observations)

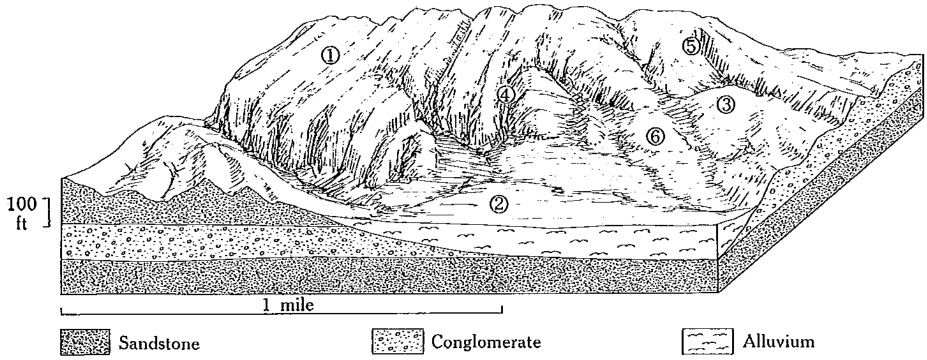
Erosional remnants of siltstone, sandstone, and quartz, widespread; skeletal soils, gradational red soils, and yellow earth-type soils; woodland (semi-deciduous eucalypt) or stunted woodland (mixed).



Unit	Area and Distribution	Geomorphology	Soils	Vegetation
1	55%	Hill slopes and summits of low strike hills and minor erosional remnants; up to 60 ft high, slopes to 8%, in places to 27%; variable lithology, including sandstone, siltstone, greywacke chert, quartz, and silicified dolomite; frequent outcrop on slopes above 8%; even surface layer of angular siltstone flakes or subangular stony quartz gravels; sheet wash, scalding, rare gullying except on chert and higher hills; on chert knolls, boulder-strewn slopes up to 23%, with gullies up to 40 ft deep and 100 ft apart	Skeletal soils dominate as in unit 1 of Baker land system, but associated soils more common, e.g. Cahill and Munmarlary on or near lateritized outcrop and Elliott on lower slope sites, mostly with class 5 surface stone cover	Woodland or stunted woodland, height 30 ft and less, visibility 250 yd, over tall, mid-height, or short grass (*E. bleeseri*, *E. dichromophloia*, *E. foelscheana*, *E. clavigera*, *E. latifolia*, *E. phoenicea*, *E. tectifica*, *E. alba*, *Pandanus*, *Petalostigma*, *Terminalia ferdinandiana*, *Xanthostemon*, *Erythrophleum*, *Cochlospermum*, *Gardenia*, annual *Sorghum*, *Heteropogon triticeus*, *Chrysopogon*, *Themeda*, *Schizachyrium*, *Eriachne*); occasional tall open forest, same as unit 1 of Kay land system near the coast, with an admixture of *Alphitonia*, *Canarium*, *Alstonia*, and lianes
2	25% Throughout	Colluvial wash slopes: to 5%, width to 500 yd, locally to ¾ mile; continuous veneer of siltstone flakes and/or stony to gravelly subangular quartz over stony quartz in loamy matrix; detrital or pisolitic laterite in places below 2 ft of colluvium; scalding, rill and gully erosion, incision by channels up to 6 ft deep and 25 ft wide	Skeletal soils share dominance with Elliott soils, which are most common on lower slope sites; minor alkaline lithosols (Angelara) on shales; Batten (sandy loam to clay gradational with an A_2) and Stapleton (deep A_2) occur marginal to the alluvial flats. Munmarlary soils also occur with laterite	Woodland or stunted woodland, as for unit 1 but slightly taller and denser and with an admixture of *E. papuana* and *E. apodophylla* in the woodland
3	15% Throughout	Alluvial flats and channels: up to 600 yd wide, slopes less than 3%; channels up to 6 ft deep and 30 ft wide incised into deep alluvial sands and loams, in places over clay; scalding, seasonal gullying, aggradation, subsurface concretionary ironstone forming locally	Mainly colluvial–alluvial soils including Batten (dominant), Stapleton, and Elliott on foot-slope margins and shelving narrow, head-water flats: some silty alluvial soils (Mary) and rare colluvial Munmarlary soils. Kapalga (grey sands) have been recorded in an area where ridge crests are capped by sandy Cockatoo soils	Grassland, usually mid-height, occasionally tall, rarely short (*Themeda*, *Eriachne burkittii*, Cyperaceae, *Panicum delicatum*, *Coelorachis*, *Ischaemum*, *Pseudopogonatherum*, *Heteropogon triticeus*); scattered *Pandanus*, *Melaleuca nervosa*, *E. papuana*, *E. polycarpa*, *E. clavigera*, *E. alba*, *E. foelscheana*, *E. latifolia*, *E. apodophylla*
4	5% Some in centre, occasional in south-east	Laterite outcrops: up to 50 yd wide on 1–6% slopes; benches 2–3 ft high of vesicular, pisolitic, or detrital laterite on lower margins of unit 2; bare pavements on unit 2, upper margins of unit 4; rare patches on bevelled summits of unit 1 where next to Kay land system; minor occurrences of river laterite	Very thin gravels over laterite, or Elliott soils where laterite is not contributing to soil formation	Woodland, height 45 ft, visibility 250 yd, eucalypts over tall, mid-height, and short grass (*E. bleeseri*, *E. miniata*, *E. clavigera*, *E. tectifica*, *E. foelscheana*, *E. papuana*); non-eucalypts as in unit 1, with some spinifex

Buldiva Land System (30 sq miles, 14 observations)

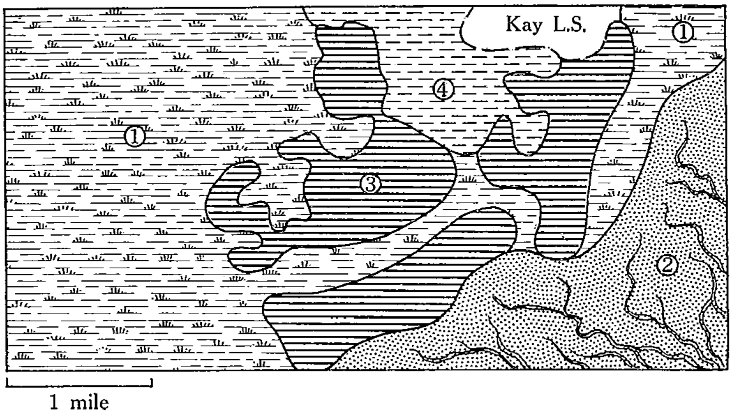
High sandstone plateau outliers, chiefly along south-east border; skeletal soils and outcrop, minor uniform and gradational red sandy soils; woodland (eucalypt with spinifex).



Unit	Area and Distribution	Geomorphology	Soils	Vegetation
1	40% Along Arnhem Land margins and Mt. Douglas	Rocky plateau surface: slopes generally below 10%, locally variable; subhorizontal, massive, thickly bedded arenites, rudites, and conglomerates, fissured vertical joint planes; sheet wash and joint-guided run-off	Mainly outcrop with rare thin skeletal soils	Grassland with scattered shrubs (spinifex, *Micraria, Eriachne mucronata, Schizachyrium*, shrubs varied): sometimes with *E. phoenicea* to form a savannah
2	25% Along Arnhem Land margins and Mt. Douglas	Coarse quartzose sandy wash slopes: to 2%, up to ½ mile wide, over 5 ft deep, no surface gravel; occasional wide shallow stream beds; rare laterite outcrops, sheet floods, lateral eluviation	Cahill and Munmarlary soils, and rare Cockatoo	Varied—woodland, eucalypts dominant over tall grass (*E. bleeseri, Livistona, Petalostigma, Terminalia ferdinandiana, Acacia cunninghamii, Erythrophleum, Owenia, Planchonia*, annual *Sorghum, Heteropogon triticeus, Eriachne triseta*); or savannah (*E. papuana, Livistona, Pandanus, Grevillea pteridifolia* over *Stylosanthes* or short grass); stream beds with similar savannah grading into grassland or sedge land with scattered trees
3	15% Along Arnhem Land margins and in extreme south-west	Minor erosional remnants: tilted and fallen blocks of quartz sandstone up to 50 ft high and 200 yd long; frequent core stones and weathered subrounded sandstone blocks on rocky surfaces, slopes and dips variable; exfoliation, joint-guided seepage and corrosion, solution pitting, sheet wash	Skeletal soils and outcrop	Woodland, height 50 ft, visibility 200 yd, eucalypts dominant over tall and mid-height grass (*E. tetrodonta, E. papuana, Erythrophleum, Terminalia, Acacia cunninghamii, Owenia, Bossiaea, Calytrix*, annual *Sorghum, Eriachne triseta, E. ciliata*); in sheltered places as for unit 4
4	10% Along Arnhem Land margins and Mt. Douglas	Deep gorges with seasonally flowing streams: joint-controlled ravines with side slopes to 70%; up to 500 yd wide, 200 ft deep; rocky, abundant outcrop; sandy bed-load in wider gorges, angular boulders in narrow headwater ravines; vertical erosion	Some skeletal soils and Cullen soils likely on gorge floors	Semi-deciduous forest with an admixture of *Callitris, Acacia, Denhamia, Gardenia, Terminalia ferdinandiana, Erythrophleum*; scanty ground cover
5	5% Along Arnhem Land margins and Mt. Douglas	Scarp face: cliffs up to 200 ft high, locally undercut or vertical, rarely less than 60%; strata up to 30 ft thick, in places dipping 30°; structural benches, often due to coarse quartz pebble conglomerate; undercutting and collapse	—	Woodland, height 25 ft, visibility 200 yd, mainly eucalypts over tall grass (*E. clavigera, E. bleeseri, E. phoenicea, Livistona, Petalostigma, Cochlospermum, Terminalia ferdinandiana, Acacia cunninghamii*, spinifex, *Heteropogon triticeus*); bare where vertical
6	5% Along Arnhem Land margins and Mt. Douglas	Scree slopes: concave, up to 300 yd wide; slopes 45–12%, minor outcrops; attrition, creep; sharp slope break to unit 5	Shallow stony and grey sandy to loam gradational Cullen soils	

COPEMAN LAND SYSTEM (200 SQ MILES, 4 OBSERVATIONS)

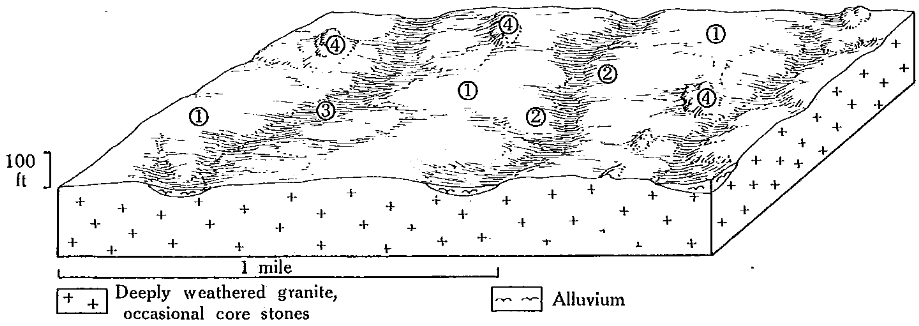
Low swampy coastal plains, freshwater over estuarine clays, north of area; black cracking clays over gleyed muds; herbaceous swamp vegetation.



Unit	Area and Distribution	Geomorphology	Soils	Vegetation
1	50% Throughout	Low ill-drained plains: up to 3 miles wide, slopes less than 0·3%; flooded 6–12 months to depths up to 5 ft; freshwater over estuarine clays; small islands and infilled meander cut-offs of high ground; forming mud flats in dry season	Black cracking clays over gleyed and saline estuarine muds (Wildman), and weakly cracking clays, wet, with deep black peaty A horizons (Dashwood)	Herbaceous swamp vegetation, mainly sedges, grasses, and water-lilies (*Scleria, Fimbristylis, Cyperus, Oryza, Hymenachne, Pseudoraphis, Panicum trachyrachis, Caldesia, Ludwigia adscendens, Nymphoides indica, Phyla, Utricularia, Azolla, Marsilea, Chara*); higher areas bare or with scanty cover (*Marsilea, Phyla, Fuirena*); wide and indefinite transition to unit 3
2	20% Throughout	Complex of anastomosing narrow channels and intervening higher ground: low levee benches flanking former channels (aerial observations only)	No observations	Herbaceous swamp vegetation as in unit 1, or open water; levees often under *Barringtonia* or *Melaleuca cajaputi, M. leucadendron* (aerial observations only)
3	20% Throughout	Higher seasonally dry plains: similar to unit 1 of Cyperus land system	Carmor (cracking clays over calcic estuarine muds)	Sedge land same as unit 1 of Cyperus land system
4	10% Along landward margins of Cyperus land system	Extensive water-filled depressions (aerial observations only)	—	Open water, or herbaceous swamp vegetation rooted in mud or floating (aerial observations only)

Cully Land System (140 sq miles, 18 observations)

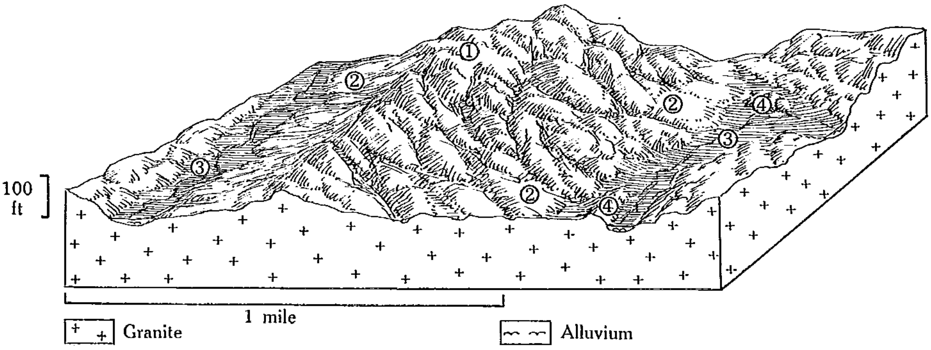
Undulating to rolling deeply weathered granitic lowlands, south and west of area; coarse-textured stony and gravelly yellow-red gradational sandy earth soils; woodland (eucalypt and mixed).



Unit	Area and Distribution	Geomorphology	Soils	Vegetation
1	50% Throughout	Undulating deeply weathered lowlands: up to 1 mile wide with convex slopes up to 5%; outcrops of vein quartz and granite on up to 15% of the area; stony to gravelly sandy colluvium over deeply weathered granite; sheet wash, gullying, eluviation	Skeletal soils and Masson (moderately deep coarse sand to sandy clay gradational, yellow-pink), minor Cullen	Woodland, height 30 ft, visibility 300 yd, eucalypt and mixed, over mid-height grass (*E. polycarpa*, *E. tetrodonta*, *E. miniata*, *E. phoenicea*, *E. clavigera*, *E. alba*, *Livistona*, *Erythrophleum*, *Petalostigma pubescens*, *Planchonia*, *Terminalia ferdinandiana*, *Themeda*, *Eriachne triseta*, *Chrysopogon*, annual *Sorghum*, *Schizachyrium*, sedges)
2	20% Throughout	Colluvial foot slopes: concavo-convex, up to 100 yd wide, slopes less than 7%, overlain by coarse sandy to gravelly colluvium up to 5 ft deep; occasional outcrops up to 50 yd wide and 10 ft high, smoothly convex or with rounded core stones up to 8 ft undergoing subsurface corrosion; sheet wash, minor gullying	Masson soils, Elliott (yellow gradational sands to clay) on lower slopes, and Howard (sand over acid clay) on margins of unit 3	As for unit 1, but often in a more open form
3	20% Throughout	Alluvial flats and channels: up to 600 yd wide with channels up to 4 ft deep and ill defined, except where incised in bed-rock; slopes less than 2%, river gradients 1 in 200; water-tables to 2 ft; sandy to loamy alluvium; local patches of (?)lacustrine clay	Howard soils and Nourlangie (sand over alkaline clay)	Grassland, mid-height and tall, with small annual non-grass herbs, often with scattered trees to form an open savannah (*Eriachne burkittii*, *Chrysopogon*, Cyperaceae, *Drosera*, *Utricularia*, *Stylidium*, *Mitrasacme*, *Pandanus*, *E. polycarpa*, *E. alba*, *E. papuana*, *Melaleuca nervosa*)
4	10% Sporadic	Granite tors and core stones: up to 100 ft high, boulder-strewn slopes 50–70%; eluviation and concentrated wash; exhumation of deeply weathered joint blocks	Skeletal soils and outcrop	Woodland, non-eucalypts over tall grass (*Ficus*, *Gardenia*, *Terminalia ferdinandiana*, *Erythrophleum*, *Petalostigma pubescens*, *Grewia*, *Canarium*, *Livistona*, annual *Sorghum*, *Heteropogon triticeus*); or tall open forest (*E. tetrodonta*, *E. miniata*) over the same grasses

Currency Land System (20 sq miles, 6 observations)

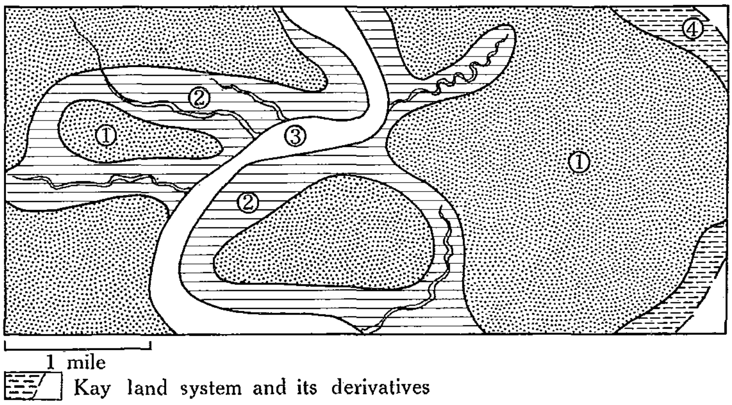
Rugged granite hills, south and west of area; skeletal soils and minor coarse sandy yellow soils; woodland (eucalypt and mixed).



Unit	Area and Distribution	Geomorphology	Soils	Vegetation
1	70% Mt. Bundey area and Mt. George	Crests and hill slopes: 40–60%, strewn with boulders up to 10 ft diam.; up to 6 in. discontinuous sandy wash; splitting, exfoliation, collapse	Skeletal soils and outcrop	Woodland, non-eucalypt over tall grass, or tall open forest as in unit 4 of Cully land system
2	15% Mt. Bundey area and Mt. George	Colluvial foot slopes: up to 7%, width to 100 yd, sharp break of slope to unit 1, higher sections strewn with 2 ft boulders; gravelly sandy colluvium up to 5 ft deep; sheet wash	Mainly skeletal with Masson and Elliott soils, as in unit 2 of Cully land system	Woodland, eucalypt and mixed, over mid-height grass as for unit 1 of Cully land system
3	10% Mt. Bundey area and Mt. George	Alluvial flats and ill-defined channels: up to 100 yd wide with slopes up to 5%; channels up to 4 ft deep and 20 ft wide	Howard soils, as for unit 3 of Cully land system	Mid-height and tall grassland and non-grass herbs, often with scattered trees as in unit 3 of Cully land system
4	5% Mt. Bundey area and Mt. George	Minor outcrops: up to 10 ft high and 20 yd wide; rounded core stones up to 8 ft high in places, perched on level granite rock platform	As for unit 1	As for unit 1

Cyperus Land System (1225 sq miles, 26 observations)

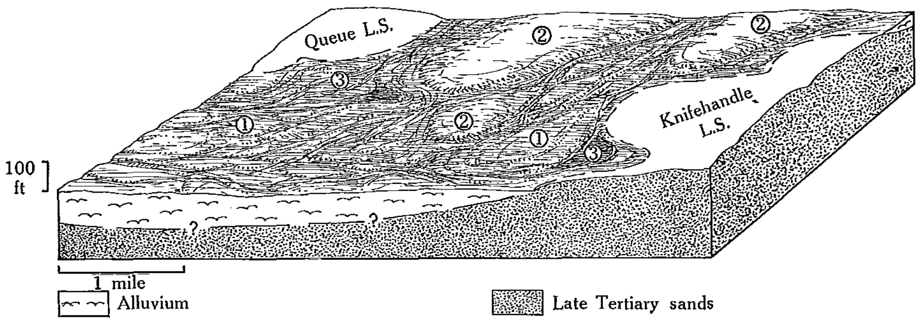
Seasonally flooded coastal plains, freshwater clays over estuarine clays, north of area; black cracking clays over mainly calcic estuarine muds; sedge land.



Unit	Area and Distribution	Geomorphology	Soils	Vegetation
1	75% Mainly southern half	Higher, seasonally dry plains: slopes 0·3–0·8%, elevation 10–40 ft, relief to 4 ft; occasional shallow pans and buffalo wallows; freshwater clays over estuarine clays, in places with subfossil gastropods (*Turritella* spp.); 2-4 miles, in places up to 6 miles wide; flooded 3–6 months to depths up to 1 ft, rapid drying once rains cease; very slow aggradation; rare subparallel dunes up to 4 ft high with slopes to 5%, minor levees	Black cracking carbonate rich clays (Carmor) near old channels and higher areas: Wildman (clays over gleyed muds) in lower sites; Adelaide (self-mulching) soils on old levees; minor Cairncurry (gypsic clays) on former swamp sites; minor dune sands	Sedge land, dense robust sedges up to 2 ft with occasional scattered or patchy *Sesbania*, rarely dense mid-height grassland (*Ischaemum*); dunes, mixed scrub over short grass (*Acacia*, *Pandanus*, *Ficus*, *Canarium*)
2	15% Mainly northern half	Low, ill-drained, seasonally tidal plains; similar to unit 1 of Copeman land system	Predominantly Wildman soils and organic clays (Dashwood) in wet sites. Carpentaria saline clays near areas of tidal influence	Herbaceous swamp vegetation as for unit 1 of Copeman land system
3	5% Trending south to north at broad intervals	Main channels: up to ½ mile wide and 30 ft deep; minor tributaries up to 6 ft deep and 40 ft wide, over ½ mile apart; bed-load of silt and clay; lower reaches tidal in dry season	—	Open water, or herbaceous swamp vegetation rooted in mud or floating; occasional clumps of *Barringtonia* or *Melaleuca cajaputi* and *M. leucadendron*
4	5% Southern margins next to Kay land system and its derivatives	Up to 400 yd wide, slopes to 0·8%; elevation *c.* 30–45 ft; freshwater clays over buried sands and ironstone gravels derived from adjacent deeply weathered lowlands; minor channels and billabongs up to 6 ft deep and 50 ft wide; rare gilgai areas, puffs 3–4 ft across, 6–12 in. amplitude	Acid to neutral clays over sands or rock (Counamoul)	Sedge land: fine sedges up to 12 in., scattered *Melaleuca argentea*, or *E. papuana*, *Panicum trachyrachis* in gilgai depressions, *Heteropogon contortus* on rises; low-lying areas, herbaceous swamp vegetation as for unit 1 of Copeman land system

EFFINGTON LAND SYSTEM (120 SQ MILES, 16 OBSERVATIONS)

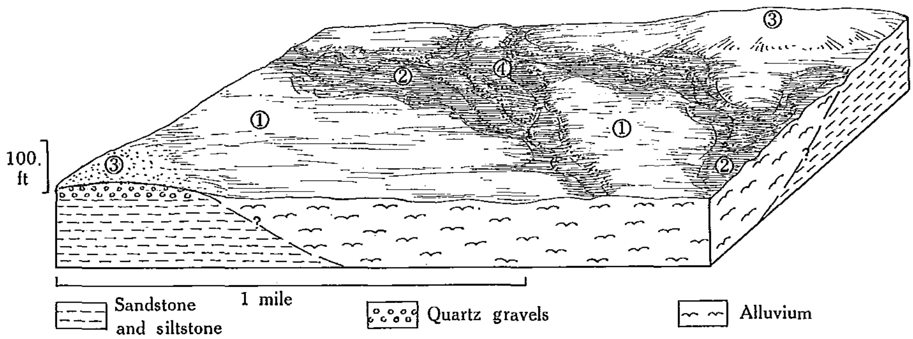
Flood-plains of dominantly sandy alluvium, east of area; uniform, gradational, and texture-contrast sandy soils with a variety of site factors; savannah, minor treeless areas.



Unit	Area and Distribution	Geomorphology	Soils	Vegetation
1	60% East of South Alligator River	Low active flood-plains: up to ½ mile wide if bare, less if wooded; slopes to 3·5%; relief to 5 ft; elevation 50–100 ft; sands over loams and clays; seasonally flooded up to 6 months to 3 ft, along upper margins termitaria (8 ft) often undercut to 1 ft; alluviation, vertical and lateral seepage, minor sandy levees up to 3 ft high, slopes to 9%	Marrakai gradational (silt to clay, acid) soils on poorly drained sites; Baroalba (yellow sand) on levees and treeless flood-plains; Magela (yellow-red sands to sandy loam gradational) on higher sites as for unit 2; and rare Murrabibbi (sand over mottled clay) on margins of Kay and Queue land systems	About two-thirds savannah, mainly non-eucalypts over tall or mid-height grasses with small annual non-grasses (*Pandanus*, *E. polycarpa*, *Banksia*, *Grevillea pteridifolia*, *Tristania*, *Melaleuca nervosa*, *M. symphyocarpa*, *E. papuana*, *E. latifolia*, *Livistona*, Cyperaceae, *Eriachne burkittii*, *E. triseta*, *Chrysopogon*, *Themeda*, *Ectrosia*, *Vetiveria*, *Chloris*, *Panicum*, *Schizachyrium*, annual *Sorghum*, *Drosera*, *Utricularia*, *Stylidium*, *Mitrasacme*); about one-third treeless
2	25% East of South Alligator River	Stable flood-plain: up to ½ mile wide; slopes to 2%, generally 1%; sands over loams locally over stony to gravelly quartz and nodular ironstone, some termitaria (7 ft); slow aggradation, vertical seepage	Baroalba and Magela soils under mainly savannah co-dominate; Nourlangie (sands over alkaline-calcic clays) and gravelly clays or Jim Jim sands over calcic B horizons; Howard (sands over acid clays) under *Grevillea*-dominated savannah near margins of Kay and Queue land systems	As for unit 1, with minor differences (less *Tristania*, *Melaleuca*, *Vetiveria*, *Eriachne burkittii*, Cyperaceae)
3	15% East of South Alligator River	Channels and billabongs: up to 1 mile apart; depth to 15 ft, 30 yd wide, in places flanked by low broad levees up to 3 ft high; sandy channel bars locally up to 6 ft high, 30 ft wide; sandy bed-load, weak incision; local meandering and braided flow	As for unit 1; Baroalba soils on levees and channel bars and Marrakai in poorly drained sites dominate	Paperbark forest (*Melaleuca cajaputi*, *M. leucadendron*, *Tristania*, *Pandanus*, *Barringtonia*), scanty or patchy ground cover as in unit 1

Fabian Land System (220 sq miles, 7 observations)

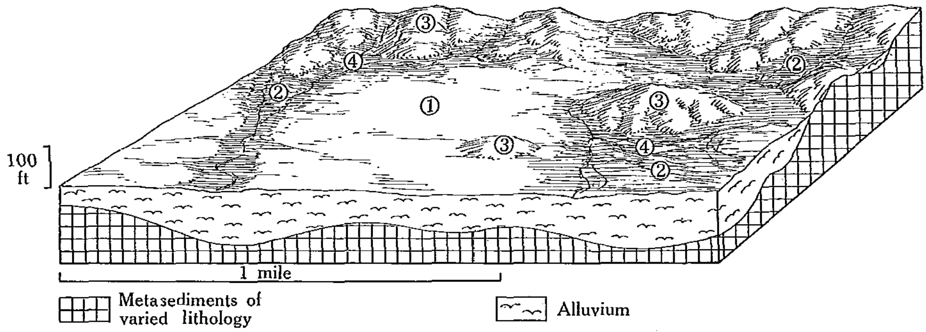
Flood-plains of dominantly silty alluvium, west and centre of area; texture-contrast (solodized solonetz) soils and gradational yellow loamy soils, alkaline and acid; grassland.



Unit	Area and Distribution	Geomorphology	Soils	Vegetation
1	55% Throughout west of South Alligator River, scattered in centre and south-west	High stable flood-plains: up to 4 miles wide: slopes to 1%; relief to 8 ft; loams and silts over clays and clay loams; local scalding, in places subsurface formation of ironstone concretions	Predominantly Margaret (texture-contrast with fine-textured bull dust surface and concretions capping a columnar B horizon) or similar gradational textured Moline soils; Marrakai (silts over acid clays) in drainage depressions and minor Stapleton soils in savannah and under *Themeda*, as in unit 2 of Rumwaggon land system	Tall and mid-height grassland (*Themeda*, *Chrysopogon*, Cyperaceae, *Eriachne burkittii*, annual *Sorghum*, *Heteropogon triticeus*, *Panicum delicatum*, *Ectrosia*, *Ischaemum*, *Eragrostis*); minor areas of savannah as in unit 1 of Fleetwood land system
2	20% Throughout west of South Alligator River, scattered in centre and south-west	Low active flood-plains: same as unit 1 of Effington land system, but with silts and fine-textured alluvium	Mary (silty alluvial brown soils), some Marrakai and stratified recent alluvial deposits	As for unit 1, but with added *Eriachne burkittii*, *E. triseta*, and *Vetiveria*, and less *Themeda*
3	15% Throughout west of South Alligator River, scattered in centre and south-west	Low erosional remnants and gravelly rises: as for units 1 and 4 of Rumwaggon land system	Skeletal and Elliott soils as in unit 4 of Rumwaggon land system	Woodland, mixed, over tall and mid-height grass, as for unit 3 of Flatwood land system
4	10% Throughout west of South Alligator River, scattered in centre and south-west	Channels and billabongs: same as unit 4 of Flatwood land system	Silty bed-loads	No consistency, as for unit 4 of Flatwood land system

Flatwood Land System (540 sq miles, 23 observations)

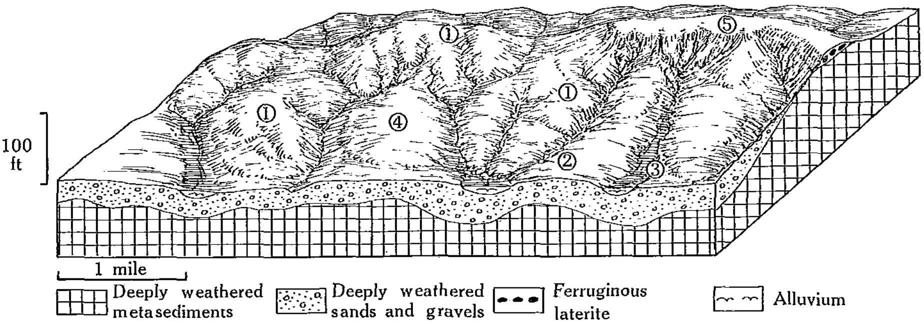
Flood-plains of dominantly silty alluvium and minor hills, west and centre of area; gradational yellow loamy soils and minor texture-contrast soils; savannah, some mixed woodland.



Unit	Area and Distribution	Geomorphology	Soils	Vegetation
1	45% West of South Alligator River, mainly in centre and south-west	Stable flood-plains: up to 600 yd wide; slopes to 2·5%; relief to 15 ft; elevation 50–250 ft; loams over sandy clay loams to sandy clays, in places containing nodular ironstone gravels, some termitaria (12 ft); subsurface formation of ironstone concretions; vertical eluviation, shallow flooding for 4–6 months	Elliott (yellow sands to clays with cemented ferruginous zones or buried clay) soils dominant; Marrakai (acid loam to clay in low-lying zones), McKinlay (yellow sand to alkaline clays), and Stapleton soils (near plains margins) also occur; minor treeless areas have texture-contrast alkaline Margaret soils	Savannah, eucalypts over tall and mid-height grasses as in unit 1 of Fabian land system (*E. papuana*, *E. polycarpa*, *Pandanus*, *Melaleuca*, *E. apodophylla*, *E. alba*, *E. clavigera*, *E. latifolia*); minor treeless areas
2	25% West of South Alligator River, mainly in centre and south-west	Active flood-plains: up to 600 yd wide; mean slopes 1·8%, locally to 5%; relief to 15 ft; loams over variable locally gravelly subsoil, termitaria up to 8 ft high on pedestals scoured up to 1 ft above ground level; alluviation, vertical and lateral seepage	Marrakai soils on moist or swampy sites with minor Stapleton soils; large areas of stratified sands and silts on South Alligator plains	As for unit 1, but with added *Eriachne burkittii*, *E. triseta*, and *Vetiveria*, and less *Themeda*
3	20% West of South Alligator River, mainly in centre and south-west	Low erosional remnants and gravelly rises; same as for units 1 and 4 of Rumwaggon land system	Complete surface stone cover (class 5); some skeletal soils but mainly Elliott	Woodland, mixed, over tall and mid-height grass, height 35 ft, visibility 300 yd (erosional remnants *E. alba*, *E. papuana*, *E. miniata*, *Xanthostemon*, *Terminalia ferdinandiana*, *Planchonia*, *Buchanania*, *Petalostigma*, annual *Sorghum*, *Chrysopogon*, *Eragrostis schultzii*, *Themeda*, Cyperaceae; gravelly rises *E. papuana*, *E. polycarpa*, *Pandanus*, *Melaleuca nervosa*, *M. argentea*, *Themeda*, *Chrysopogon*, *Eriachne triseta*, Cyperaceae, *Eriachne burkittii*)
4	10% West of South Alligator River, mainly in centre and south-west	Channels and billabongs: variable depth and width, mean 6 ft by 40 ft; shallow swampy channels less than 3 ft deep; discontinuous strings of shallow billabongs adjoin deeper gullies; major channels same as in unit 4 of McKinlay land system; silty bed-loads	—	No consistency, varying from grassland through savannah to paperbark forest and scrub of *Pandanus* and *Bambusa*

Jay Land System (555 sq miles, 12 observations)

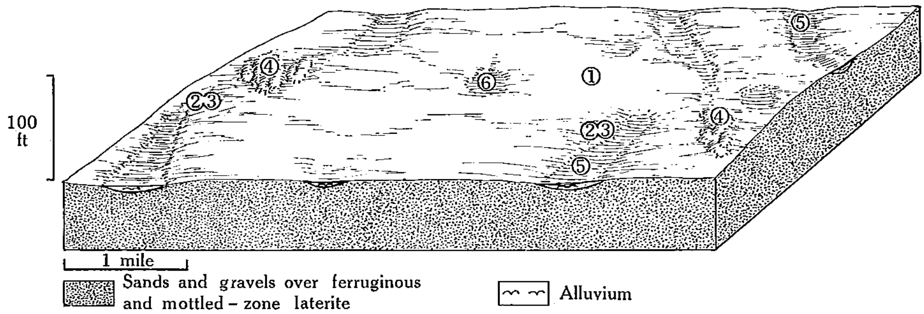
Dissected, rolling, deeply weathered eastern lowlands; gradational yellow-red or yellow sandy and loamy soils, gradational loose grey sandy soils; woodland (mixed) or tall open forest.



Unit	Area and Distribution	Geomorphology	Soils	Vegetation
1	45% Throughout east of South Alligator River	Upper slopes and summits: ironstone gravels in leached sandy loam matrix; up to ½ mile wide; slopes to 2%; gently undulating multiconvex surface; sheet wash, eluviation, minor gullying	Munmarlary (yellow to yellow-red sand to clay gradational) soils or Woolner (with strongly mottled lower horizons) co-dominate	Woodland (mixed) on slopes, over tall and mid-height grass (*E. tetrodonta*, *E. terminalis*, *E. clavigera*, *E. bleeseri*, *E. dichromophloia*, *E. latifolia*, *Livistona*, *Cochlospermum*, *Planchonia*, *Gardenia*, *Terminalia ferdinandiana*, *Buchanania*, *Grevillea pteridifolia*, *G. heliosperma*, *Acacia*, *Petalostigma quadriloculare*, annual *Sorghum*, *Chrysopogon*, *Eriachne triseta*); summits tall open forest same as unit 1 of Kay land system
2	20% Throughout east of South Alligator River	Lower wash slopes: concave, to 2%, locally to 5%; width to 500 yd; regolith stony to gravelly in loamy matrix; scattered termitaria in places up to 10 ft high; sheet wash, eluviation, concretionary iron forming below the surface in places	Cullen (sandy to loamy light grey soils)	As for unit 1, but more open and *E. bleeseri* rare
3	15% Throughout east of South Alligator River	Alluvial flats and channels: up to 600 yd wide; slopes to 1·7%; channels up to 1 mile apart, 6 ft deep, and 40 ft wide incised in sandy alluvium; bed-load sand, in places pebbles and cobbles, local outcrops of river laterite; gullying, scalding, sheet wash	Mainly Elliott (yellow gradational soils); Cullen soils on margins and Woolwonga (gradational silt to grey alkaline–calcic clay soils) in channel areas	Flats grassland or savannah (*Themeda*, annual *Sorghum*, scattered *E. papuana*, *E. latifolia*); channels sometimes fringed with *Pandanus* and non-eucalypt trees and shrubs
4	10% Throughout east of South Alligator River	Upper slopes and summits overlain by residual quartz: slopes to 3·5%; elevation 20–150 ft; up to 1 mile wide; stony regolith over clay; sheet wash, eluviation, gullying along lower margins	Skeletal soils and outcrop; minor Elliott, surface stoniness generally to class 5	As for unit 1
5	10% Occasional	Breakaways formed on ferruginous laterite overlying deeply weathered rock: up to 30 ft high; slopes to 11%; bevelled hill top overlain by vesicular or detrital laterite up to 2 ft thick, now being undercut; seepage, basal sapping, collapse, mechanical disintegration, diffuse wash	Laterite outcrop and shallow Koolpinyah soils; surface stoniness class 5 throughout	No observations

Kay Land System (900 sq miles, 27 observations)

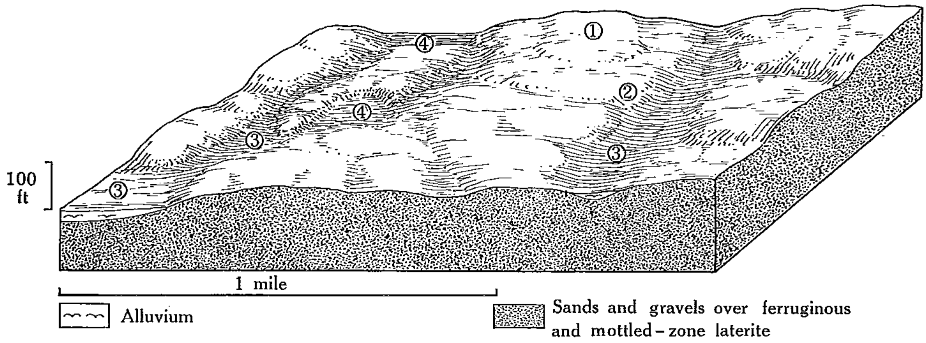
Level, deeply weathered north and central lowlands; gradational and uniform loamy and sandy red gravelly soils; tall open forest.



Unit	Area and Distribution	Geomorphology	Soils	Vegetation
1	65% Throughout	Level to undulating surface with ironstone gravels over deeply weathered bed-rock: up to 3 miles wide; marginal slopes to 3·5%; elevation 50–280 ft; local relief generally less than 20 ft; in north-west up to 5 ft of rounded ironstone gravel over deeply weathered sandstone cropping out locally; gravel elsewhere, over clay and/or decayed quartzite, sandstone, or laterite; slow attrition of gravels; eluviation	Dominated by Hotham (gradational loam to clay red gravelly soils) and Cahill (uniform red gravelly or stony); Berrimah (deep red loamy clay gradational soils) common in north-west only	Tall open forest, height 50 ft, visibility 50 yd, eucalypts over tall, mid-height, and short grass (*E. tetrodonta*, *E. miniata*, *E. terminalis*, *Erythrophleum*, *Livistona*, *Pandanus*, *Acacia cunninghamii*, *Grevillea heliosperma*, *Xanthostemon*, *Terminalia ferdinandiana*, *Planchonia*, *Gardenia*, *Buchanania*, *Cochlospermum*, annual *Sorghum*, *Chrysopogon*, *Heteropogon triticeus*, *Schizachyrium*, Cyperaceae, *Eriachne triseta*, *Thaumastochloa*; *Cycas* west of Adelaide River)
2	15% Throughout	Gravelly wash slopes: to 3·5%; width to 1 mile; elevation 40–280 ft; relief to 25 ft; in north-west as in unit 1; elsewhere additions of subrounded to angular quartz and weathered sandstone gravel in sandy loam matrix; eluviation	Cahill dominant with Hotham; Munmarlary and Koolpinyah (yellow loose gradational soils) common on lower slopes	As for unit 1, but more open and with some *E. clavigera* and *E. bleeseri* and added shrubs
3	5% Throughout	Sandy wash slopes and inclusions of Queue land system: up to 200 yd wide; slopes to 3·5%; elevation 35–250 ft; relief to 30 ft; deep well-drained gravel-free sands; eluviation	Berrimah soils and Basedow (yellowish red sandy to loam gradational) soils co-dominate mainly on higher sites; Cockatoo (red sands) in inclusions of Queue land system	Tall open forest as in unit 1 (but *E. miniata* rare on slopes), often grading into woodland height 20 ft, visibility 150 yd, non-eucalypts over the same grasses (*Melaleuca nervosa*, *Xanthostemon*, *Acacia cunninghamii*, *Pandanus*, *Calytrix*, *Grevillea*, *Eugenia*, *Petalostigma pubescens*, *Alphitonia*, *Canarium*)
4	5% Sporadic	Laterite outcrops: up to 100 yd wide: slopes to 1·7%; bare pavements or remnant blocks of sheet laterite; pisolitic, detrital, vesicular, or laminar laterite up to 3 ft thick, grading into unit 2, the detrital laterite with inclusions of subangular quartz and subrounded deeply weathered sandstone; undercutting, collapse, mechanical disintegration, subsurface chemical decay, sheet wash	Some shallow Cahill soils	Leguminous–myrtaceous scrub with mid-height and short grass and scattered eucalypts (*Calytrix*, *Bossiaea*, *Acacia* spp., *Schizachyrium*, *Thaumastochloa*, *Gomphrena*, spinifex, *E. bleeseri*)
5	5% Sporadic	Alluvial flats and channels: flats up to 250 yd wide; slopes to 1·7%; channels up to 8 ft deep and 30 ft wide; bed-load of fine sand	Kapalga (deep, grey sands) only observed; Howard and Nourlangie soils probably occur also	Variable: savannah over mid-height grass (*Melaleuca nervosa*, *E. polycarpa*, *Pandanus*, *E. papuana*, *Banksia*, *Eriachne triseta*, *Schizachyrium*, Cyperaceae, *Paspalum*, *Ectrosia*); or paperbark forest (*Melaleuca cajaputi*, *M. leucadendron*, *Syzygium*, *Tristania*, *Canarium*, and rain forest species over shrubs and non-grass herbs)
6	5% Sporadic	Isolated internal drainage depressions as for units 1, 3, and 5 of Krokane land system		As for units 1, 3, and 5 of Krokane land system: herbaceous swamp vegetation, paperbark forest, or savannah

KEATING LAND SYSTEM (215 SQ MILES, 9 OBSERVATIONS)

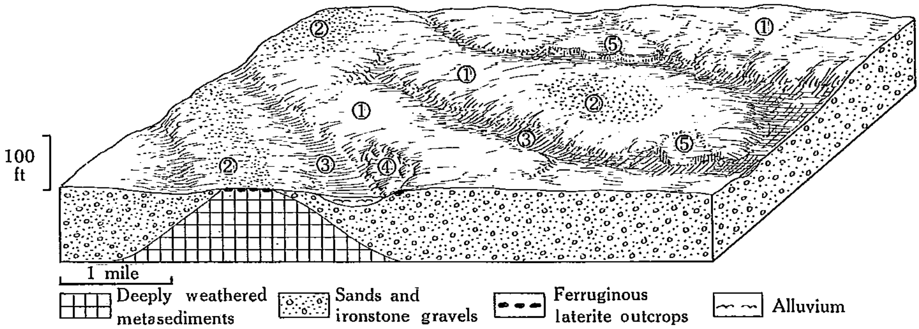
Undulating, deeply weathered, slightly eroded north-west and central lowlands; gradational, gravelly, yellow and red sandy to loamy soils and sandy derivatives; tall open forest or woodland (eucalypt).



Unit	Area and Distribution	Geomorphology	Soils	Vegetation
1	65% Throughout	Level remnants of Kay land system, gravelly wash slopes, and occasional laterite outcrops: up to 1 mile wide; slopes to 2%. In north-west up to 5 ft rounded ironstone gravels in sandy loam matrix over locally outcropping deeply weathered sandstone; minor occurrences of pisolitic laterite, in places covered by up to 1 ft of sandy wash; sheet wash and eluviation	Koolpinyah (gravelly yellow gradational sand to loam) soils dominate; Woolner soils (with mottled clay B and D horizons) on margins and slopes	Tall open forest or woodland, same as unit 1 of Kay land system, but more open or trees smaller (height 24–40 ft), with an admixture of *Alphitonia*, *Grevillea*, *Petalostigma pubescens*, and *Canarium*, and, especially on laterite outcrops, heathy shrubs with short grass (*Bossiaea*, *Calytrix*, *Verticordia*, *Schizachyrium*, Cyperaceae, *Eriachne triseta*, *Thaumastochloa*)
2	20% Throughout	Sandy wash slopes: concave; up to 300 yd wide; slopes to 3%; local relief to 20 ft; deep sands and loams; vertical eluviation, local scalding	Mainly Woolner with some Koolpinyah soils; Basedow (non-gravelly deep yellow-red soils) on high slopes; Berrimah soils	As for unit 1, with some *E. polycarpa* and *Tristania*
3	10% Occasional	Alluvial flats and channels: up to 400 yd wide with slopes to 1·7%; channels up to 5 ft deep and 30 ft wide	Howard and Nourlangie with some Kapalga soils, same as unit 5 of Kay land system	Same as unit 5 of Kay land system
4	5% Sporadic	Internal drainage depressions: same as unit 6 of Kay land system	Marrakai soils in permanently moist areas; other soils as for unit 3, and same as units 5 and 6 of Kay land system, with none dominant	Same as unit 6 of Kay land system

KEEFERS HUT LAND SYSTEM (515 SQ MILES, 26 OBSERVATIONS)

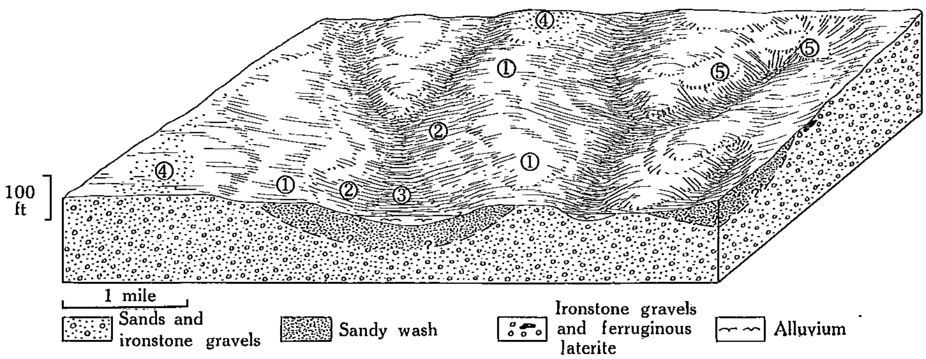
Dissected, rolling, deeply weathered north and central lowlands with frequent remnants of Kay land system; a variety of transitional soils, gradational yellow and red, uniform red, sands and loams over laterite; gradational yellow loamy soils derived from parent rock; woodland (eucalypt).



Unit	Area and Distribution	Geomorphology	Soils	Vegetation
1	50% Throughout	Gravelly wash slopes: to 5%; width to 300 yd; in north-west up to 5 ft of rounded ironstone gravels over locally outcropping deeply weathered sandstone; eluviation	Soils derived from the disintegration of laterite dominate: viz. Koolpinyah and Munmarlary with minor Cahill. Some Elliott soils observed where unweathered rock contributes to soil formation	Woodland, eucalypts over tall, mid-height, and short grass, height 40 ft or less, visibility variable (*E. tetrodonta*, *E. miniata*, *E. terminalis*, *E. bleeseri*, *E. clavigera*, *E. latifolia*, *Livistona*, *Terminalia ferdinandiana*, *Petalostigma quadriloculare*, *Buchanania*, *Erythrophleum*, *Xanthostemon*, *Heteropogon triticeus*, annual *Sorghum*, *Chrysopogon*, *Schizachyrium*, *Coelorachis*, spinifex, *Eriachne triseta*, Cyperaceae); towards base, grading into mixed scrub (*Melaleuca nervosa*, *Calytrix*, *Pandanus*, *Eugenia*, *Eriachne burkittii*, *Themeda*)
2	20% Throughout	Level margins and convex remnants of Kay land system: up to 300 yd wide; slopes to 4%, locally to 8%; relief to 60 ft; in north-west as in unit 1; sheet wash, eluviation	Hotham (red gradational loams) and Cahill (red uniform sands and loams) co-dominant	Tall open forest same as unit 1 of Kay land system
3	10% Throughout	Narrow alluvial flats: to 0·8%; up to 100 yd wide; shallow ill-defined channels; sands and gravelly loams locally over clay	Koolpinyah dominant on margins, Howard and Nourlangie soils common	Tall, mid-height, or short grassland with small annual non-grass herbs (*Eriachne burkittii*, *Schizachyrium*, *Panicum delicatum*, Cyperaceae, *Eriachne triseta*, *Pseudoraphis*); or savannah, eucalypt and non-eucalypt, over the same grasses (*Pandanus*, *Melaleuca nervosa*, *Tristania ferdinandiana*, *Eugenia*, *Grevillea pteridifolia*, *Banksia*, *E. polycarpa*, *E. clavigera*, *E. papuana*); some mixed scrub
4	10% Sporadic	Bouldery lateritic slopes: up to 250 yd wide; slope 0·4–2%, disintegrating blocks of detrital, vesicular, or pisolitic laterite up to 2 ft thick; subsurface decay, mechanical disintegration	Shallow very gravelly Cahill or Koolpinyah soils dominant; Elliott soils as in unit 1	Woodland as in unit 1, some tall open forest same as unit 1 of Kay land system, shrubs abundant
5	5% Sporadic	Level pavements: of massive laminar, vesicular, or pisolitic laterite; slopes to 1·7%; width to 250 yd; local outcrops vein quartz with 5% mean wash slopes; mechanical disintegration, subsurface decay	Koolpinyah and Cahill soils	Woodland, eucalypt and non-eucalypt, with shrubs and short grass (*E. miniata*, *E. tetrodonta*, *E. patellaris*, *E. bleeseri*, *E. clavigera*, *Cycas*, *Calytrix*, *Verticordia*, *Acacia cunninghamii*, *Erythrophleum*, *Eriachne triseta*, *E. ciliata*, *Cymbopogon*, annual *Sorghum*, *Gomphrena*)

Knifehandle Land System (360 sq miles, 19 observations)

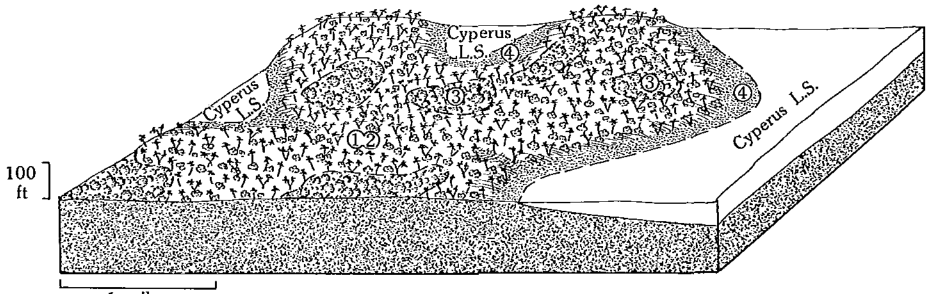
Shallow valleys, wash slopes, and coalescent valleys next to Kay and Queue land systems; uniform deep grey and yellow sands with sandy and gravelly gradational soils (red and yellow) on upper slopes, texture-contrast soils on alluvial flats; woodland (eucalypt) or mixed scrub of dwarf paperbark, *Grevillea*, and shrubs.



Unit	Area and Distribution	Geomorphology	Soils	Vegetation
1	35% Throughout	Low gravelly spurs and wash slopes: up to 3·5%; relief to 30 ft; width to 400 yd; minor outcrops of pisolitic or detrital laterite, regolith of ironstone gravels in sandy loam matrix; sheet wash, local scalding, eluviation	Berrimah (deep gradational loam to clay) and Hotham (gravelly loam to clay) red soils with Munmarlary and Koolpinyah soils (yellow-red and yellow sand to loam, with sandy earth fabric); none dominant	Woodland, same as unit 1 of Kay land system, but more open and with a little *E. bleeseri*, *E. clavigera*, and spinifex, grading towards foot into mixed scrub (height 30 ft, visibility variable) of non-eucalypts over tall, mid-height, and short grass (*Melaleuca nervosa*, *Pandanus*, *Grevillea pteridifolia*, *Eugenia*, *Tristania*, annual *Sorghum*, *Chrysopogon*, *Eriachne ciliata*, *E. triseta*, Cyperaceae)
2	30% Throughout	Sandy wash slopes: up to 2%, in places to 3·5%; width to 300 yd; relief to 15 ft; minor outcrops of massive, pisolitic laterite breaking down to blocks up to 2 ft thick; eluviation	Deep grey sands (Kapalga) and yellow sands with gravels (Baroalba); some sand over clay (Howard) soils marginal to unit 3	Mixed scrub, height 25 ft, visibility 60 yd, non-eucalypts over tall, mid-height, and short grass (*Melaleuca nervosa*, *Acacia* spp., *Pandanus*, *Eugenia*, *Grevillea pteridifolia*, *Banksia*, *Hakea*, *Eriachne triseta*, *Restio*, *Xyris*, annual *Sorghum*, *Schizachyrium*, *Ectrosia*)
3	20% Throughout	Alluvial flats and channels: mean slopes 1%, up to 3% along margins; width to 600 yd; channels up to 6 ft deep, 30 ft wide, incised in sands, silts, and loams that locally overlie ironstone gravels. This unit in places represents segmented partially infilled spillways or major channels; aggradation currently exceeds removal	Howard soils dominate with Nourlangie (sands over carbonate clays and gravelly phases); Jim Jim (silts over carbonate-alkali clays) on seasonally dry central zones of valley floors; and Woolwonga (gradational silt to alkaline–calcic clay soils)	Tall, mid-height, or short grassland (annual *Sorghum*, *Vetiveria*, *Coelorachis*, *Eriachne burkittii*, *E. triseta*, *Ectrosia*, sedges, *Pseudoraphis*, *Urochloa*), sometimes with scattered trees to form savannah (*Melaleuca nervosa*, *Pandanus*, *E. alba*, *Tristania*, *E. papuana*)
4	10% Next to Kay land system	Gravelly upper slopes: width to 400 yd; slopes up to 1·7%; relief to 10 ft; otherwise as for unit 1	Hotham and Cahill soils, often with dense lag gravels, and Koolpinyah soils	Woodland, same as unit 1 of Kay land system, but more open and with a little *E. bleeseri*, *E. clavigera*, and spinifex
5	5% Sporadic	Bare laterite pavements: up to 50 yd wide, on slopes up to 2·5%, massive, laminar, vesicular, or pisolitic laterite; mechanical disintegration, subsurface decay	Bare laterite with shallow (<12 in.) dense lag gravels of Cahill family, shallow phase	Leguminous–myrtaceous scrub, same as unit 4 of Kay land system

KOSHER LAND SYSTEM (525 SQ MILES, 40 OBSERVATIONS)

Margins of deeply weathered lowlands sloping gently towards Cyperus land system; colluvial gravelly and stony red and yellow gradational soils and sandy derivatives of Queue and Kay land system soils; patchy grassland, *Pandanus* scrub, and mixed scrub.



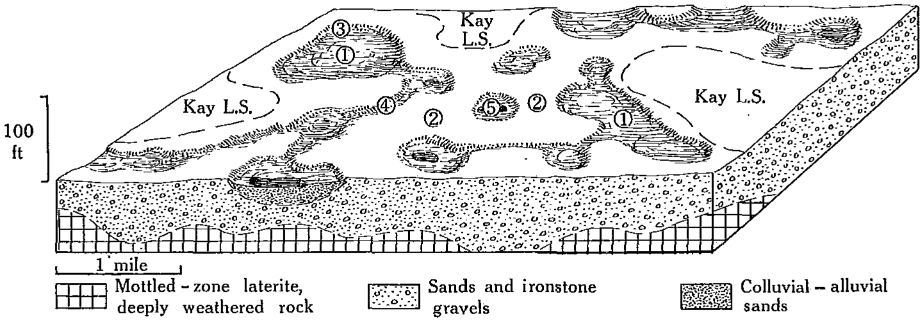
Sands and ironstone gravels over ferruginous and mottled-zone laterite

Estuarine and freshwater clays

Unit	Area and Distribution	Geomorphology	Soils	Vegetation
1	40% Throughout	Sandy wash slopes: up to 1·7%, locally 5%; width to 500 yd; relief to 25 ft, with minor outcrops of detrital, vesicular, or pisolitic laterite up to 50 yd wide, 3 ft thick; sands and loams, in places over ironstone and quartz gravels; termitaria to 5 ft, scoured to 1 ft; eluviation	Berrimah (red gradational loam to clay), Hotham (red gravelly loam to clay), Basedow (brown-red gradational sand to clay), and Woolner (with mottled clay subsoils) on higher slopes; Koolpinyah (yellow gradational sand to loam), Kapalga, and Baroalba (uniform sands) on lower slopes; none dominant; very rare podzols (part of Murrabibbi family) under rain forest sites	Mixed scrub or *Pandanus* scrub, height 30 ft, visibility variable, clumpy, over short, occasionally mid-height, grass (*Pandanus, Eugenia, Acacia, Grevillea pteridifolia, Parinari, Tristania, Alphitonia, Alstonia, E. papuana, Schizachyrium, Stylosanthes, Thaumastochloa, Eragrostis, Eriachne ciliata, Urochloa, Eleusine, Digitaria, Hyptis*); occasional patches of rain forest
2	25% Throughout	Gravelly wash slopes: up to 3·5%, mean 2%; up to 500 yd wide; relief to 20 ft; elevation 40–170 ft; in north-west up to 5 ft rounded ironstone gravel over locally outcropping deeply weathered sandstone, elsewhere additions of stony to gravelly quartz and sandstone in matrix of sandy loam to sandy clay loam; local scalding, eluviation, disintegration and subsurface decay of laterite	Koolpinyah soils dominant; minor Cahill (uniform red gravelly soils) and minor Baroalba on lower slopes	As for unit 1, but rain forest not recorded
3	20% Throughout		As in unit 1. Munmarlary (yellow-red gradational gravelly and stony soils) and Koolpinyah soils dominant on stripped lower slopes	Leguminous or Myrtaceous scrub or short grassland with occasional trees and mid-height grasses (*Calytrix, Acacia* sp., *Verticordia, Eugenia, Parinari, Acacia cunninghamii, Petalostigma pubescens, Schizachyrium, Eriachne triseta, E. ciliata, Eragrostis, Thaumastochloa, Cynodon, Stylosanthes*)
4	15% Throughout	Lower sandy wash slopes: generally next to Cyperus land system; up to 3·5%; width to 700 yd; minor outcrops of seepage laterite up to 40 yd wide on slopes up to 2%; frequent termitaria to 4 ft, undercut to 6 in.; localized scalding, subsurface formation of ironstone concretions; minor narrow alluvial depressions	Baroalba soils on higher sites (marginal to unit 2); Murrabibbi (melanized loam over sand over clay) on lower slope sites transitional to coastal plains soils; Howard, Nourlangie, and Woolwonga dominant on margins of alluvial flats	Mid-height or short grassland, often secondary (*Urochloa, Ectrosia, Eragrostis, Dactyloctenium, Eriachne burkittii, E. triseta*, Cyperaceae, *Stylosanthes*)

KROKANE LAND SYSTEM (155 SQ MILES, 17 OBSERVATIONS)

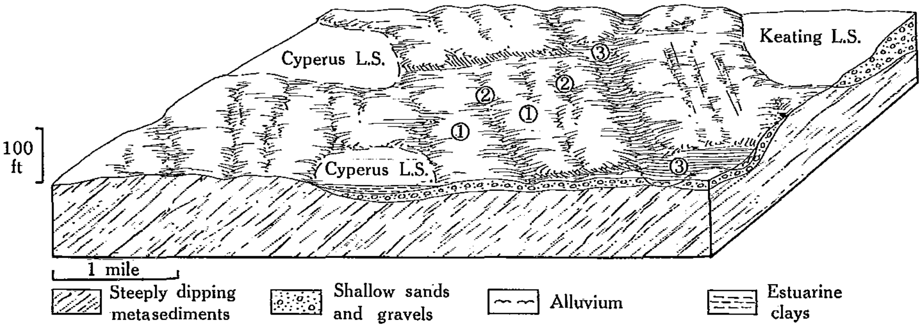
Internal drainage depressions and segmented valleys in deeply weathered lowlands, widespread; texture-contrast soils and uniform sands; paperbark forest, grassland, or herbaceous swamp vegetation.



Unit	Area and Distribution	Geomorphology	Soils	Vegetation
1	35% Throughout	Seasonally flooded depressions: up to 100 yd wide and 10 ft deep; slopes to 2%; deep sands and loams in places over clays and/or ironstone gravels; sheet wash, aggradation	Nourlangie (sand over alkaline calcic clays) on outer margins; Jim Jim (shallow sand over alkaline clay) and Marrakai (gradational silt to clay, acid) on moist central zones of depressions and channels; gravelly phases mainly in Jim Jim and Marrakai soils	Varied; mid-height or short grassland often with scattered trees to form an open savannah (*E. polycarpa, Pandanus, Melaleuca argentea, M. nervosa*); or paperbark forest over short grass or bare ground
2	25% Next to Kay and Queue land systems	High level surfaces: slopes to 2%; deep sands or ironstone gravels in sandy loam matrix; similar to units 1 and 2 of Kay and Queue land systems	Gravelly yellow (Koolpinyah) and red (Hotham) soils	Tall open forest, same as units 1 and 2 of Kay and Queue land systems
3	15% Throughout	Edges of depressions and billabongs: up to 80 yd wide; slopes to 3·5%; peripheral outcrops of laminar seepage laterite up to 40 yd wide and 6 in. thick; minor outcrops of massive, vesicular, or pisolitic laterite; sands and loams, in places over clays, ironstone gravels, or weathered quartz; sheet wash, minor gullying, seasonal seepage, eluviation, undercutting and disintegration of laterite	Uniform deep sands (Kapalga), with some Baroalba yellow sands on higher slope and organic surface phase near billabongs; Howard (sands over clays) and Murrabibbi (loam over sand over clay) on lower slopes marginal to, and extending into, unit 1; shallow gravelly Koolpinyah soils near laterite outcrops	Paperbark forest with *Tristania, Melaleuca cajaputi, M. leucadendron, M. viridiflora, E. herbertiana*, often in pure 20-yd zones; or tall, mid-height, or short grassland with scattered trees (*Eriachne triseta, Vetiveria, Chrysopogon, Pseudopogonatherum*, annual *Sorghum, E. polycarpa, Pandanus*)
4	15% Throughout	Sandy spillways: of deep sand linking units 1 and 5	Baroalba soils and possibly some Kapalga	Grassland with scattered trees and clumps of trees (*Themeda, Eriachne burkittii, E. triseta, Chrysopogon*, Cyperaceae, *Coelorachis, Sclerandrium grandiflorum, Panicum delicatum, Tristania, Pandanus, E. polycarpa*)
5	10% Throughout	Perennial billabongs: up to 500 yd wide, 3 miles long, and 8 ft deep; in north-west circular billabongs up to 200 yd wide, 10 ft deep, flanked by mottled zone of deeply weathered sandstone; sandy bedload	—	Open water or herbaceous swamp vegetation rooted in mud or floating

KYSTO LAND SYSTEM (240 SQ MILES, 15 OBSERVATIONS)

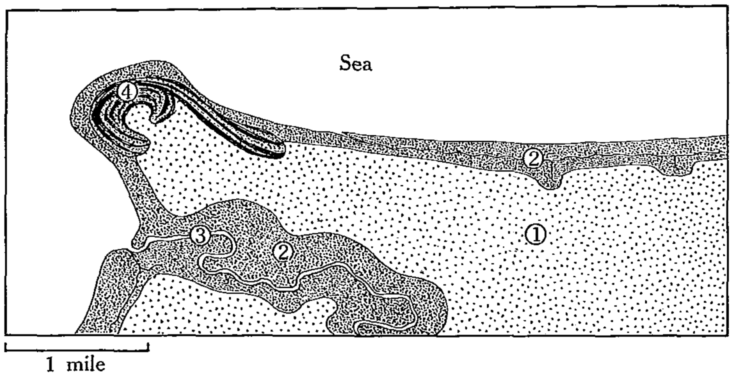
Low rises and swales and minor isolated low strike ridges next to deeply weathered lowlands; shallow stony and gravelly gradational red and yellow-red soils and uniform red soils; bands of tall open forest and woodland, very variable, often strike-aligned.



Unit	Area and Distribution	Geomorphology	Soils	Vegetation
1	45% Throughout	Rises and domes: up to 10%; width to 100 yd; relief to 25 ft; stony very variable regolith; minor outcrops of massive, pisolitic, or detrital laterite; minor depressions as in unit 2; eluviation, rill erosion	Dominantly shallow remnant soils over laterite, or laterite-derived Hotham (gradational) or Cahill (uniform); rare yellow-red Munmarlary soils and rare skeletal where influence of unweathered rock is dominant	Bands of tall open forest, height 50 ft, visibility 50 yd, same as unit 1 of Kay land system, occasionally with some *E. bleeseri* and *E. clavigera*
2	40% Throughout	Linear depressions: up to 3%; width to 100 yd; variable regolith, in places deep loams and clays, shallow sands, minor rises as in unit 1; sheet wash, scalding, slow alluviation	Munmarlary soils and yellow gradational Koolpinyah soils; rare Baroalba (uniform yellow sands)	Bands of woodland, height 20 ft, visibility 250 yd, varied eucalypts over tall, mid-height, and short grass (*E. clavigera, E. papuana, E. tectifica, E. foelscheana, E. ferruginea*); other shrubs and grasses same as unit 1 Kay land system, shrubs sometimes dominant, with much *Calytrix*
3	15% Throughout	Alluvial flats: up to 200 yd wide with slopes up to 1%; shallow ill-defined channels; deep loams, locally over massive nodular laterite; termitaria (4 ft) in places on scalded pedestals up to 1 ft high; sheet wash, in places subsurface iron concretions forming	Dominantly Elliott soils (yellow gradational sand to clay, hard-setting), reflecting influence of unweathered rock	Grassland with scattered trees, or savannah (*Eriachne burkittii, Themeda*, Cyperaceae, *Vetiveria, Chrysopogon, Panicum delicatum, E. papuana, Melaleuca nervosa, Pandanus*)

Littoral Land System (270 sq miles, 17 observations)

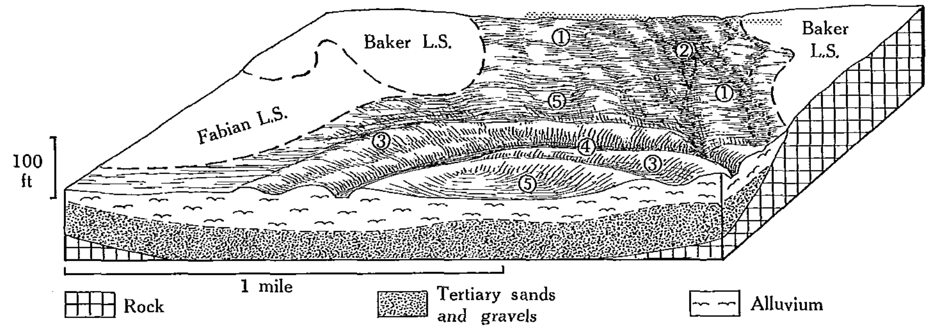
Level tidal flats and emergent coastal plains, active and fixed coastal sand-dunes, northern coastal fringe; saline muds and grey cracking clays; samphire, sedge land, or mangrove scrub.



Unit	Area and Distribution	Geomorphology	Soils	Vegetation
1	60% Extreme northern margins	Tidal flats: up to ½ mile wide; slopes less than 0·4%; recent estuarine and marine clays, in places over buried mangroves; seasonal drying and surface cracking; intermittent tidal flooding and sedimentation during king tides	Strongly saline weakly cracking grey clays (Carpentaria)	Samphire or sedge land or bare
2	25% Extreme northern margins	Coastal and riverine mangrove fringe: up to 100 yd wide; slopes up to 0·9%; riverine mangrove on low clay levees up to 100 yd wide and 4 ft high; sedimentation, minor gullying, daily tidal flooding	Gleyed saline muds and minor Carpentaria	Mangrove scrub
3	10% Occasional	Channels: major channels up to 30 ft deep and 200 yd wide with outlets up to 2 miles wide; minor channels up to 15 ft deep and 40 yd wide; bed-load silt and clay	—	—
4	5% Mainly around headlands of northern lateritic plains	Coastal dune complex: active and fixed beach ridges, up to ¾ mile wide; active outer dune shelving seawards up to 40%; deep shelly sands; up to 5 fixed dunes, each up to 200 yd wide, 30 ft high, with slopes up to 9%; deep sands and loamy sands; inter-dune swales up to 100 yd wide; slopes up to 0·8%; clays, sandy clays, and loams; coastal outcrops of laminar, massive, vesicular, or pisolitic laterite, or of beach rock, up to 50 yd wide on 0·9% slopes, overlain by sandy beach to landward; variable tidal flooding, lateral seepage, eluviation; run-off concentrated along swales	Dune sands and weakly cracking clays over sand in inter-dune swales (Counamoul); Carpentaria soils over sands in swales where tidal flooding occurs	Woodland, height and visibility variable, mainly non-eucalypts (*Acacia*, *Pandanus*, *Abrus*, *Eugenia*, *Canarium*, lianes), or semi-deciduous forest; ground vegetation very sparse in both, but litter plentiful

McKinlay Land System (270 sq miles, 27 observations)

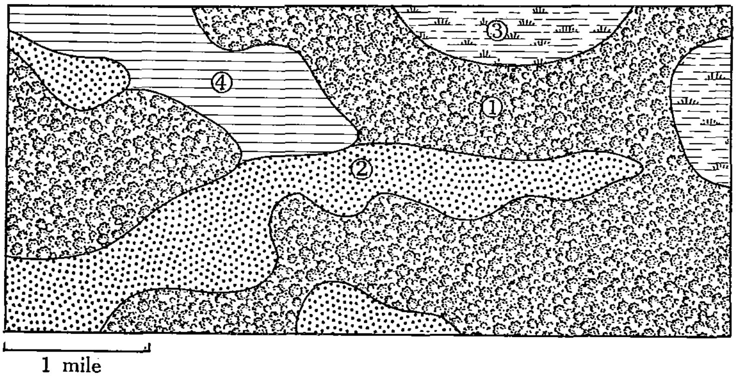
Channels and flood-plains, widespread; uniform sands and silts, gradational acid loamy and sandy soils, gradational alkaline loamy soils and alkaline texture-contrast soils; paperbark forest or savannah, very variable.



Unit	Area and Distribution	Geomorphology	Soils	Vegetation
1	45% Widespread	Flood-plains, often gullied, with billabongs: up to 400 yd wide; slopes up to 2%; silts and sands over clay; flooded 4–6 months up to 2 ft; *occasional billabongs up to 5 ft deep and 30 yd wide*; sheet floods, slow alluviation, erosion by gullies up to 20 ft deep and 50 ft wide, with spring sapping in places, subsurface formation of ironstone concretions	West of the South Alligator River fine-textured soils on silty parent alluvia: a variety of soils on minor sites typical of other land systems (Fabian, Flatwood); Mary (uniform brown silt) and Elliott (gradational yellow loam to clay) on recent flats; minor Moline (gradational loam over alkaline structured clay) and Margaret (texture-contrast loam over alkaline clay); Marrakai (gradational loam to acid clay) on poorly drained sites. East of the South Alligator soils are derived from sandy alluvia as in unit 2	Grassland or savannah, as in Fabian or Flatwood land systems
2	20% Along rivers east of South Alligator River	Braided channels and sand bars: up to 800 yd wide with variable slopes; channels up to 8 ft deep and 40 ft wide; deep alluvial sands; lateral corrasion, seasonal scour, deposition	Baroalba (recent uniform sands); Magela (gradational sand to sandy clay loam) on recent and active areas; Howard (sand over acid clay), Woolwonga (silt to clay gradational), and Jim Jim (shallow sand over alkaline clay) on minor stable sites; none dominant	Predominantly paperbark forest or grassland
3	15% Along main rivers west of South Alligator River	Levees and swales: up to 2 well-defined benches 15 ft high and 60 yd wide separated by swales to 40 yd wide; mean slopes to 1·7%–9% along margins; deep loams locally over clay; aggradation, eluviation, and gullying on levees; scalding, subsurface formation of ironstone concretions, seasonal ponding of flood waters in swales	Mary soils on recent levees and Katherine (gradational loam to clay red soils) on older levees	No consistency, varying from grassland through savannah to paperbark forest and scrub of *Pandanus* and *Bambusa*
4	10% Main rivers west of South Alligator River	Major channels: up to 35 ft deep; width to 100 yd; bank slopes up to 60%; local outcrops of rock in channel bed; bed-load sand and silt in major rivers, gravels and cobbles in headwater tributaries; vertical and lateral corrasion	—	Banks paperbark forest, beds mainly bare
5	10% Main rivers west of South Alligator River	Levee back slopes: up to 200 yd wide; slopes up to 1%; silts, loams, and sands, in places over clay; sheet floods, scalding, slow alluviation	Katherine on higher back plains and Moline (gradational loam over alkaline structured clay) on lower sites; minor Mary and Marrakai soils	As for unit 3

Pinwinkle Land System (340 sq miles, 16 observations)

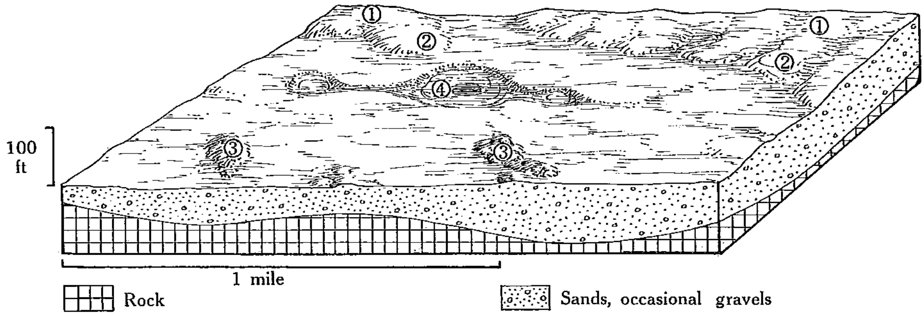
Swampy depressions on the coastal plains; black uniform cracking clays over gleyed estuarine muds and riverine sands, texture-contrast peaty loam over clay soils; paperbark forest.



Unit	Area and Distribution	Geomorphology	Soils	Vegetation
1	70% Scattered throughout	Wooded swamps: up to 4 miles wide; slopes to 1·2%; flooded to 3 ft or more except along higher margins which dry out seasonally; freshwater over estuarine clays, slow aggradation	Mostly permanently wet gleyed cracking clays over estuarine muds (Wildman); gypsic at A/C horizon transition (Cairncurry), and Cooinda (texture-contrast black loam over clay)	Paperbark forest, height 50 ft, visibility 70 yd (*Melaleuca cajaputi*, *M. leucadendron*, *M. viridiflora*), and occasional clumps of *Barringtonia* over herbaceous swamp vegetation rooted in mud or floating
2	15% Sporadic	Slightly raised treeless areas: width to 500 yd; slopes, to 0·8%, locally to 2%, flooded 4–8 months to 4 ft, drying out rapidly in upper few feet	Predominantly Wildman with minor Cairncurry, Cooinda as in unit 1, and minor Counamoul (clay over acid sands) in inland areas	Bare or with scanty cover of herbs (*Marsilea*, *Phyla*)
3	10% Along southern margins of coastal plains	Depressions and channels next to the deeply weathered surface: up to 300 yd wide; slopes to 2% along margins, mean slopes 0·4%; channels variable in depth and width, seasonal flooding to 4 ft; freshwater over estuarine clays or wash derived from Kay land system and its derivatives; slow aggradation, sheet wash, eluviation	Murrabibbi (loam over sand over clay) and Koolpinyah (yellow gradational sand to loam)	Paperbark forest or grassland, as in unit 3 of Krokane land system
4	5% Occasional in NE. and SE.	Alluvial plains: flooded 4–6 months to 2 ft; well drained; up to 500 yd wide; slopes to 1·2%	Counamoul soils dominant in transition zone between inland alluvium and coastal plains; rare Carmor	Paperbark forest as in unit 1, with occasional *Acacia auriculiformis* and *Terminalia melanocarpa*; sparse ground cover of short annual and perennial grasses or of *Marsilea* and *Phyla*, some parts bare

QUEUE LAND SYSTEM (250 SQ MILES, 8 OBSERVATIONS)

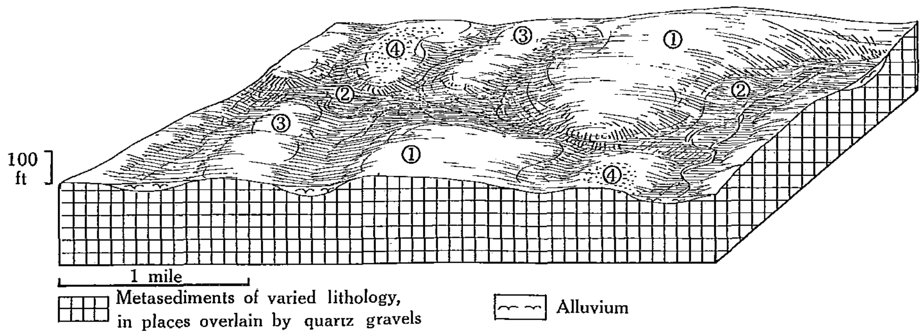
Level sandy lowlands, widespread; uniform red sandy soils, uniform grey and yellow sands; tall open forest.



Unit	Area and Distribution	Geomorphology	Soils	Vegetation
1	80% Throughout	Level surfaces: up to 2 miles wide; slopes to 3·5%; relief to 20 ft; sands generally over 5 ft deep, but in places overlying decayed fragments of detrital or pisolitic laterite; sheet wash, eluviation	Cockatoo (uniform red sands underlain by gravelly alluvium or detrital laterite)	Tall open forest, as unit 1 of Kay land system but taller and more open (height 60 ft, visibility 100 yd)
2	10% Occasional	Sandy wash slopes: up to 400 yd wide; slopes to 1·7%; relief to 20 ft; well-drained, gravel-free sands, over 5 ft deep; eluviation, sheet wash	Basedow (gradational yellow-red sand to clay) on higher slopes; Baroalba (yellow uniform sands) and Kapalga (grey sand) on lower slopes	Tall open forest or woodland, as unit 3 of Kay land system
3	5% Sporadic	Laterite outcrops and minor gravelly wash slopes: up to 150 yd wide; slopes to 1·7%	Only Basedow soils observed	Inadequate observations
4	5% Sporadic	Elongated depressions or spillways, often with perennial billabongs	Baroalba soils dominant, with minor Marrakai (gradational silt to acid clay)	Paperbark forest, grassland, or water-weeds in open water

Rumwaggon Land System (710 sq miles, 35 observations)

Hills or raised gravel patches and intervening alluvial flats in south-west; skeletal soils and gradational yellow loamy soils on hill slopes, texture-contrast alkaline soils on flats, woodland (semi-deciduous eucalypt) or stunted woodland (mixed) on hill slopes, savannah woodland on flats.



Unit	Area and Distribution	Geomorphology	Soils	Vegetation
1	45% Throughout	Low erosional rises or convex knolls: up to 60 ft high; slopes to 25%; varied lithology (weathered sandstone, siltstone, chert, greywacke, and deeply weathered shales and sandstone); frequent rock outcrop on slopes above 8%; discontinuous stony regolith on steeper slopes, even layer of siltstone flakes and gravels on gentle slopes, buried pisolitic laterite cropping out locally; sheet wash and eluviation	Skeletal soils and Elliott (gradational yellow loam to clay); rare Angelara (clays derived from weathered alkaline shales)	Woodland or stunted woodland, height 30 ft and less, visibility 200 yd, eucalypt and non-eucalypt over scanty tall, mid-height, or short grass (*E. clavigera*, *E. ferruginea*, *E. alba*, *E. foelscheana*, *E. tectifica*, *Erythrophleum*, *Xanthostemon*, *Cochlospermum*, *Grevillea heliosperma*, *Petalostigma*, *Gardenia*, *Themeda*, *Chrysopogon*, *Eriachne triseta*, annual *Sorghum*, *Heteropogon triticeus*, *Schizachyrium*, *Thaumastochloa*; *Cycas* west of Adelaide River)
2	25% Throughout	Alluvial flats: up to 300 yd wide; slopes less than 2%; channels up to 25 ft wide, 2–15 ft deep, incised locally into bed-rock; sheet floods and scalding, with termitaria locally undercut up to 1 ft above ground level; in places incipient lateritization of alluvial clays and loams; eluviation of sands and sandy loams	Dominantly Margaret soils (texture-contrast loam over alkaline columnar-structured clay); Moline (gradational as above) on flats, McKinlay (gradational yellow loam to alkaline clay), and Stapleton (gradational yellow loam to clay with A_2 horizons) on marginal areas	Grassland, same as unit 1 of Fabian land system, or savannah, same as unit 1 of Flatwood land system
3	20% Throughout	Wash slopes: to 2%; up to 150 yd wide; gravelly colluvium in sandy loam matrix; shallow streams dry for 6 months or more; locally incised into bed-rock; some termitaria (10 ft); sheet wash and scalding	Batten soils (gradational yellow loam to clay with shallow A_2) dominant, with Stapleton and Elliott soils	Woodland or stunted woodland, as for unit 2 of Bend land system
4	10% Occasional	Slightly raised patches of residual gravels: up to 200 yd wide; slopes generally less than 2%, locally to 5%; relief to 15 ft; minor laterite outcrops; stony regolith of angular quartz; rare patches of water-worn rounded cobbles flanking the middle reaches of the Mary River; sheet floods, local scalding	Elliott soils dominant, with skeletal soils, minor Batten	As for unit 1, but with occasional *Melaleuca argentea*, *M. nervosa*, *E. ferruginea*, perennial *Sorghum*, *Ischaemum*, and *Pseudopogonatherum*

PART IV. THE CLIMATE OF THE ADELAIDE–ALLIGATOR AREA

By J. R. McAlpine*

I. Introduction

The climate of this area has previously been described (Anon. 1961; Christian and Stewart 1953; and Southern 1966). Some aspects of these works are briefly summarized and the relation of pasture growth to rainfall is discussed. For a fuller climatological survey, the reader is referred to the publications of Anon. (1961) and Southern (1966). The agroclimatology of the adjoining Tipperary area to the south has been discussed by Fitzpatrick (1965) and Slatyer (1960).

II. Principal Climatic Controls

Two distinct seasons occur in the area, an almost rainless dry season from May to September and a wet season from November to March. Southern (1966) further differentiates between organized rainfall, typified by monsoonal or cyclonic weather and widespread convection, and non-organized rainfall, typified by apparent random or mesoscale convection. He distinguishes five categories of rain-producing systems, the interplay of which produces the seasonality and character of the rainfall in the area. These are shown diagrammatically in Figure 3.

III. General Climatic Characteristics

Mean monthly rainfall for eight stations is given in Table 1 and the spatial distribution of this rainfall is shown on an isohyet and histogram map (Fig. 4). The concentration of stations on the periphery of the area, particularly to the west, makes the delimitation of isohyets somewhat arbitrary. Annual variability of rainfall as expressed in the coefficient of variation (standard deviation as a percentage of the mean) is less than 18% in the Darwin–Oenpelli sector (Anon. 1961) and increases in a south-easterly direction to 25% at Adelaide River.

Percentage frequencies of rainless days and daily rainfalls within specified limits are given in Table 2, which also serves as a rough measure of variations in seasonal rainfall intensity. Intensity of daily rainfall reaches a peak in January and February and falls away rapidly during March and April.

Other climatic characteristics are illustrated by reference to records kept at the Coastal Plains Research Station, CSIRO, near Humpty Doo (Table 3). Mean temperatures are at their lowest during June and July (mean max. 88°F, mean min. 60°F, mean 74°F). Mean maximum temperature reaches its highest in November (96°F), whilst mean minimum temperature reaches its peak in December (76°F). Evaporation increases during the dry season, particularly towards its conclusion when it reaches 9 in. a month.

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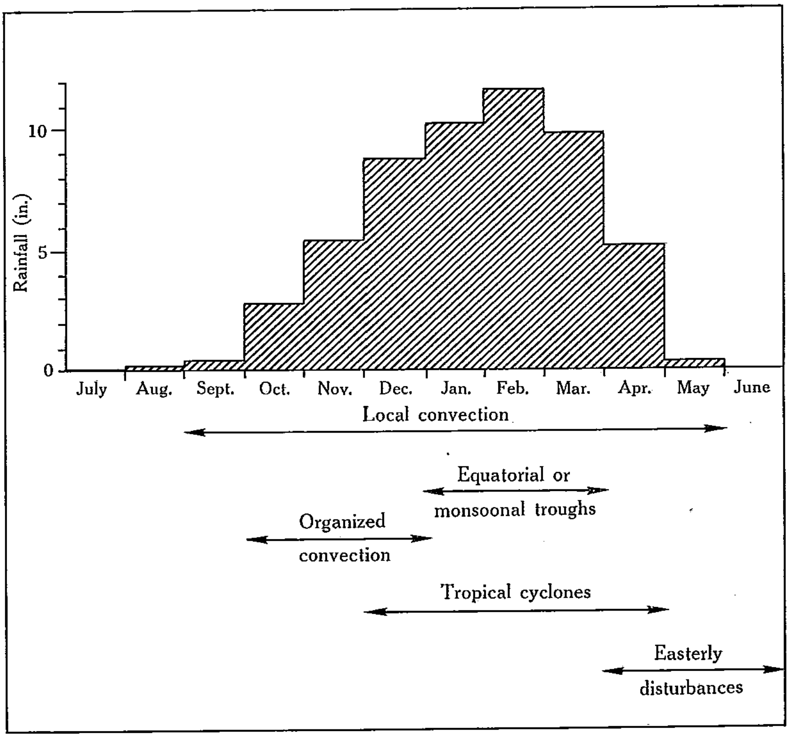

Fig. 3.—Annual rainfall at Humpty Doo and five categories of rainfall-producing systems (after Southern 1966).

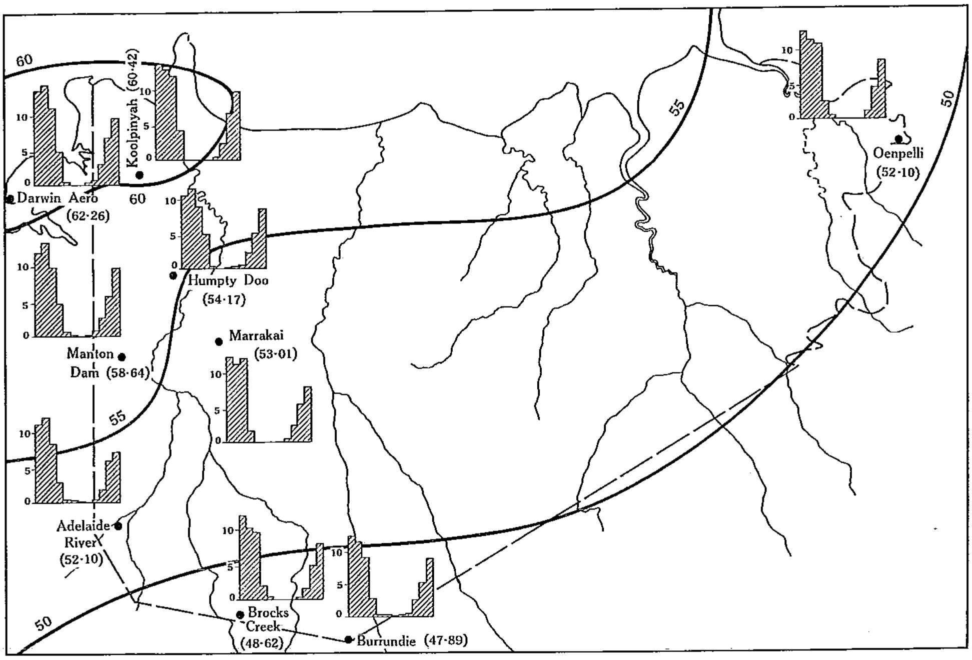

Fig. 4.—Distribution of mean annual rainfall (in.) (from January to December). Values shown with station names are the mean annual rainfall (in.) for the station.

TABLE 1

MEAN MONTHLY RAINFALL FOR NINE STATIONS (IN.)*

Station	Years of Record	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Adelaide River	17	11·25	12·46	8·79	3·02	0·51	0·27	0·12	0·05	0·63	2·19	5·32	7·49	52·10
Brocks Creek	44	11·79	10·00	9·83	1·69	0·23	0·20	0·06	0·03	0·52	1·55	4·75	7·97	48·62
Burrundie	45	11·29	10·45	8·12	2·28	0·18	0·17	0·12	0·07	0·46	2·12	4·49	8·14	46·87
Darwin Aero	15	10·34	11·63	9·11	5·14	0·25	0·02	0·08	0·14	0·44	2·80	5·41	8·81	54·17
Koolpinyah	45	13·30	12·76	11·84	3·79	0·28	0·08	0·06	0·06	0·50	2·05	6·37	9·33	60·42
Manton Dam	10	11·88	13·15	9·63	4·49	0·79	0·06	0·15	0·01	0·65	2·74	5·21	9·88	58·64
Marrakai	24	12·14	11·01	12·03	1·75	0·16	0·11	0·02	0·05	0·46	2·20	5·26	7·82	53·01
Oenpelli	46	12·68	11·13	10·74	2·80	0·44	0·08	0·11	0·02	0·11	1·16	4·48	8·35	52·10

* Bureau of Meteorology (1961).

IV. Rainfall and Pasture Growth

A system of soil water balance accounting used by Fitzpatrick (1965) for estimating duration of pasture growth has been adopted here using the long-term records available for Darwin, Oenpelli, and Adelaide River. This method is based on a model using weekly rainfalls as increments to available soil moisture and mean

Table 2

PERCENTAGE* OF DAYS WITH RAINFALL WITHIN SPECIFIED LIMITS AND DAYS WITHOUT RAIN FOR THE MONTHS OCTOBER TO APRIL

Range (in.)	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
				Darwin			
Nil	84	62	48	38	33	43	72
0·01–0·49	12	25	32	35	39	36	32
0·50–0·99	2	6	9	13	13	10	7
1·00–1·99	1	5	7	9	11	7	5
2·00–2·99	1	2	2	3	3	3	2
3·00–3·99	—	—	—	2	1	1	—
⩾4·00	—	—	—	1	—	—	—
				Adelaide River			
Nil	87	71	62	49	50	63	91
0·01–0·49	9	18	21	24	24	20	5
0·50–0·99	3	5	8	11	10	9	2
1·00–1·99	1	5	6	12	11	5	2
2·00–2·99	—	1	2	3	3	2	—
3·00–3·99	—	—	—	1	1	1	—
⩾4·00	—	—	—	—	1	—	—
				Oenpelli			
Nil	94	72	56	42	37	46	85
0·01–0·49	4	18	28	32	37	32	10
0·50–0·99	1	5	9	13	14	11	3
1·00–1·99	1	4	5	10	9	8	2
2·00–2·99	—	1	2	2	2	1	—
3·00–3·99	—	—	—	1	1	1	—
⩾4·00	—	—	—	—	—	1	—

* To the nearest whole percentage.

weekly evaporation as a basis for evapotranspiration withdrawals. The evaporation data used have been taken from a standard Australian tank evaporimeter at the CSIRO Coastal Plains Research Station for the years 1961–65 inclusive and applied to each of the stations listed.

TABLE 3

METEOROLOGICAL ELEMENTS AT COASTAL PLAINS RESEARCH STATION EXPRESSED ON MEAN FORTNIGHTLY BASIS

Fort-night*	Temperature (°F) Mean Max.	Mean Min.	Mean	Mean Relative Humidity (%)	Mean Vapour Pressure† (mb)	Evaporation (in.)	Rain (in.)
1	90·46	75·06	86·27	84·1	9·17	2·87	3·29
2	90·97	75·12	83·04	87·0	9·17	2·94	4·69
3	89·52	75·21	82·62	86·8	9·20	2·66	6·47
4	91·47	75·44	83·46	85·0	9·29	3·08	4·43
5	89·93	75·66	82·80	82·0	9·02	2·87	5·19
6	91·38	75·85	83·62	85·0	9·17	3·08	5·36
7	91·44	75·19	83·32	83·0	8·81	2·94	1·95
8	90·87	73·07	81·99	79·1	8·24	3·36	0·74
9	91·58	69·69	80·71	71·0	7·19	3·57	0·06
10	90·57	66·31	77·47	65·2	5·92	3·78	0·11
11	90·35	65·54	78·08	73·0	6·67	3·36	0·04
12	89·73	63·16	76·59	67·0	5·74	3·50	—
13	87·98	61·22	73·94	61·0	4·65	3·78	0·02
14	88·63	59·63	74·13	63·0	4·86	3·57	—
15	88·78	58·03	73·50	58·0	4·34	3·71	—
16	89·73	60·36	75·08	61·1	4·93	3·85	—
17	91·81	62·69	77·22	66·1	5·92	3·99	—
18	93·70	66·04	79·85	67·5	6·53	4·55	—
19	95·17	70·34	82·78	69·5	7·29	4·62	0·08
20	96·55	72·34	84·45	67·0	7·54	4·90	0·12
21	96·55	74·43	85·69	67·0	7·88	5·04	1·16
22	95·86	74·13	84·96	70·0	8·15	4·41	2·26
23	96·18	75·26	85·75	75·0	8·75	3·57	2·55
24	93·49	74·50	83·99	77·0	8·66	3·57	3·42
25	93·64	75·37	84·51	79·5	9·14	3·36	2·80
26	92·52	76·14	84·33	81·8	9·05	3·36	5·62

* Starting Jan. 1. † At 9 a.m.

TABLE 4

CHARACTERISTICS OF THE PERIOD OF PASTURE GROWTH

	Darwin	Adelaide River	Oenpelli
Commencement of estimated useful pasture growth			
Median date	Nov. 2	Nov. 9	Nov. 11
Lower quartile	Oct. 19	Oct. 31	Nov. 2
Upper quartile	Nov. 17	Nov. 16	Nov. 26
Cessation of estimated useful pasture growth			
Median date	May 16	May 4	May 10
Lower quartile	May 8	Apr. 28	May 3
Upper quartile	May 25	May 14	May 16
Total duration of estimated useful pasture growth (i.e. average annual number of weeks with available water)	28	25	25
Total duration of estimated active pasture growth (i.e. average annual number of weeks with available water exceeding 2·50 in.)	20	19	19

TABLE 5

PROBABILITY OF USEFUL PASTURE GROWTH COMMENCING AND CEASING BY A SPECIFIED DATE*

	Commencing Date									Probability = 1·00 by
	Oct. 19	Oct. 26	Nov. 2	Nov. 9	Nov. 16	Nov. 23	Nov. 30	Dec. 7	Dec. 14	
Darwin	0·155	0·239	0·253	0·521	0·662	0·718	0·831	0·859	0·901	Dec. 28
Adelaide River	0·077	0·154	0·192	0·423	0·615	0·731	0·801	0·846	0·961	Dec. 21
Oenpelli	0·051	0·051	0·077	0·256	0·436	0·564	0·692	0·872	0·897	Jan. 18
	Ceasing Date									**Probability = 1·00 by**
	Apr. 26	May 3	May 10	May 17	May 24	June 1	June 8	June 15	June 22	
Darwin	0·042	0·084	0·225	0·408	0·718	0·831	0·887	0·929	0·958	July 12
Adelaide River	0·231	0·346	0·654	0·731	0·770	0·885	0·923	0·961	0·961	June 29
Oenpelli	0·025	0·128	0·359	0·667	0·923	0·974	0·974	0·974	1·00	June 22

* Date is middle date of week for which probability is calculated.

The tentative simple working model assumes that actual evapotranspiration (ET) is related to evaporation from a standard tank evaporimeter (E) by the relationship $ET = 0 \cdot 8E$ for those weeks with storage plus rainfall exceeding 2·50 in., and by $ET = 0 \cdot 4E$ when it is below this. The model is a more generalized version of that used by Slatyer (1960) for crops, and is based upon the principle that evapotranspiration decreases as available water is reduced. The model may tend to underestimate the evapotranspiration when the upper parts of an otherwise dry soil profile are wetted by rains of less than 2·5 in., and overestimate it during weeks without rainfall when stored soil water in the upper profile is nearing depletion. However, the effect of this is not likely to be of great significance for purposes of general assessment over a number of years. A maximum storage of 4·00 in. has been assumed. These relationships have been used elsewhere (Fitzpatrick and Arnold 1964; Slatyer 1964; Fitzpatrick 1965) for interpreting weekly rainfall data in northern Australia in relation to pasture growth. The data used in the model have been processed by computer.

The results of these analyses are shown in Tables 4 and 5. Table 4 indicates the characteristics of the period of pasture growth and gives an approximation of the total period during which some *useful* growth might be expected. The more restricted duration with available water exceeding 2·50 in. is taken to represent the period over which more *active* growth conditions prevail. Table 5 indicates the probability of useful pasture growth commencing or ceasing at certain stated periods.

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PART V. GEOLOGY OF THE ADELAIDE–ALLIGATOR AREA

By M. A. J. WILLIAMS*

I. PREVIOUS WORK

Tenison Woods (1864) first described the laterite profiles characteristic of much of the Katherine–Darwin area, and later (1886) described the Mullaman Beds. In 1895, Brown recognized marine shales of Mesozoic age at Charles Point, and he subsequently concluded that the Mullaman Beds were at least in part of Lower Cretaceous age (Brown 1895, 1908).

The general stratigraphy of the area was tentatively outlined by Woolnough (1912). A series of detailed memoirs, relating chiefly to mineral-bearing rocks, appeared between 1935 and 1940. These embody the work of the Aerial, Geological, and Geophysical Survey of Northern Australia, and have been summarized by Hossfeld (1954).

In 1946, Noakes (1949) mapped the Katherine–Darwin area at reconnaissance level, and more detailed recent mapping by the Bureau of Mineral Resources has been described by Malone (1962*a*, 1962*b*), Walpole (1962), and Dunn (1962). In the following account, references to structure and lithology are based chiefly on their work, supplemented by field observations carried out during the survey.

II. TECTONIC SETTING

The Pine Creek Geosyncline forms the dominant regional structure in the survey area (Fig. 5). It consists of a central trough containing sediments which attain a maximum thickness of 13,000 ft near Hayes Creek. The South Alligator trough was a secondary tectonic depression associated with the Pine Creek Geosyncline. The eastern boundary of this trough coincides roughly with the present course of the East Alligator River, for quartz mica schists of probable Archaean age were noted in the Magela Creek area (Dunn 1962) and some 15 miles west of that stream during the survey.

The geosyncline extends beyond the survey area in the west and south. The Rum Jungle granitic inlier represents an exposed portion of the ancient Archaean Basement which underlies the geosynclinal deposits (Rhodes 1965).

The geosynclinal sediments have been strongly folded along north and north-westerly axes. Isoclinal folding and associated reverse folding are common, and in general the sediments have undergone very low-grade regional metamorphism. Locally, the folds have been directed around Archaean massifs (as at Rum Jungle), and here intense faulting and dynamic metamorphism are pronounced.

Regional structures (Fig. 6) trend north and north-west in the south and west,

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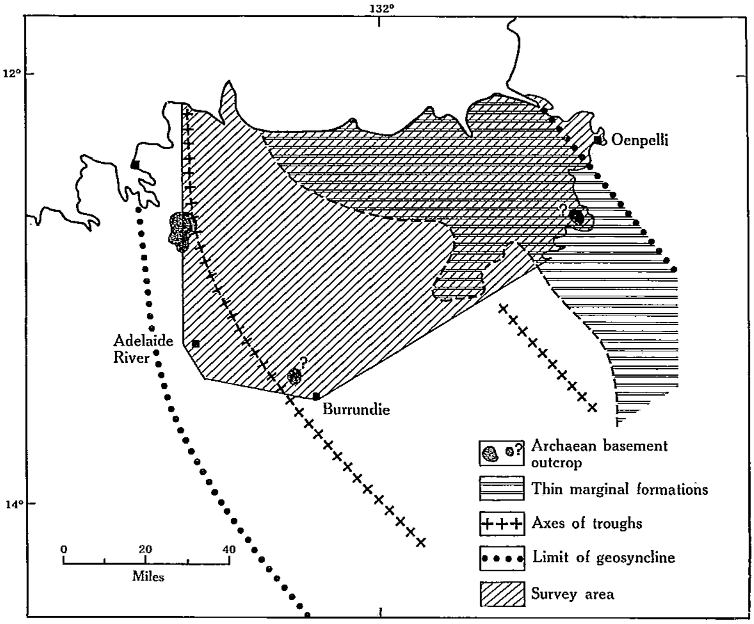

Fig. 5.—Pine Creek Geosyncline (after Walpole 1962).

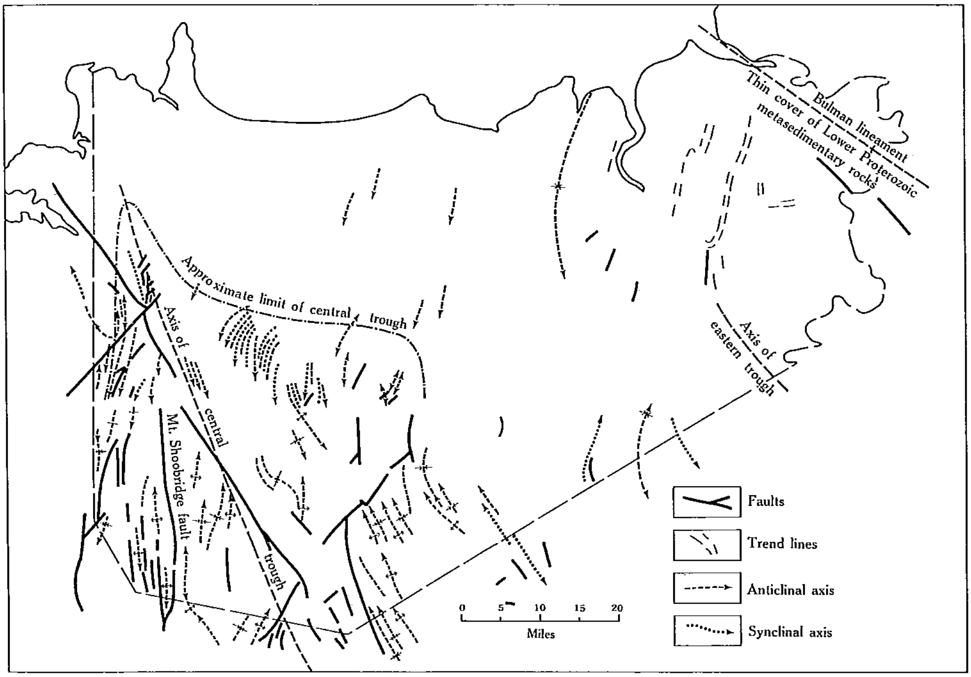

Fig. 6.—Simplified structural map of the Adelaide–Alligator area adapted from Malone (1962*a*, *b*), Dunn (1962), and Walpole (1962).

and north-east in the north and east, and are reflected in a discontinuous series of strike ridges that rarely rise more than 200 ft above the surrounding plains.

Subhorizontally bedded sandstones of Upper Proterozoic age unconformably overlie the folded Lower Proterozoic formations originally laid down in the Pine Creek Geosyncline. They crop out along the eastern and south-eastern boundaries of the survey area, and form the Buldiva plateau. There is no evidence to suggest that the Upper Proterozoic rocks have undergone any major post-depositional warping. A series of faults trending north-west and west partly controls the plateau configuration, but more important are the vertical joints, probably in part caused by tension (Dunn 1962) associated with faulting, which strike north-east, north-west, north, and north-north-east.

Elsewhere in the survey area, two main generations of faults are recognizable: on the one hand, major tear faults and associated minor shear faults of late Lower Proterozoic age (Giants Reef fault, Mt. Shoobridge fault); on the other hand, block faults of post-Upper Proterozoic age (Mt. Douglas boundary fault).

The Giants Reef fault runs from south-west to north-east and has a horizontal displacement of 3 miles. Manton River follows the fault line in its lower course, and the breaching of Acacia Gap may have been due to the superimposition of a fault-guided proto-Manton across otherwise highly resistant quartz sandstones lying transverse to the line of drainage.

Mt. Shoobridge fault runs from south to north, and for 15 miles controls the course of Howley Creek and Bridge Creek; further north the Adelaide River follows the fault line for 4 miles. The McKinlay runs directly along a fault line for some 20 miles, and there are many minor fault-controlled stream patterns.

North of the Wildman, a series of minor tear faults runs at 45° to the fold axes, and interrupts the continuity of the strike ridges.

Mt. Douglas is down-faulted into Lower Proterozoic formations. Its bounding scarps are partly fault-controlled and partly erosional.

Figure 6 shows the major faults in the survey area. The structural influence exerted by folds is discussed in Section IV.

III. Geological History

As rocks older than Lower Proterozoic are very rare in the survey area, this account will begin with the deposition of Lower Proterozoic sediments onto the Archaean basement rocks. The general stratigraphy of the area is summarized in Table 6.

(*a*) *Deposition of Lower Proterozoic Sediments*

A considerable thickness of alternating clastic and dolomitic sediments was laid down in the extensive crustal depression termed the Pine Creek Geosyncline. Conglomerates, greywacke, and basal arkose of the Batchelor Group rest unconformably on Archaean rocks at Batchelor, and may represent the earliest Lower Proterozoic sedimentation in the area. Subsequent deposits including dolomites and pyritic carbonaceous shales from the north-east and later from the west were in turn overlain by extensive shallow-water sediments.

(*b*) *Lower Proterozoic Diastrophism*

Intense folding and shearing of sediments took place in late Lower Proterozoic times, and hitherto unaltered sediments were locally converted to phyllites and schists by dynamic metamorphism. Over much of the area, however, the sediments have undergone only a slight change due to low-grade regional metamorphism.

The zone of maximum folding and faulting was in the Pine Creek area, to the north and east of which the fold structures broaden out to form a series of elongated tectonic domes and basins.

(*c*) *Intrusion of Lower Proterozoic Granites*

This phase of diastrophism was succeeded by a period of large-scale intrusions of granitic rocks. Evidence from potassium–argon and rubidium–strontium dating suggests that the intrusions took place between 1500 million and 1700 million years ago (Malone 1962*b*). Some of the intrusions are markedly discordant to earlier structural trends, although others have merely caused localized doming of the adjacent metamorphic rocks. The quartz sandstones, siltstones, and conglomerates of the Mt. Partridge formation have been deflected from their original SSE.–NNW. trend through almost 90° by the intrusion of the adamellites and biotite hornblende granites of Mt. Bundey, situated between the Margaret and Mary Rivers.

In several areas, regionally metamorphosed sediments can be traced into the hornfelsed aureole adjacent to the granite intrusions (Hossfeld 1954). This seems to imply that the emplacement of the granite and consequent formation of the aureole took place after the close of the regional and dynamic metamorphism in that locality.

Not all the granites in and near the survey area were intruded at this time, however. Some form part of the original Archaean complex, others are Archaean granites remobilized probably in Lower Proterozoic times with no great change in their original position.

(*d*) *Uplift and Erosion of the Lower Proterozoic Formations*

The unconformable contact between Lower and Upper Proterozoic rocks indicates that considerable uplift and erosion took place prior to the Upper Proterozoic transgressions. Strong dissection resulted in an irregularly dissected surface upon which were scattered many broad depressions. These became basins of deposition during the Upper Proterozoic transgression.

(*e*) *Upper Proterozoic Transgression*

Shallow-water arenaceous sediments were laid down during the marine transgression resulting from subsidence of the Lower Proterozoic landscape. The locus of sedimentation appears to have moved slightly to the west in Upper Proterozoic times, and gradual downwarping to the west and south-east took place towards the end of this era and continued into Lower Cambrian times (Hossfeld 1954).

Except where local tilting or faulting has occurred, the Upper Proterozoic quartzites, sandstones, and conglomerates are disposed in horizontal or near-horizontal strata, and there is no evidence of any Upper Proterozoic folding or major tectonic warping.

TABLE 6

STRATIGRAPHIC COLUMN IN THE ADELAIDE–ALLIGATOR AREA

Age	Rock Unit	Lithology	Maximum Thickness (ft)	Structure
Quaternary	Superficial deposits	Alluvial sands, silts and clays; estuarine and marine clays and muds; coastal beach sands; colluvial gravels and stony loams; river and sheet laterites; organic swamp soils	?50	Unconsolidated and undeformed
Tertiary	Superficial deposits	Pisolitic, vesicular, or detrital laterite with associated sandy or gravelly derivatives	?100	Unconsolidated, with minor faulting and warping
Lower Cretaceous	Mullaman Beds	Undifferentiated freshwater and marine sandstone, siltstone, and conglomerate	200	Horizontal with minor intraformational folds
		Unconformity		
Upper Proterozoic	Kombolgie Formation	Coarse- to medium-grained sandstone and quartz greywacke. Pebble conglomerate. Interbedded volcanics and tuffaceous sediments	1500	Very gentle dips. Down-faulted outlier at Mt. Douglas
	Buldiva Sandstone, Depot Creek member	Pink, ripple-marked, cross-bedded quartz sandstone	1000	Gentle dips, steepening next to faults
		Unconformity		
Lower Proterozoic (Agicondian system)	Burnside Granite	Muscovite–biotite adamellite (Brocks Creek area)	—	—
	Cullen Granite	Composite batholith, ranging from adamellite to granite, with syenite differentiates (Mt. George)	—	—
	Margaret Granite	Biotite adamellite (Margaret River headwaters)	—	—

	Prices Springs Granite	Biotite–hornblende granite (Grove Hill area)	—	—
	Nanambu Granite	Garnetiferous and gneissic granite (minor outcrops between South and East Alligator Rivers)	—	—
	Mount Bundey Granite	Biotite–hornblende granite, adamellite	—	—
	Goyder Syenite	Quartz syenite and syenite	—	—
	Burrell Creek Formation	Siltstone, greywacke siltstone, greywacke	8000	Steeply dipping and tightly folded; minor faults
	Noltenius Formation	Quartz greywacke, greywacke, quartz pebble conglomerate, siltstone	8000	
	Golden Dyke Formation	Quartz siltstone and pyritic carbonaceous siltstone, in places slumped and brecciated, containing angular chert lenses and nodules. Locally capped by gossans; thin-bedded siltstone, dolomite, massive-bedded and nodular chert, silicified dolomitic slump breccia	9000	Steeply dipping and tightly folded; minor faults
	Koolpin Formation	Silicified dolomite, silicified dolomitic breccia, pyritic carbonaceous siltstone, and chert nodules, bands, and lenses; pyritic siltstone	5000	Steeply dipping and tightly folded; minor faults
	Acacia Gap Tongue Masson Formation	Quartz greywacke and quartz sandstone, pyritic and silicified in places. Silicified and pyritic carbonaceous siltstone	3000	Steeply dipping and tightly folded; minor faults
	Mount Partridge Formation	Quartz sandstone, siltstone, and pebble conglomerate; arkose, quartz greywacke, silicified dolomite. Local gossanous cappings	10,000	Steeply dipping and tightly folded; minor faults
Archaean	Rum Jungle Granite	Granite complex	—	—

(*f*) *Palaeozoic Planations*

South-west of Burrundie and somewhat outside the survey area, minor outcrops of Lower Cambrian age rest unconformably on Upper Proterozoic rocks, and are in turn unconformably overlain by rocks of Middle Cambrian age (Malone 1962*b*). Further erosion preceded the Mesozoic transgression, giving rise to the sub-Cretaceous surface. In all, at least three phases of denudation took place between Upper Proterozoic and Mesozoic times, probably as a result of gentle upwarping. No major orogeny has occurred since the Proterozoic Era (Noakes 1949), and the resulting prolonged erosion of a comparatively stable surface brought about the formation of a landscape of low relief cut across dominantly Precambrian rocks.

(*g*) *Mesozoic Transgression*

Downwarping of the gently undulating surface in late Jurassic–early Cretaceous times resulted in a series of basins which were initially lake-filled. Freshwater sandstones and conglomerates form the base of the Mesozoic series, and in the lower part of the sequence there are fossil freshwater plants which are either late Upper Jurassic or early Lower Cretaceous in age (Malone 1962*a*), indicating that the overlying strata are probably of Lower Cretaceous age. With the transgression of the Cretaceous sea the lacustrine deposits were buried beneath marine sediments. These and the underlying Mesozoic deposits were later compacted to form the horizontally bedded conglomerates, sandstones, and shales known as the Mullaman Beds.

(*h*) *Deep Weathering and Uplift of the Lower Cretaceous Sediments*

As the Cretaceous sea withdrew, the Mullaman Beds were planed down to form a very gently undulating surface. This even surface cuts across the present-day subhorizontally dipping Mesozoic strata at a very gentle angle, suggesting that little or no youthful dissection of the Mesozoic formations occurred. During this interval of tectonic stability and proximity to sea level, deep weathering of the sandstones and shales took place, and this is now reflected in the lateritic profiles that characterize the Mullaman Beds along the south-western border of the survey area.

The Miocene orogeny only caused gentle warping and rare faulting in and immediately around the survey area, and was associated with prolonged and gradual uplift of the land surface. The ensuing dissection of the uplifted and deeply weathered Mullaman Beds is discussed in Section IV of Part VI.

IV. General Geology

The survey area may be divided into six broad geologic regions, each characterized by a distinctive structure and lithology. The regions are broadly equivalent to the six geomorphic regions discussed in Part VI. The percentage area occupied by each region is shown in parenthesis in the headings.

(*a*) *Pine Creek Geosyncline* (18%)

In this area, regional structural trends control the disposition of the north–south-aligned strike ridges of erosional origin.

In the Wildman–West Alligator River area, rocks of the Mt. Partridge Formation (Table 6) have been warped beneath the South Alligator Trough to form a synclinorium in which steep folds and occasional overfolds have given rise to relatively high narrow strike ridges, with dips between 50° and 80° (Mt. Cahill, Mt. Basedow).

(*b*) *Granite Complexes* (2%)

These have considerable economic importance in the area, since all major metalliferous mineralization took place along or near the margin of granitic masses.

Variation in the age and stratigraphic position of the granites may have considerable economic significance. The Margaret Granites are marked by discordance to prior structures and make abrupt contact with older ore-carrying beds, while the concordant dome of Cullen Granite near Brocks Creek may once have been capped by mineral-bearing strata, but has since been too deeply eroded for the preservation of other than marginal and often superficial ore bodies (Sullivan and Iten 1952).

Depending on the age and erosional history of the intrusions, they may form rugged hills, as at Mt. Bundey, or low undulating to rolling lowlands, as at Brocks Creek. The contact aureoles are in general narrow.

(*c*) *Buldiva Plateau* (<1%)

Forming the south-eastern and eastern boundaries of the survey area is a series of steep cliffs, often up to 600 ft high, and rising in places to 800 ft above the plain. These form the north-western boundary of the Arnhem Land plateau, and are on erosional scarps formed by back-wearing of massive horizontally bedded arenites and rudites of Upper Proterozoic age. Occasional mesa-like erosional outliers lie to the north and west of the plateau, as at Cannon Hill, and Mt. Douglas near the Mary River is a major down-faulted outlier.

Dips range from 0° to 10°, and only on outliers are dips up to 30° recorded, rising to 50° near faults.

Selective joint-guided vertical erosion, allied to the resistance of the massive quartzites to chemical weathering, is responsible for the preservation of the steep plateau scarp.

(*d*) *Koolpinyah Surface* (47%)

Late Tertiary sediments and their more recent derivatives extend from the Lower Proterozoic foothills in the south to the coastal plains which overlie them in the north and form the Koolpinyah surface. They consist of clays, silts, sands, and gravels, derived from Cretaceous, Upper Proterozoic, and Lower Proterozoic formations, which have undergone a number of minor phases of deep weathering, erosion, re-sorting, and partial relateritization.

Certain areas mapped as Lower Cretaceous Mullaman Beds on the 1:250,000 Darwin geological sheet consist of reworked sandy, gravelly, or lateritic deposits. They have been tentatively reinterpreted as Late Tertiary sediments.

Evidence from boreholes drilled by the Water Resources Branch, N.T.A., indicates that the total thickness of the Late Tertiary sediments rarely exceeds 100 ft and is often less. In the north-west of the area up to 30 ft of reworked Late Tertiary ironstone gravels and ferruginous rubble overlies deeply weathered Lower Cretaceous rock which appears to represent the truncated pallid zone of a former standard lateritic profile (Whitehouse 1940). Elsewhere, bevelled and in places deeply weathered Lower Proterozoic rocks have been buried beneath a layer of Late Tertiary sediments which were later lateritized.

In the absence of fossil evidence to the contrary, the term Late Tertiary is used here to describe any ferruginous rubble or unconsolidated sediments post-dating the Lower Cretaceous Mullaman Beds and known to be older than the Quaternary alluvia lining the major river valleys. Deposits eroded from these sediments and reincorporated into them in post-Tertiary times are thus included in this category, which is descriptive rather than chronologically exact. Throughout this and the ensuing chapters, it is important to bear in mind the implications of this definition.

Kay, Keating, and Keefers Hut land systems are, respectively, unmodified, slightly dissected, and strongly dissected portions of the Koolpinyah surface.

Scattered at intervals on the Koolpinyah surface is a series of extensive sand plains, sometimes level (Queue land system), sometimes eroded (Knifehandle land system). These occur both above and below the adjoining Kay land system and its derivatives.

In addition, since both Queue and Kay land systems have nearly identical photo-patterns, and since it was not possible to visit and sample each occurrence of that pattern, in certain areas there is still doubt as to whether a given locality is in fact Kay or Queue land system. Hence, some areas have been tentatively ascribed to a particular land system on the basis of their geographical association with known areas nearby.

Due to these difficulties of interpretation, and for greater clarity and convenience, Queue, Knifehandle, and sandy elements of Krokane land systems have been considered as belonging to the Koolpinyah surface (see geomorphology map, and Part VI). This is not to deny that these land systems may sometimes coincide with the sandy products of Pleistocene erosion, and so could, in such cases, equally logically be grouped under the general heading of Quaternary Alluvial Plains.

Since laterites and lateritic debris are major constituents of the regolith on the Koolpinyah surface, the different types of laterite recognized are described below.

(i) *Laterite Fabric*.—The origin and distribution of laterites are discussed in Part VI. The following is an attempt to define certain morphological types of laterite. No occurrence of bauxite is known in the survey area, so that the laterites consist of residual and reworked highly weathered sands and clays rich in secondary iron oxides. In addition, they are poor in humus, depleted of bases and combined silica, sometimes with small amounts of weatherable primary minerals, silicate clays, or quartz, and are either hard or harden on exposure. The hardening may be seasonal or comparatively permanent and, if caused by erosion or deforestation, may for all practical purposes be regarded as "irreversible".

The standard lateritic profile described by Whitehouse (1940) was nowhere observed in the survey area. Profiles were either truncated remnants of the standard profile, or else in a state of arrested development.

Six classes of laterite characterized by a distinctive fabric are recognized in the survey area; intergrades also occur, and the laterite of one class may contain inclusions of other classes. In order of abundance, the laterites are detrital, concretionary, pisolitic, mottled, gossanous, and vesicular.

(ii) *Detrital Laterite*.—This is any laterite formed mainly from any type of reworked material cemented together in a ferruginous matrix to form irregular sheets or blocks. It forms foot-slope benches, conglomeratic river laterites, or stratified sheets of ferruginous lateritic rubble, and occurs most commonly as relict blocks up to 3 ft in diameter. The blocks may contain fragments of quartz, highly weathered sandstone, mottled-zone material, and angular ironstone nodules. Hill-foot benches of detrital laterite are common on slopes between 1 and 8%, and rare outcrops occur on slopes between 12 and 16%.

(iii) *Concretionary Laterite*.—This is any laterite of directly pedogenetic origin, and may include pisolitic ironstone concretions on and within solonetzic domes, ferruginous mottles in ill-drained alluvial soils, and ironstone nodules occurring *in situ* in the soil profile. Concretionary laterite is characteristic of the alluvial Effington, Fabian, Flatwood, McKinlay, and Queue land systems, and of the alluvial land units within other land systems, in particular Rumwaggon and Keating. It is forming actively on flood-plains with slopes between 0·5 and 2%, and rare instances were noted on 3% slopes near perennial billabongs.

(iv) *Pisolitic Laterite*.—This consists dominantly of cemented ironstone pisoliths, between ¼ cm and 1 cm in diameter, spherical to subrounded, and often case-hardened or varnished. It may contain minor inclusions of fine quartz, angular ferruginous flakes, or rolled ironstone nodules of secondary origin. Bare localized pavements of pisolitic laterite crop out on slopes between 0·4 and 2% on Keating and Keefers Hut land systems, and isolated blocks occur on hill slopes up to 4% and, more rarely, up to 9% on Baker, Bend, and Rumwaggon land systems.

(v) *Mottled-zone Laterite*.—This is the middle portion of the standard lateritic profile, and consists of massive deeply weathered bed-rock that grades upwards into a ferruginous zone of pisolitic or vesicular laterite and downwards into a pallid zone of non-ferruginous highly kaolinized rock. In the north-west of the survey area and in parts of the centre and east, erosion of the fully developed or standard lateritic profile has resulted in removal of the original ferruginous zone and partial truncation of the mottled zone. Colluvial–alluvial mantles of ironstone gravels were subsequently laid down over the irregularly dissected mottled zone which now crops out in valley sides, gullies, billabongs, and sea cliffs.

The upper, vesicular portion of the mottled zone is yellow, yellow-brown, brownish red, red, and orange; the lower, massive portion is pink, yellow, pale purple, and white, becoming whiter with depth. Red and purple ferruginous nodules may occupy 10% of the lower portion of the mottled zone and appear to have formed *in situ*.

The cliffs at Cape Hotham and Fright Point appear to consist only of the upper few feet of mottled zone overlying a pallid zone of unknown depth. Sands, shingle, beach rock, tidal muds, or bedded vesicular laterite fringe the cliff base and the underlying platform of marine abrasion is cut into the pallid zone.

In this report, the term mottled zone denotes both true mottled-zone material and fragments of pallid-zone material that have been secondarily iron stained. There are two reasons for this: the transition from mottled to pallid zone is very gradual; and leached pallid portions of deeply weathered rock occur within the main mottled zone just as mottled rock occurs in the true pallid layer. Isolated fragments resembling mottled- or pallid-zone material cannot be assigned to either zone on the grounds of their appearance alone, unless there is additional evidence of their origin.

(vi) *Gossanous Laterite*.—This occurs as a capping of massive haematitic, limonitic, or goethitic rock over pyritic carbonaceous and dolomitic siltstones and greywacke of the Koolpin, Golden Dyke, and Masson Formations (Sullivan and Iten 1952). Fragments of silicified siltstone and nodular chert are common within the gossan. Ferruginized quartz veins and contorted or banded pyritic siltstone may crop out on the surface. Gossans over 60 yd wide and 400 yd long are rare. They crop out on hill tops and hill slopes in Bend and Baker land systems, and always occur *in situ*.

(vii) *Vesicular Laterite*.—This is brown or purple-black, brittle, slag-like laterite, often with a thin secondary coating of ferruginous nodules and pisoliths. It is found in a variety of situations, often as remnant blocks up to 3 ft in diameter, and generally in localities where laterite is not now forming.

In Baker land system, residual vesicular laterite occurs very occasionally on the summits of truncated ridges of steeply inclined quartzose bed-rock. Massive vesicular blocks are sometimes scattered along 5% colluvial foot slopes in the Bend land system. In Knifehandle and Keefers Hut land systems, bare pavements of vesicular laterite crop out on 0·5–1% slopes, and are sometimes coated with rounded ironstone nodules made up of cemented pisoliths. In these situations, the vesicular laterite occurs as bedded sheet laterite with secondary surficial additions. Within 50 yd of certain perennial billabongs in Queue land system, soft red vesicular blocks crop out near shallow gullies and grade into pisolitic laterite.

(*e*) *Quaternary Alluvial Plains* (12%)

Two types of alluvium are distinguished. On the one hand, coarse or fine flood-plain alluvium laid down at various stages during the Quaternary by still active rivers is confined to the major river valleys; on the other hand, coarse sandy Late Tertiary and Quaternary alluvium deposited by since-vanished streams is restricted to broad depressions and sand plains on the Koolpinyah surface. Discussion of these older deposits (Queue, Knifehandle, and some of Krokane land systems) is deferred until Part VI.

Of the alluvium laid down by still active rivers, that on flood-plains and aggradational river terraces east of the Jim Jim–South Alligator drainage system is dominantly sandy, having derived from the breakdown of the arenaceous Kombolgie Sandstone Formation, of which the Buldiva plateau is largely composed. Similar material near

Nourlangie, Baroalba, and Magela Creeks appears to be related but older, for it flanks the younger alluvial terraces below it and follows roughly the same course.

To the west of the South Alligator River, Quaternary fluvial deposits consist of silts, clays, and loams. Both the Mary and the Adelaide are flanked by two sets of wide alluvial terraces. Coarse river gravels and cobbles crop out locally on the higher terrace of the Mary.

Up to 30 ft of stratified fine sands, silts, and loams are exposed in the channels of the Mary, Adelaide, McKinlay, South Alligator, and East Alligator Rivers. Rock-bars crop out only locally in the river beds, indicating a depth of alluvium in excess of 30 ft near the rivers. The alluvium probably thins out away from the main channels. Coastwards the alluvium grades into or passes beneath the coastal plains clays.

(*f*) *Quaternary Estuarine and Littoral Plains* (21 %)

The precise age, thickness, and stratigraphy of the coastal plains sediments remain obscure, but from their position between north-striking Lower Proterozoic ridges and headlands and from their low elevation and flatness, they appear to represent the infilled estuaries of north-flowing rivers drowned by the last Pleistocene rise in sea level of 200 ft or so (Noakes 1949). Gastropods of *Turritella* spp. were found below 3 ft in a number of localities, while more local occurrences of buried mangroves and of buried crayfish shells have also been recorded, confirming the probable estuarine origin of these plains. Southwards and inland the coastal plains clays overlie sandy wash at the foot of the Tertiary surface. Extensive fluvial aggradation and several changes in the courses of main rivers accompanied the rise in general base level, and are discussed in Section III of Part VI.

In the east, a series of low dunes occurs in places on the clay plain between the main rivers and extends up to a mile inland. They run parallel to the present shore line, and appear to represent the approximate position of former coastlines. Present-day littoral deposits are tidal muds, and sands are localized around headlands. By analogy with the present situation, it seems likely that these dunes were longshore drift deposits carried from the East Alligator region by easterly currents.

The six regions described above occupy 94 % of the survey area. Rivers and their wide tidal outlets occupy the remainder of the area.

V. Geology and the Land Systems

Although in three-quarters of the survey area Late Tertiary and Quaternary sediments form a more or less thick mantle that effectively blankets the underlying geological structures, certain direct and indirect structural controls may still be recognized.

(*a*) *Direct Structural Controls*

The general north–south alignment of strike ridges and vales in Baker and Rumwaggon land systems is a reflection of Lower Proterozoic structural trends (Figs. 6 and 7). Strong structural control over topography is exerted by the Kombolgie Sandstones in Buldiva land system. The plateau form is due to the horizontal bedding, while the height and steepness of the scarp are a function of the resistance to weathering of the quartzites and quartz-conglomerates, and of joint control over run-off. A broadly spaced joint pattern and occasional minor faults have meant rapid vertical erosion but little back-wearing or widening of youthful ravines. The crenellated plateau outline results from irregular scarp retreat by sporadic under-cutting and collapse.

In their southern, or foothill, reaches, the Adelaide–Margaret and Mary–McKinlay river systems are in close accordance with the regional structural trend from south-south-east to north-north-west (Part VI and Fig. 6). Once the trunk streams leave the dissected foothills, structural control weakens and the rivers follow a sinuous course as extended consequents superimposed onto and across the emergent coastal plains.

(*b*) *Indirect Structural Controls*

The closeness of the joint pattern, the presence of faults or zones of intense shearing, and the disposition of feldspathic strata in dominantly quartzose formations will influence the depth to which intense chemical weathering can penetrate, and so will indirectly control topographic evolution during a later period of erosion. Structures least prone to deep weathering will persist as hills, zones of weakness in which deep-seated weathering occurred will undergo preferential stripping.

Concealed structures will be resurrected in areas where the original cover formations were thin, as in Bend and Rumwaggon land systems, or where the deep-weathering profile has been strongly dissected, as in Keefers Hut and Jay land systems.

Kysto land system occurs where the weathered zone has been almost entirely stripped off, so that the structures underlying the basal weathering front are just perceptible.

(*c*) *The Influence of Lithology*

(i) *Granite.*—Fresh granites coincide with the steep, rugged, boulder-strewn hills of Currency land system, while the deeply weathered granites of Cully land system form an isolated portion of the undulating Koolpinyah surface. Drainage deflection is common around the intrusions and their aureoles. For instance, a headwater tributary of the Mary originates south-west of the Mt. Bundey granite massif, and flows west, north, and finally east in almost a full circle around the intrusion. The headstream of the Margaret boxes the compass in similar fashion around the Margaret intrusion, flowing east, north, west, and finally north-west towards the Adelaide River.

(ii) *Metasediments.*—Owing to the complex variations in rock type and relief within a small area, it was not possible to recognize simple land systems characterized by one or a few definite lithologies in regions of Lower Proterozoic metasediments. Baker, Bend, and Rumwaggon land systems were selected on the basis of relief and the areal extent of alluvium between hills, but within each system, certain units of more or less homogeneous lithology could be recognized.

Siltstones give rise to narrow sharp-crested ridges or low convex knolls, depending on dip and stage of erosion, but often grade into greywacke siltstones or occur in close association with sandstone and greywacke. Three or more rock types typically occur on a single hill.

Sandstones, greywacke sandstones, and greywacke form convex hills or broad strike ridges, often with bevelled summits, and, more rarely, form low erosional remnants within Rumwaggon and Bend land systems.

Arkose, quartzite, silicified dolomite, and quartzose sandstones are associated with steep rugged hills and major strike ridges in the south, and where hills of substantial relief protrude from the Late Tertiary land surface to the north, they are generally formed of quartzitic or silicified metasediments.

Chert hills are sufficiently distinct in shape, regolith, and vegetation to warrant unit status in Baker land system. They are characteristically convex, with steep boulder-strewn slopes and deeply incised youthful valleys.

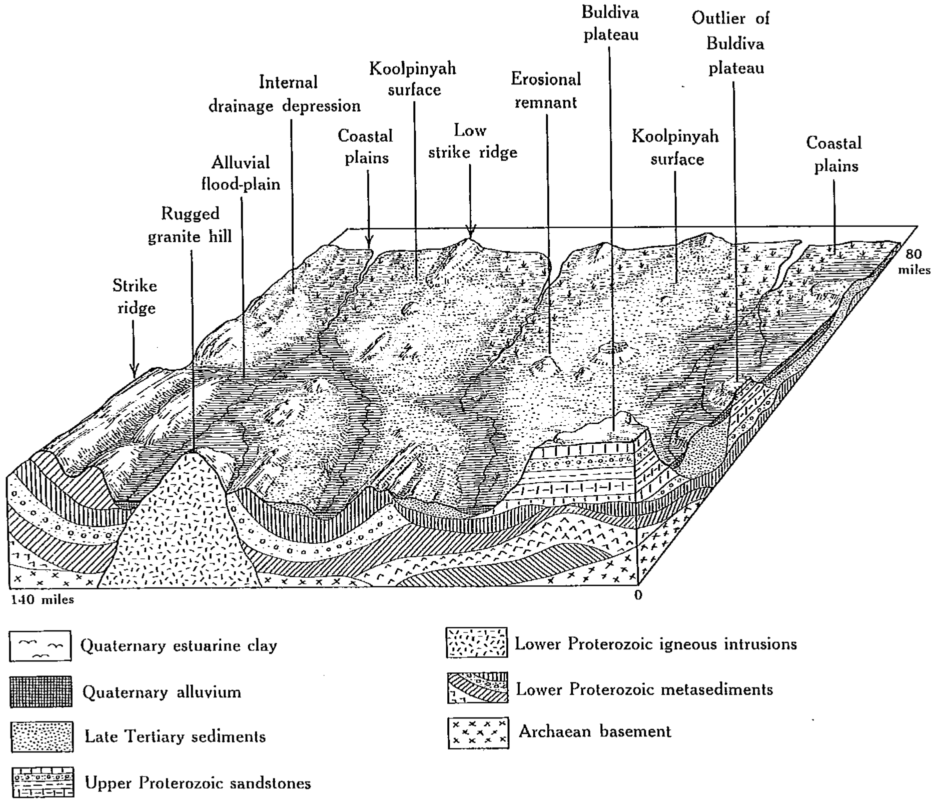

Fig. 7.—Stratigraphy and landscape in the Adelaide–Alligator area.

(*d*) *Geology and the Geomorphology Map*

Since Late Tertiary sediments comprise 40% of the survey area, land systems have been grouped according to whether they occur on, above, or below the Late Tertiary or Koolpinyah surface. Further subdivisions are on the basis of lithology, relief, and drainage. Twelve broad lithological classes have been recognized.

Land systems on the generally unmodified Koolpinyah surface are characterized by ironstone gravels and laterite, those on the dissected Koolpinyah surface by additions of quartz gravels and sands. Those on the Koolpinyah surface which are depositional in origin consist of laterite-derived sands.

Where erosional land systems have been cut above or below the Koolpinyah weathered zone, they have been put into six broad lithological classes: fresh metasediments, slightly weathered metasediments, fresh quartzites and arenites, fresh granites, weathered granites, and an admixture of metasediments and younger alluvium. These six lithological groups correspond closely to six relief types.

Post-Tertiary depositional land systems fall into three broad textural classes —sands, silts, and clays—and are grouped accordingly (Part VI).

The generalized relationship between landscape, lithology, and structure is shown in Figure 7.

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PART VI. GEOMORPHOLOGY OF THE ADELAIDE–ALLIGATOR AREA

By M. A. J. Williams*

I. Regional Description

The area may be divided into six physical regions (Fig. 8) equivalent to the six broad geological units reviewed in Part V. Two of the regions (the granite hills and lowlands and the Buldiva plateau) each occupy less than 2% of the total survey area, but have such distinctive landscapes that they have not been grouped as part of a complex. The Koolpinyah surface, by contrast, occupies almost half the total area, the coastal plains nearly a fifth, and each of the two remaining regions an eighth.

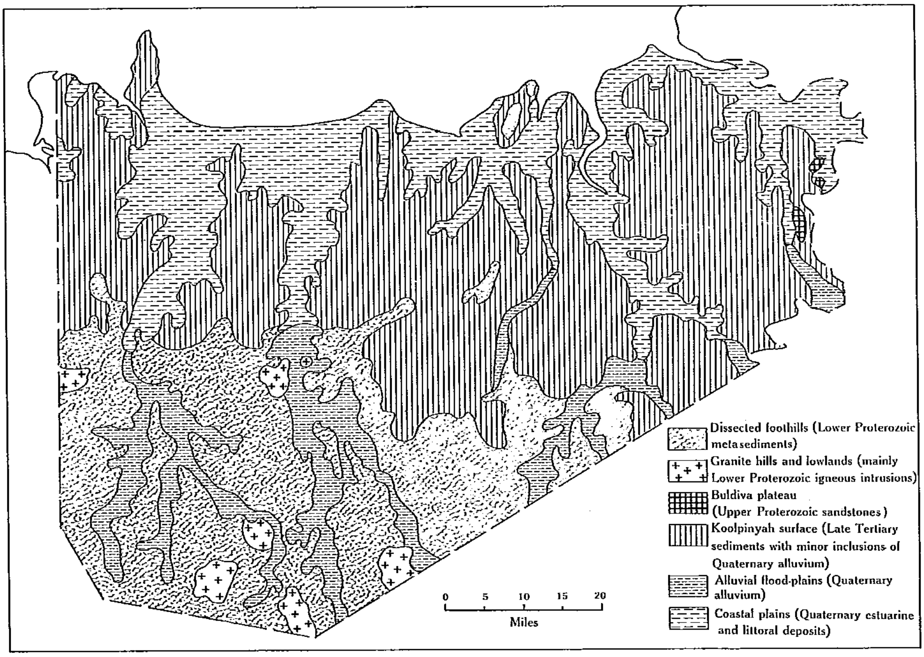

Fig. 8.—Physical regions in the Adelaide–Alligator area.

(a) *The Dissected Foothills*

These are hills formed by erosion of the Bradshaw surface (Wright 1963), and are essentially foothills cut into or below the plateau formed by the intact remnants of that surface.

This region attains its greatest development in the south and west of the survey area, and consists of high rugged strike ridges rising 600–700 ft above sea level and

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200–300 ft above the surrounding plains. Further north, broad tongues of the Koolpinyah surface begin to penetrate the foothills. The hills finally become a series of low ridges rising 50–150 ft above the deep-weathered Koolpinyah sediments and rarely more than 250 ft above sea level. Near the main rivers, isolated hills emerge from extensive level tracts of Quaternary alluvium.

Typically, the hills form a sequence of rocky strike ridges flanked by narrow wash slopes or pediments, and separated from one another by alluvial flats of variable width. Soils are almost invariably skeletal on slopes above 5%, and outcrop is frequent where slopes exceed 14%.

(*b*) *The Buldiva Plateau*

The south-eastern and eastern boundaries of the area consist of steep cliffs rising up to 600 ft above the plains. Minor erosional outliers fringe the main plateau, forming a series of mesas and buttes flanked by basal wash slopes overlain by coarse arenaceous sands. The wash slopes may grade fairly abruptly into finer-textured plains.

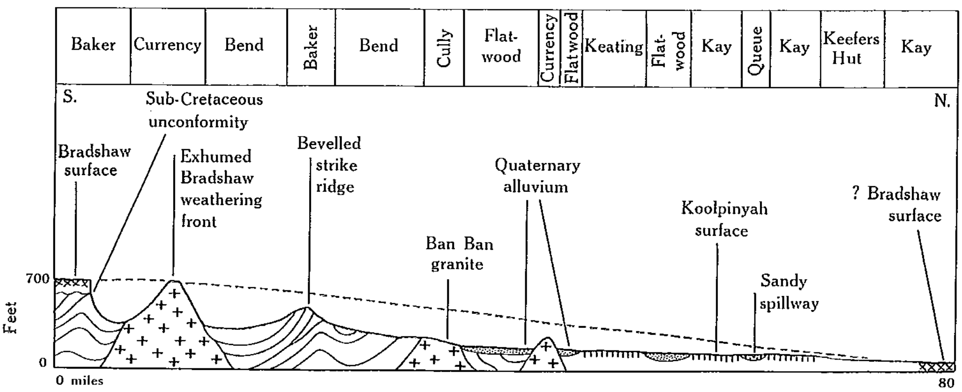

Fig. 9.—Erosional and depositional surfaces in the west of the survey area.

(*c*) *The Granite Hills and Lowlands*

Partial stripping of an irregular weathering profile in the survey area has given rise to two types of granite landscape (Fig. 9). Where the post-Cretaceous Bradshaw deep weathering profile has been entirely stripped away from resistant rock masses, steep, rugged, boulder-strewn hills occur, as at Mt. Bundey or Mt. George. These hills may rise from 150 to 300 ft above the Koolpinyah surface and the Quaternary alluvial plains. Elsewhere, a deep-weathering profile masks the underlying rock structures, and finds expression in a rolling to undulating landscape of deeply weathered slopes with scattered granite tors and corestone masses.

(*d*) *The Koolpinyah Surface*

The dissected foothills are bounded northwards by deeply weathered lowlands developed mainly on sediments of Late Tertiary age. Interrupted only by the major river valleys, these level to rolling plains form a broad belt extending from the Buldiva plateau in the east to the Lower Proterozoic ridges of the west. Ruling gradients are low, rarely exceeding 3 % in the west and centre, although low steep breakaway scarps occur in the more dissected eastern lowlands (Fig. 10). Throughout this report the term "Koolpinyah surface" is used to refer to these lateritic plains developed over Late Tertiary sediments and the underlying planed-off Lower Proterozoic formations.

A puzzling feature of the Koolpinyah surface is the number of enclosed depressions that occur scattered throughout the region. In the west of the survey area, the distribution of some of the larger internal drainage depressions accords with the known subsurface distribution of Lower Proterozoic formations characterized by dolomitic rocks. Recent drilling by the Water Resources Branch, N.T.A., has shown that many of the more extensive depressions on the Tertiary land surface in the Darwin area are underlain by dolomite at depths ranging from 70 to 150 ft. On Palaeozoic rocks in south Wales, Thomas (1958) has described collapsed depressions occurring on formations where the underlying limestone is over 250 ft below the surface. Solution of the dolomite, and consequent collapse of the overlying formations, may also account for some of the depressions in the Adelaide–Alligator area.

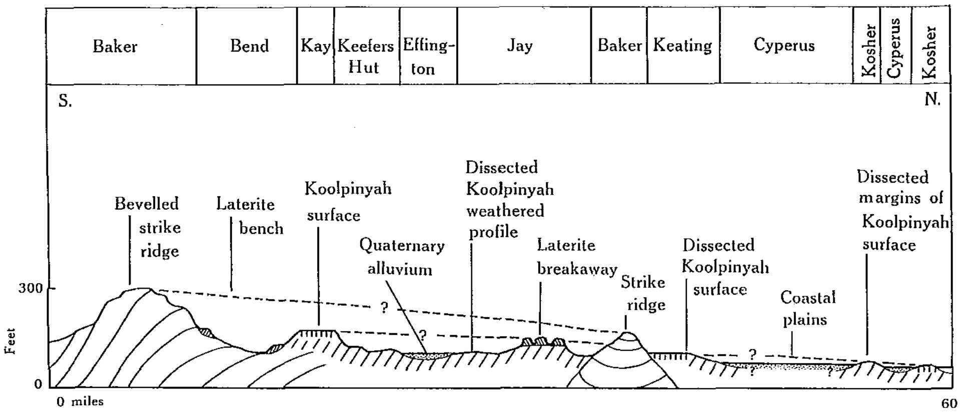

Fig. 10.—Erosional and depositional surfaces in the east of the survey area.

Another possibility is that the depressions originated through differential lowering of the Koolpinyah surface by solution of the underlying deeply weathered rock during the process of lateritization (Trendall 1962). The close association between internal drainage depressions and deep-weathered Tertiary surfaces may be indicative of a genetic relationship, and has been noted elsewhere in Australia (Whitehouse 1940). They occur on the deep-weathered Karoon, Eurunga, Strathpark, and Margulla land systems of the Leichhardt–Gilbert area (Perry *et al.* 1964) and on Junee land system of the Isaac–Comet area (Story *et al.* 1967).

(*e*) *The Alluvial Flood-plains*

In their middle sectors, the Mary, Adelaide, South Alligator, and East Alligator Rivers are incised into mature flood-plains with remarkably level gradients. To the north, these flood-plains grade into the estuarine coastal plains, while to the south they are hemmed in by the hills and ranges of the dissected southern foothills. The Mary plains descend gently from a height of about 150–200 ft above sea level in the foothills region to about 30 ft in the transitional zone between alluvial flood-plain and coastal plain; a fall of roughly 150 ft over 70 miles, or 1 in 2500.

Scattered across the surface of the stable flood-plains in Fabian, Flatwood, and Rumwaggon land systems is a series of low gravelly rises and slightly raised patches of old alluvium. The soils on these rises are often partly lateritized, containing one or more layers of ironstone concretions and ferruginous mottles parallel to the ground surface. These layers may have formed in relation to formerly higher seasonal water-tables, and lowering of the water-table may have taken place *pari passu* with the dissection of the older higher flood-plains. They appear to owe their survival as raised remnants on the lower stable flood-plains to the indurated nature of their associated soils.

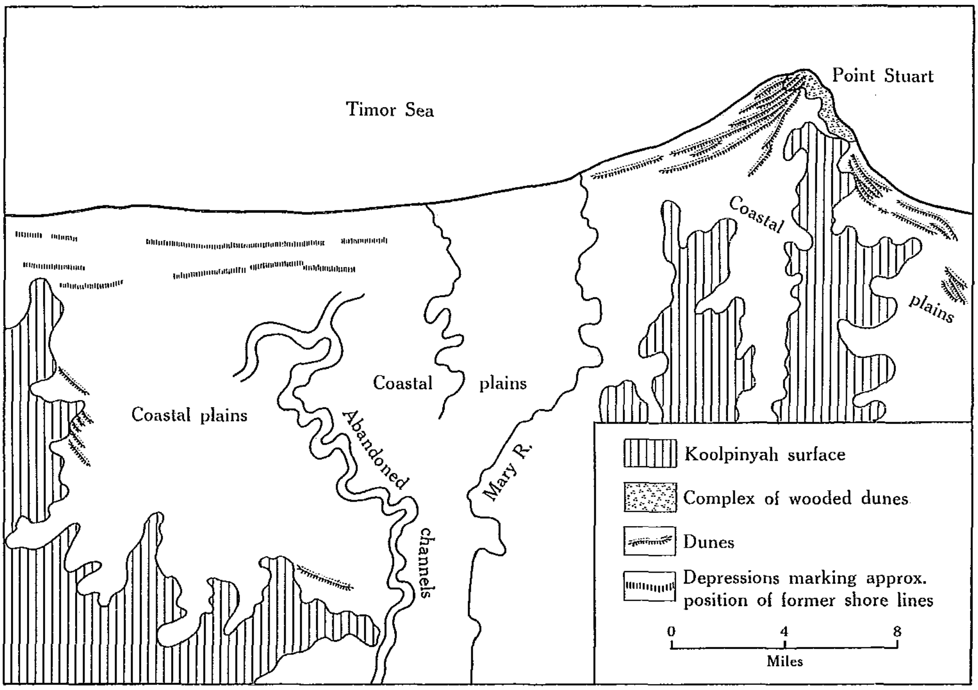

Fig. 11.—Sand dunes in the Point Stuart area.

(*f*) *The Coastal Plains*

Along the coastal margins of the survey area are extensive, very flat, often ill-drained plains, which penetrate far into the Koolpinyah surface along the broader river valleys.

The plains consist mainly of exposed estuarine sediments laid down in drowned river valleys. Littoral clays and muds are also represented, relict dunes occur locally, and buried mangrove layers are known to occur sporadically. Throughout the plains, several feet of freshwater clays have been deposited over the gleyed estuarine or coastal muds and clays, and each year the plains are flooded by fresh water to depths up to 6 ft for up to 6 or 8 months. Certain low-lying portions of the plains form perennial sedge or paperbark swamps, which are particularly common in embayments and depressions next to the Koolpinyah surface.

Dunes extend up to 10 miles inland near the lower reaches of the Mary River. Their height ranges from a few inches to 15 ft, and they never occur above about 50 ft above sea level. They originated as sand-bars and extended south-westwards from the now wooded recurved sand spits at Point Stuart, shifting progressively seawards and northwards (Fig. 11). The oldest of these now discontinuous dunes once extended as a smoothly curved bay-mouth bar from Point Stuart south-west along the foot of the Koolpinyah surface to link up with it once more to the west of the Mary near Alligator Head. Here it changes direction and runs north-west.

The dunes are thus a rough guide to the position of former coastlines. In addition to having resulted from emergence, the dunes in the Point Stuart area may have caused accretion and coastal progradation.

II. Land-forming Processes

(*a*) *Climatic Influence*

The climate is characterized by high average temperatures (Darwin, mean min. temp. May–Sept. 70°F) and by high-intensity seasonal rainfall. If rainfall intensity is computed on the basis of rain per wet day, Darwin has an intensity of 0·60 in., twice as high as the mean for the southern two-thirds of Australia (Christian and Stewart 1953). When intensity is mapped on an Australia-wide basis using the more refined measure of maximum rainfall to be expected per 24 hr storm per year (Jennings 1967), values found in and around the survey area are consistently and strikingly high.

Under these conditions run-off is rapid, and selective removal of the finer soil particles by diffuse wash and sheet floods is responsible for the stony nature of almost all slopes above 5%. On the upper surfaces of the Koolpinyah surface, stony soils may occur on slopes as gentle as 0–1%.

Rain-drop impact and sheet erosion are likewise responsible for the soil surface seals (Arndt 1965) and the scalded appearance of the older flood-plains.

(*b*) *Surface and Subsurface Drainage*

On the steeper slopes and narrow alluvial flats of the dissected foothills streams are markedly seasonal, and during the 7-month dry season only major rivers and occasional spring-fed creeks continue to flow. Despite this, water-tables remain high, particularly on the undissected portions of the Koolpinyah surface, and in the west rarely exceed depths of 20 ft during the dry season. They are probably only 100 ft below the surface on Lower Proterozoic rocks (Dunn 1962). The lower horizons of soils on the coastal plains and on some of the lower flood-plains are perennially waterlogged.

Prolonged water circulation, a seasonally fluctuating water-table, and high temperatures are conducive to intense chemical weathering. This has a dual role: it prepares rock for removal by eluviation and sheet wash through hydration, softening, and weakening of structure; and it plays an active role in lateritization.

(c) *Laterite Genesis*

The gossanous, mottled-zone, and concretionary laterites are *primary* laterites, formed *in situ*. The detrital laterites are secondary laterites, formed by the cementation of colluvial or alluvial deposits, with secondary iron enrichment from seepage. Vesicular and pisolitic laterites are sometimes of primary and sometimes of secondary origin.

Gossans result from the exposure of pyritic rocks to weathering, and always occur at the surface. Mottled-zone laterite (Whitehouse 1940) results from prolonged deep weathering of rock, and is the transitional layer between the surface ferruginous zone of iron enrichment (which may appear as vesicular or pisolitic laterite) and the subsurface pallid zone which is depleted of iron and alumina, and is often highly kaolinized.

Concretionary laterite forms in the soil and develops either sporadically in the B horizon or as a definite intra-solum formation. The ironstone concretions overlying solonetz B horizons follow the contours of the dome surface very closely and are of this type. These are discussed more fully in Part VII.

Pisolitic laterite may occur *in situ* from the induration of a concretionary layer, but is more likely to result from the cementation of concretions eroded from the solum and accumulated elsewhere as colluvial or alluvial gravels. Depending on the original depth of soil and its concretionary content, and on the original topography, the pisoliths may be contaminated with weathered rock and resistant quartz fragments. When more than a third of the laterite visibly consists of extraneous rock fragments or reworked ironstone rubble, it is classed as detrital.

Vesicular laterite forms both by deep weathering *in situ*, with mobilization of iron and the removal of soluble bases resulting in a relative accumulation of sesquioxides, and by the absolute accumulation of iron seepage, particularly near gullies, billabongs, and closed depressions. Many of the bare laterite pavements on Keefers Hut and Knifehandle land systems are due to seepage and the cementation of fine sandy wash, itself often derived from older, higher laterites. In several localities, pavements are forming around billabong margins at the same time as nearby slightly higher outcrops of laterite are disintegrating. The absolute elevation of laterite remnants is no real guide to their age, since laterite pavements in adjacent areas may differ in age although they are at roughly accordant heights.

On a number of sandy wash slopes near the margins of the Koolpinyah surface, a narrow lunate band of ferruginous laterite parallels the contour and indicates earlier seepage of water, controlled by a higher seasonal water-table. On reaching the outer zone of unsaturated aerated soil, the dissolved iron hydroxides were precipitated and a platform of vesicular laterite was slowly developed. The process was probably assisted by sheet wash causing recurrent exposure of the mottled subsoil and irreversible hardening of the eroded surface.

The source of iron in ferruginous laterite derives ultimately from the bed-rock. In the survey area, the major sources of iron appear to be the sandstone, greywacke, siltstone, and granite formations. The iron content of the sandstones and greywacke is about 2·5%, of the granites 2–3%, and of the siltstones and argillaceous rocks 3–4·5% (Hays 1967). Both primary and secondary laterites are rare on quartzose rocks, silicified dolomites, and their derivatives. This is partly because of their low iron content, and partly because they are not susceptible to chemical weathering and so lack a regolith through which iron-charged solutions can percolate.

(*d*) *Laterite Distribution*

Figure 12 and Table 7 show the distribution of the main types of relict and actively forming laterites in the survey area. The marked correlation between different land systems and different laterite types suggests that topography, drainage, and lithology were, and are, important factors controlling laterite formation. Of all the laterite occurrences noted, only 30% are forming under present conditions, 45% are visibly disintegrating, and the remainder are stable remnants formed by deep weathering during an earlier period.

On the Koolpinyah surface, 40% of the laterites consist of remnant blocks of pisolitic laterite which are being destroyed by current erosion and weathering; 20% consist of mottled-zone outcrops with a veneer of ironstone gravels indicating prior truncation of a standard lateritic profile; and a further 20% consist of disintegrating fragments of pisolitic and detrital laterite in unconsolidated ironstone gravels beneath a surface layer of sandy wash.

On the alluvial flood-plains almost 80% of the laterites are concretionary, and still appear to be forming by normal pedogenetic processes. It is probable that in due course, with selective erosion and concentration of the concretions, these primary laterites will form secondary pisolitic laterite.

Laterites vary considerably on the dissected foothills. Remnant benches of detrital laterite are widespread, and disintegrating blocks of dominantly pisolitic laterite are also common.

(*e*) *Laterite Disintegration*

Disintegration of formerly extensive ferruginous laterite sheets is now taking place, particularly on the gently undulating wooded Koolpinyah surface. Under dense woodland, laterite only occurs as brittle decayed fragments in a matrix of ironstone gravels. Under more open woodland, irregularly disposed blocks of laterite occur tilted at angles up to 25%, often against the general slope and sometimes forced upwards by tree roots. Above ground level the blocks are a dull reddish black, between 6 in. and 3 ft in diameter, and occasionally case-hardened. The shiny brown "varnish" never occurs below the surface, where the blocks consist of brittle creamy yellow fragments set in a soft earthy matrix of yellow to red laterite. In certain areas, decayed fragments of moist friable laterite crumble at a touch to fine sand, and are the probable source of the deep red earths in these localities.

Unbroken pavements of ferruginous laterite are devoid of soil and vegetation, but towards their margins they are overlain by a veneer of sandy wash. Eventually vegetation becomes established, trees send down roots, and mechanical disintegration of the laterite begins. As cracks develop and further sand accumulates around the

TABLE 7

TYPES OF LATERITE OCCURRING IN THE ADELAIDE–ALLIGATOR AREA

Symbol on Fig. 12	Nature and Type of Laterite	Distribution	Land Systems
	Dominantly relict and stable		
A	Bare pavements of massive laminar laterite and some detrital or pisolitic laterite	Sporadic throughout Koolpinyah surface	Kay, Keating, Krokane
B	Remnant blocks or pavements of detrital laterite on low hills or breakaways	Scattered in east and centre	Bend, Keating, Jay
C	Locally outcropping deep-weathered sandstone and/or mottled zone, overlain elsewhere by ironstone gravels	North-west, scattered in east and centre	Kay, Keating, Keefers Hut, Jay
D	Laterite benches (detrital, vesicular) on hill slopes and foot slopes	Centre, south, and west	Baker, Bend
E	Seepage laterite (detrital, vesicular, or pisolitic) overlain by colluvial ironstone gravels on gentle slopes	Scattered in south and centre	Keating, Jay
F	River laterite (no longer actively forming)	Sporadic	Baker, Jay
	Actively disintegrating		
G	Blocks of pisolitic laterite with associated dense layers of ironstone gravels	Widespread throughout Koolpinyah surface	Kay, Keating, Keefers Hut, Knifehandle
H	Shallow sandy wash deposits overlying ironstone gravels containing disintegrating pisolitic laterite	Widespread in north and centre	Kay, Keating, Krokane, Queue
	Actively forming		
I	River laterite	Scattered in south and south-east	Baker, Bend, Cully
J	Incipient ironstone concretions of pedogenetic origin (hardening irreversibly on exposure)	Widespread on active and stable alluvial flood-plains	Effington, Fabian, Flatwood, McKinlay

young trees, the process gains momentum. Deep soils under plant cover remain moist longer than skeletal soils over laterite so that the blocks broken off or loosened by roots become increasingly prone to chemical weathering. Provided a dense forest cover persists and conditions for soil formation remain favourable, this de-lateritization process seems irreversible, and deep red loams will acquire a humus layer and eventually become mature forest soils, other things being equal.

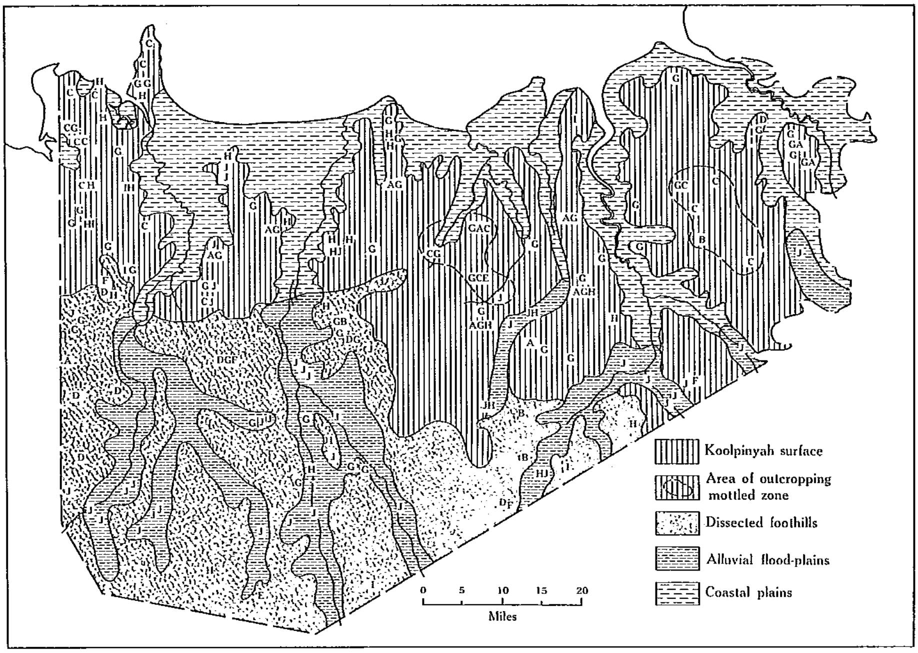

Fig. 12.—Distribution of laterites in the Adelaide–Alligator area. *A*, bare pavements; *B*, remnant blocks (stable); *C*, mottled zone; *D*, benches; *E*, foot-slope outcrop; *F*, river laterite (stable); *G*, remnant blocks (active); *H*, sands over gravel; *I*, river laterite (active); *J*, concretionary laterite (active). Each symbol relates to a specific site visited during the survey. They are described in Table 7.

(*f*) *Some Effects of Chemical and Physical Weathering*

In bare areas or on soil-free plateau summits, quartzose rocks are not susceptible to chemical decay, but in vegetated areas or when in perennial contact with slightly moist soils, the outer few inches of many quartzose rocks are friable and highly decayed. On the summit of the Buldiva plateau, little or no rock decomposition is now occurring, but woolsack boulders and a Karrenfeld microrelief not related to joints suggest that chemical weathering was once active there. This was probably at a time when a deep soil cover existed on the now bare plateau surface.

Granite tors and corestones are currently being destroyed by subaerial rock scaling, by subsurface granular disaggregation, and by fire-induced rock splitting. Many of the corestones are hard and comparatively unweathered above ground level, but immediately below the surface they yield readily to light taps with a hammer.

Even seemingly resistant low ridges of massive quartzite or silicified dolomite are susceptible to subsurface chemical weathering, and their hard shiny exposed surfaces contrast strongly with their granular crumbly textures a few inches below ground level. Only the outer few inches of rock are weathered in this manner.

Rock splitting and subaerial scaling affect other rocks besides granite, and onion weathering within low abris formed by the collapse of large blocks of arkose or quartzitic sandstone was observed occasionally. Collapse of major joint blocks consequent upon subsurface decay and undercutting is characteristic of the Kombolgie Sandstone and the arenaceous sandstones of the Mt. Partridge formation.

(*g*) *Sheet Wash*

Well-rounded ironstone gravels of medium grade ($\frac{1}{2}$–1 cm) are ubiquitous on the gently undulating Koolpinyah surface, and in many places were formed by the breakdown of pisolitic ironstone followed by the selective removal of fine particles by surface wash and mechanical eluviation.

The abundance of coarse stony detritus on all but the gentlest of colluvial wash slopes is due to the selective action of sheet wash. The size of stony and gravelly fragments on sandstone hill slopes ranging from 3·5 to 35% correlates better with distance downslope than with gradient, and there was a direct exponential relationship between the percentage frequency of various coarse fractions and their distance from the summit. This indicates transport by running water rather than the simple exhumation of weathered fragments *in situ*, since the transporting capacity of a sheet flood is proportional to the square of its velocity; velocity is a linear function of discharge; and discharge increases in geometric progression downslope.

(*h*) *Eluviation*

The annular distribution of fine-textured subsoils around certain granite hills and the mature gradational profile of many soils on both the alluvial flood-plains and the Koolpinyah surface point to the importance of vertical and lateral eluviation in the survey area. A progressive increase in clay content and degree of iron staining down the profile is a feature of well-drained soils subject to vertical eluviation, while texture-contrast soils often reflect the influence of lateral percolation.

(*i*) *Gully Erosion*

Gully erosion is especially active on the low stable flood-plain bordering the entrenched McKinlay and Mary Rivers, and is reflected in the badland topography characteristic of McKinlay land system in that area. Much of the gullying is recent, and may be related to buffalo activity, overgrazing in dry years, and the concentration of run-off along buffalo tracks and wallows.

III. Drainage

The survey area is drained by six main river systems (Fig. 13). Tributaries become fewer and the interfluves less distinct in their lower reaches. In their upper or foothill reaches structural control of drainage is strong; in their middle reaches they are cut into and pre-date the Koolpinyah surface; and in their lower reaches they are extended consequent streams developed across the emergent coastal plains.

(*a*) *Upper Reaches*

In their upper reaches the streams are broadly accordant to structure, for the headwater catchments consist of strike vales bounded by steep ridges, while the drainage has a trellised pattern. Waterfalls coincide with the plateau margins, as at Robin Falls, where the Bradshaw surface (Wright 1963) is bounded by a scarp 500 ft high. In many areas among the foothills distinct incised channels are rare, the strike vales consisting of level alluvial flats from which hills rise abruptly.

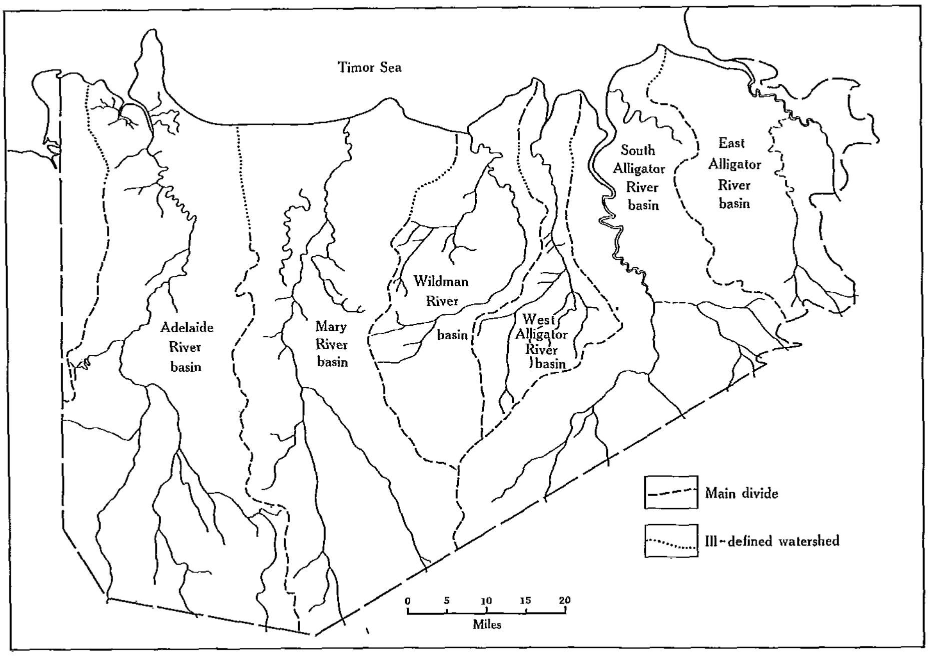

Fig. 13.—Drainage in the Adelaide–Alligator area.

Where channels are incised in bed-rock, they are sometimes bounded by benches of iron-cemented river cobbles or river laterite (the detrital laterite of White (1954) and the ferruginous sandstone and conglomerate of Dunn (1962)). In several localities a terrace of coarse river laterite is unconformably overlain by cemented water-worn pebbles or gravels of finer grade, suggesting two phases of deposition and subsequent stability. River laterite is widespread throughout the south and south-west of the area, and shows that existing streams were once capable of carrying considerably coarser bed-loads than now. An instance of underfit drainage occurs near the McKinlay River, where a former channel has been abandoned and now consists of a segmented linear depression containing billabongs flanked and floored by coarse river laterite.

(*b*) *Middle Reaches*

With the exception of the Wildman and West Alligator Rivers, the main rivers originate on the old land south of the Koolpinyah surface (Figs. 8 and 13), and flow across that surface to the coast.

As they conform to pre-Tertiary structural basins, and as there are few large abandoned channels on the Koolpinyah surface, it is probable that the courses of these four main rivers were roughly the same in Tertiary times as they are today.

In their middle reaches, the Adelaide, Mary, South Alligator, and East Alligator Rivers are entrenched in wide valleys eroded into more or less dissected tracts of the Koolpinyah surface. The valleys are floored with stratified alluvial sands and silts, which become increasingly finer with distance from the river owing to their back-plain situation. An exposed section of part of the bank of the Mary River revealed 14 distinct layers of alluvium, some clayey, some slightly stony, while slumping had concealed further evidence of older periodic depositional phases.

Mature levee benches flank the major river channels, and are contemporaneous with the stable flood-plains of Flatwood and Fabian land systems. Slightly higher patches of gravelly, frequently ferruginized, alluvium occur scattered across the flood-plains, and are especially common in Rumwaggon land system. These remnants of lateritized alluvium probably once formed extensive terraces, and are analogous to Wright's (1965) older alluvium.

(*c*) *Coastal Reaches*

In their lower reaches, the rivers pursue a meandering course which is either incised and well defined (Adelaide, East Alligator, and South Alligator) or confused and irregular (Mary). They flow across recently emerged estuarine plains, and where the original valleys were not bounded by distinct interfluvial ridges, their stream outlets have, in recent times, often shifted position.

For instance, the Mary River debouches from a comparatively narrow valley entrenched into the Koolpinyah surface out into a very broad embayment. An abandoned channel (Fig. 11) reveals that the Mary once flowed further to the west, while the discontinuous dune line between Cape Hotham and Point Stuart indicates that the shore-line once lay some 10 miles further south. As the bay prograded and extended northwards, the Mary meandered across the emerged plain, changing course frequently.

Different from this is the Adelaide River, which appears to have once flowed east of Cape Hotham. The submerged Koolpinyah surface at 6 and 10 fathoms shows that there is no sign of a drowned river channel extending the course of the present Adelaide River below sea level, but it does show that sharply incised easterly and westerly consequent streams existed at those times, and were probably in part responsible for separating the islands north of Clarence Strait from the rest of the (mainland) Koolpinyah surface. The change in course may have been due to capture by youthful stream eroding headwards and eastwards into the Cape Hotham promontory.

Although these two changes of outlet may be accounted for without invoking coastal emergence, there is no doubt that a period of prolonged submergence and off-shore sedimentation of previously wide deep river valleys took place and has recently been succeeded by emergence. At the period of maximum submergence, possibly to a depth of 200 ft (Christian and Stewart 1953), much of the original Koolpinyah surface was probably drowned, and large-scale alluviation took place in major valleys, often extending into their headwater regions. As the sea withdrew, lagoons formed by the ponding up of stream outlets by sand-bars, etc., were gradually filled in, and some of these now form part of the paperbark swamps and ill-drained depressions of Pinwinkle and Copeman land systems.

(*d*) *Seasonal Fluctuations in River Discharge and Salinity*

Tidal salt water extends well upstream in the dry season, as much as 30 miles in the East Alligator River, and even in the wet season the mixing zone between salt and fresh water may extend 12 miles from the mouth of the Adelaide River. In January–February 1961, salinity values in that river ranged from 12,000–24,000 p.p.m. of NaCl 4 miles upstream to 2500–8000 p.p.m. 16 miles from the river mouth (Forbes 1963). This phenomenon of seasonal saline influx has had considerable influence on the soils and vegetation bordering the main streams, the banks of which are often fringed with mangroves until far upstream.

IV. Evolution of the Landscape

Beginning with the development of the Bradshaw surface in Lower Miocene times, eight major stages of landscape development may be recognized. These subdivisions are for convenience only, since the overlap between stages was often very great, and evidence for the older stages is scant and ambiguous.

(*a*) *Dissection of the Bradshaw Surface*

(i) *Age of the Bradshaw Surface*.—In the extreme south-west of the survey area, a remarkably level erosion surface has been cut across Lower Cretaceous sandstones of the Mullaman Beds formation, and has been preserved on the 800–900-ft plateau summit between the Adelaide River and Burrell Creek headwaters (Fig. 9). This surface, the Bradshaw surface of Wright (1963) or the Tennant Creek surface of Hays (1966), is obviously post-Lower Cretaceous in age, and outside the survey area is characterized by a standard lateritic profile (Wright 1965). Within the area, and immediately south of Robin Falls, the silicified pallid zone is overlain disconformably by up to 30 ft of disintegrating pisolitic ironstone and occasional highly weathered vesicular blocks of mottled-zone material.

In the Barkly Tableland and in Queensland, strongly lateritized Lower Cretaceous and older formations are overlain unconformably and disconformably by siliceous limestones laid down between Middle Miocene and Pleistocene times (Whitehouse 1940; L. C. Noakes, unpublished data; Paten 1960). The limestones are not themselves lateritized, although this does not preclude the possibility that lateritization took place elsewhere during the time of their deposition. The existence of fresh Tertiary limestones over a lateritized surface sets an upper age limit to that surface, and if the Bradshaw surface is indeed equivalent to this lateritic surface on the Barkly Downs, it must have developed in pre-Middle Miocene times.

(ii) *Distribution of the Bradshaw Surface*.—Remnants of the Bradshaw surface are few, small, and discontinuous. The most conspicuous is 6 miles south of Adelaide River township and is over 800 ft above sea level. Further remnants crop out in the cliffs at Cape Hotham and Fright Point, over 80 miles north of Adelaide River town. They are preserved on a truncated secondarily iron-stained pallid zone developed in Cretaceous sandstones. Between the coast and the 800-ft plateau, occasional remnants of the surface crop out in billabongs. In an enclosed hollow 6 miles south of Koolpinyah homestead, Cretaceous sandstones crop out at 125 ft, forming part of the mottled zone developed in Mesozoic formations once the Bradshaw planation surface had formed.

If the Bradshaw surface is tentatively reconstructed from existing remnants of eroded and deeply weathered Lower Cretaceous rocks, it appears as a very gently tilted surface with a slope of 1:550.

(iii) *Uplift and Erosion of the Bradshaw Surface*.—Erosion of the Bradshaw surface began as a result of a slow uplift in Miocene times (Noakes 1949). Drainage was initiated on a gently warped surface, and erosion by down-wearing was subordinate to scarp retreat and pediplanation. This is inferred from the preservation of Cretaceous remnants and from the cliffs bordering the intact Bradshaw surface. There is no evidence that the Mullaman Beds were ever much more than 200 ft thick in the survey area.

Prolonged differential erosion from Middle to Late Tertiary times was governed by the disposition of the steeply dipping Lower Proterozoic metasediments. Strike vales were etched out between meridional ridges; rugged granite hills were exhumed from the Bradshaw weathering profile; the bevelled hill summits of the sub-Cretaceous unconformity were resurrected, and over much of the area relief attained its greatest local development.

(*b*) *Post-Bradshaw Deposition*

As uplift ceased and erosion continued, rising base levels and a progressive decline in the competence of streams to evacuate their loads resulted in the accumulation of debris in the outer foothills zone. Relief began to diminish, extensive colluvial mantles were laid down, strike vales became aggraded and blocked with coarse detritus, and many of the lower hills were almost buried in their own talus deposits.

In the west, centre, and east, the truncated ridges and waste-filled valleys formed a gently undulating plain—an early stage of the Koolpinyah surface—and thin sheets of coarse, often angular, debris were laid down across both the built-up and the rock-floor portions of the pediplain. Low erosional remnant hills protruded above the general level, while the foothills to the south retained their original strong relief. Sporadic lateritization appears to have taken place about this time.

(*c*) *Late Tertiary Erosion*

Vertical erosion, dissection of the ferruginized colluvial–alluvial mantles laid down in the previous phase, and inversions of relief seem to have been characteristic of this period for the following reasons:

On some of the hills rising 100–150 ft above the present plains, soils on the level planed-off summits are red and ferruginous, in contrast to the stony or rocky skeletal soils on the hill slopes. Where the hills rise scarcely 40–50 ft above the lowlands, the summit capping is often of coarse detrital laterite, up to 2–3 ft thick, containing quartz and weathered sandstone fragments (Fig. 10).

The concentration of well-rounded pebbles of quartz in these ferricrete caps indicates prior transport by running water, and suggests that they were laid down on what were originally valley bottoms or lower wash slopes. At present, pebbles of comparable size are rare on slopes gentler than 2%. Some of the quartz may have derived from conglomerates, but some must have come from the vein quartz common in Lower Proterozoic formations.

(*d*) *Late Tertiary Deposition and Deep Weathering*

Widespread erosion took place from the Lower Proterozoic metasediments in Late Tertiary and early Pleistocene times, with consequent deposition of sandy, silty, and clayey sediments. These processes gave rise respectively to the dissected foothills and the Koolpinyah surface, and were accompanied and succeeded by deep weathering. Not only this, but from the proportion of clay in the deposits it appears that the Lower Proterozoic metasediments from which they were derived had themselves been strongly and perhaps deeply weathered. Sandy bed-loads were derived from the arenites of the Buldiva plateau, and the stony constituents of fossil river laterite in the east and south-east of the area show that streams were capable of transporting coarser loads than they do now.

These Late Tertiary sediments were laid down to form an extensive gently undulating fringe to the southern foothills and Buldiva plateau, and slopes above 2% were rare. The Koolpinyah surface is thus a composite feature.

With high prevailing water-tables, the clays became mottled and formed concretions. These were later exposed by rill erosion and the finer particles removed by sheet wash. The gradual concentration of ironstone concretions resulted in a dense layer of surface gravels through which iron-charged solutions used to percolate. Precipitation of the iron around the concretionary gravels resulted in the formation of a highly resistant layer of pisolitic ironstone, and many of the laterites associated with the Koolpinyah surface are of this type.

(*e*) *Quaternary Erosion*

(i) *Stripping of the Weathering Profile.*—Underlying structures are now being exhumed from their Late Tertiary cover, and it is often difficult to be certain whether the cemented ferruginous rubble fringing many of the Lower Proterozoic ridges is of Late Tertiary origin or younger.

Depending upon whether the sub-Tertiary landscape has been resurrected or is still concealed beneath Late Tertiary sediments, topography is complex and irregular or smooth and gentle. Along the margins of the dissected foothills, stripping of the Koolpinyah weathering profile has been almost complete, and occasional low lateritic breakaways or lateritic benches along the lower hill slopes are the only remnants of the Koolpinyah surface. Further north and east, low gravelly rises comprising abundant quartz and strongly weathered sandstone fragments may represent lower portions of the former deep-weathered profile, and they occur amidst a profusion of low broadly convex knolls with a continuous cover of $\frac{1}{2}$–1-cm well-rounded ironstone gravels and occasional disintegrating blocks of pisolitic ironstone. In the west and north-west of the area, gentle initial slopes and permeable soils and subsoils have minimized erosion, so that extensive tracts of the original Koolpinyah surface have been preserved intact or only slightly dissected. Figures 14 and 15 show two successive stages in the dissection of the Koolpinyah surface.

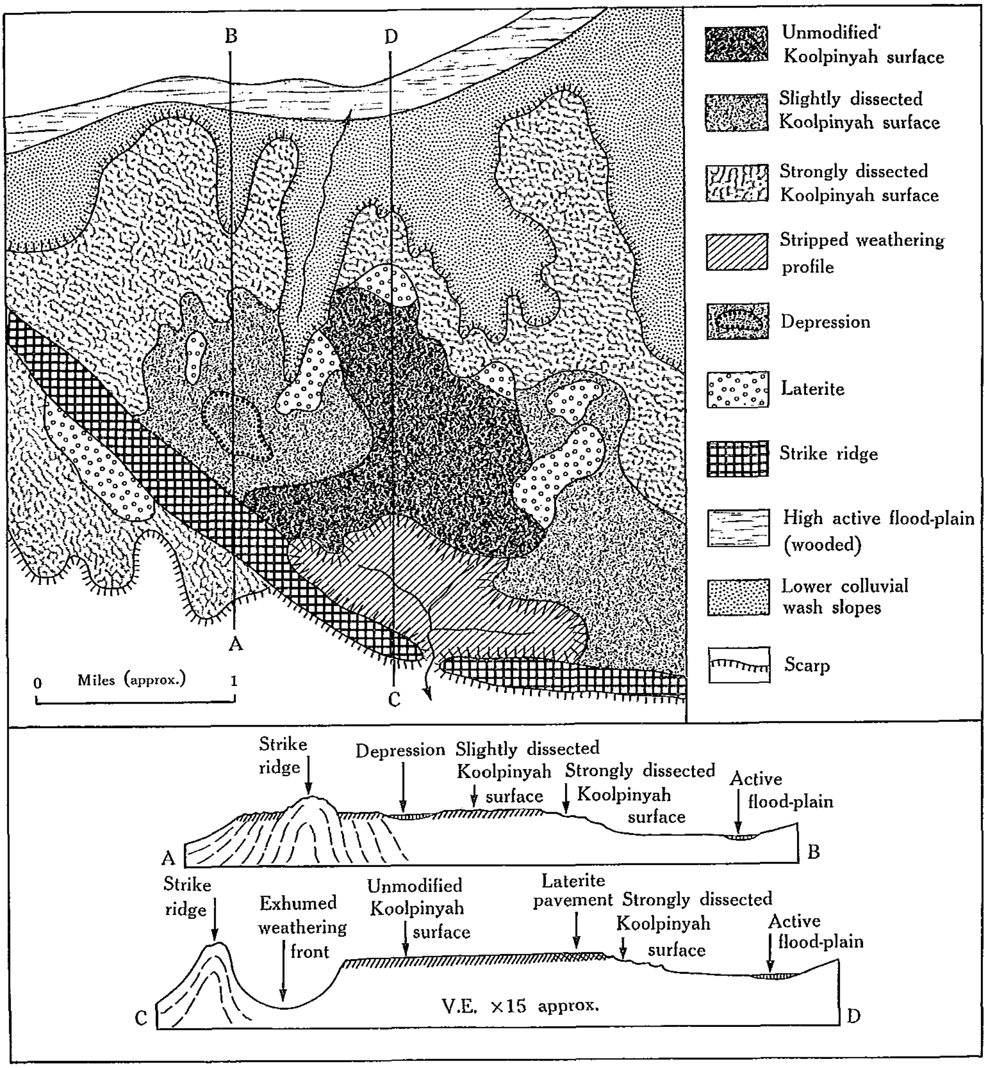

Fig. 14.—Early stage in the dissection of the Koolpinyah surface.

(ii) *Prior Drainage Network on the Koolpinyah Surface.*—A very characteristic feature of the Koolpinyah surface is the numerous internal drainage depressions. Some of these are scattered at random across the surface, but many occur as aligned partially coalescent depressions, often with billabongs, or as segmented dry valleys analogous to the blind valleys of a karst landscape. They are floored with sandy alluvium, and many are underlain by clay. Coarse water-worn ironstone gravels often occur in the clayey subsoil, indicating that the depressions are floored with alluvium containing lateritic debris derived from the Koolpinyah surface.

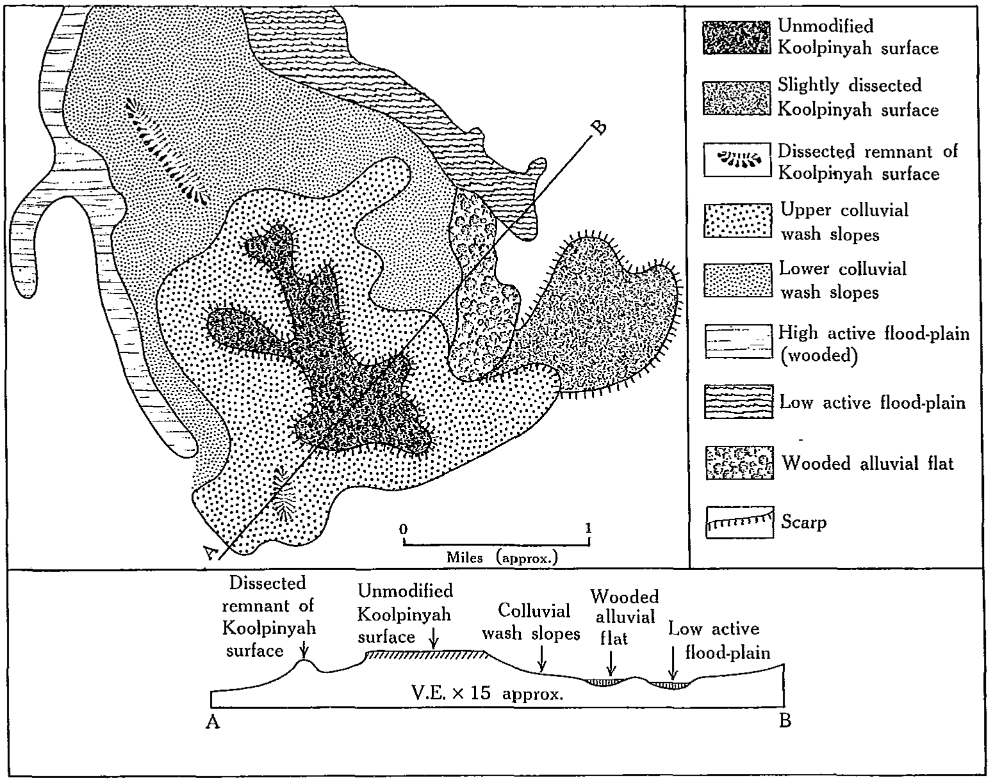

Fig. 15.—Intermediate stage in the dissection of the Koolpinyah surface.

From their position on the Koolpinyah surface, and from their roughly dendritic disposition and north–south alignment, it is reasonable to conclude that these depressions are former spillways eroded in the lateritized lowlands (cf. Mulcahy 1959). They are frequently fringed with horizontally bedded detrital laterite or with massive laminar laterite, and by analogy with the river laterites discussed previously and with the bedded laterite benches flanking alluvial flats in Bend, Baker, and Rumwaggon land systems, it is logical to infer that these laterites were formed in relation to higher water-tables associated with the streams that once flowed in the spillways. Decreased run-off and a decline in stream competence, perhaps related to a drier climatic phase, resulted in sand deposition within the spillways. There also appears to have been slope instability about this time, for many of the channels have been blocked by sandy slope-wash deposits. Some of these were subsequently relateritized, perhaps during a minor phase of deep weathering. The relationship of these spillways to possible former high sea levels remains uncertain.

(*f*) *Quaternary Alluviation*

The alluvium is distributed as follows:

(1) On the Koolpinyah surface, some of the spillway deposits form extensive level sand plains (Queue land system) into which younger valleys have been cut (Knifehandle land system). The precise age of these sandy alluvial sediments is not known; some may be Late Tertiary, others Pleistocene or even Recent in age.

(2) On the eastern alluvial flood-plains (Effington land system), active streams are flanked by at least two sets of alluvium consisting of low contemporary deposits with stable sandy wooded terraces above them. These higher wooded terraces are often difficult to distinguish from the spillway deposits (Queue land system) mentioned in (1).

(3) On the west and central alluvial flood-plains, two sets of levees with mature gradational profiles flank the Adelaide, Mary, and East Alligator Rivers. The higher outermost levee was laid down during a period of considerably greater stream discharge than at present. The innermost levee, no longer being built up to any degree, is being destroyed by gullying (McKinlay land system). The back-plain deposits (Flatwood and Fabian land systems) associated with these levees consist of stable clayey or silty flood-plains, locally overlain by gravelly patches of older alluvium. The older alluvium is often partially lateritized, suggesting that a minor deep-weathering phase may have preceded the last major aggradational phase in the area.

Major rivers are now entrenched in their alluvium, and have channels perhaps half as wide as when the outermost levees were laid down. This incision may reflect the tidal range in the area (26 ft at Darwin), or may be due to a recent increase in run-off due to a change of climate (Wright 1965), or may be an effect of the Recent fall in sea level postulated by Noakes (1949) and by Christian and Stewart (1953). There is much evidence of recent climatic change, but little to suggest a general increase in run-off. The coarse water-worn cobbles in river laterite which crops out in the upper reaches of streams now only capable of transporting bed-loads of sand or fine gravel suggest that there has been a general decline in stream competence. This could be due to a decrease in discharge caused by climatic change, or to a slowing down of stream flow due to coastal emergence.

The South Alligator plains form a transitional zone between the narrow sandy flood-plains to the east and the wide finer-textured flood-plains to the west. In one locality, low sand ridges overlie a stable flood-plain with a mature, slightly truncated, solonetzic soil profile. These ridges probably originated as sandy bed-loads of streams which transgressed across this ancient flood-plain west of the South Alligator River. During a period that may have been drier and windier than at present, deposition by running water ceased and aeolian action converted the sandy channels into a series of low sinuous ridges.

(*g*) *Recent Coastal Emergence*

Late Pleistocene or Recent emergence of estuarine clays and littoral muds has taken place wherever embayments or river mouths disrupted the continuity of the

Koolpinyah surface. It is not clear whether this emergence is due to gentle uplift or tilting of the land or to a eustatic fall in sea level, and it is equally uncertain whether the recent rejuvenation of the lower and middle reaches of some of the major rivers is eustatic or epeirogenic in origin.

The geomorphological history of the survey area from Lower Cretaceous times onwards may be summarized thus:

(1) Lower Cretaceous–Middle Miocene.—Deposition of Mullaman Beds. Slow upwarping and prolonged deep weathering. Formation of the Bradshaw surface.

(2) Upper Miocene–Pliocene.—Upwarping, faulting, and erosion of Bradshaw surface. Exhumation of Lower Proterozoic hills. Deposition of fan sediments and partial burial of strike ridges. Deep weathering and development of Koolpinyah surface (cut-and-fill polygenetic surface).

(3) Pleistocene.—Wide fluctuations of sea level and climate. Dissection of Koolpinyah surface and formation of sand plains. At least two aggradations in main valleys. Minor deep weathering phase(s).

(4) Recent.—Dissections of Koolpinyah surface. Aggradation of swales between strike ridges. Coastal emergence (*c.* 20 ft) and alluviation in lower and middle reaches of major river valleys.

(*h*) *Pleistocene Climatic Fluctuations*

(i) *Evidence from Simple Polygenetic Soil Profiles.*—In the south of the survey area coarse angular detritus overlies deep stone-free clays on slopes up to 20% on Baker, Bend, and Rumwaggon land systems. At present, clay is generally absent from the surface of slopes above 5%, so that its existence beneath a modern colluvial layer shows that it either formed *in situ* as a result of prolonged deep weathering or was laid down over parts of the dissected foothills as an extensive argillaceous mantle. This period of stability and slow aggradation was followed somewhat abruptly by a phase of widespread slope instability, probably caused by a change to a less humid climate.

A number of other profiles also point to a change from a period characterized by deep weathering and clay formation and/or deposition to one of erosion and the laying down of a coarse colluvial–alluvial mantle. For example, in Bend land system modern slope-wash deposits overlie gravel-free sands which abruptly overlie massive mottled clays. In Cully and Currency land systems, the colluvial migratory layer at the surface of wash slopes may rest upon a massive dark grey clay subsoil. These dark clays are now confined to boggy depressions, so that their presence below the surface in situations where they do not now develop implies that swampy conditions were once more widespread in these areas.

(ii) *Evidence from a Complex Polygenetic Soil Profile.*—A somewhat more complex profile is illustrated in Figure 16. From the bottom calcareous layer upwards, the sequence is gravelly clay, clay, gravelly sandy clay, gravelly sand, sand, and fine sandy loam. A tentative palaeoclimatic reconstruction is as follows. The earliest phase (VI) was wet and characterized by shallow lakes. A drier climate ensued, and calcium carbonate was precipitated in and around the lakes as they dried out. Conditions became wetter during phase V, and erosion of pre-existing laterites took place. In phase IV, the climate became wetter, slopes became stable, and clay was laid down anew. Phase III was one of erosion under a less humid climate, followed

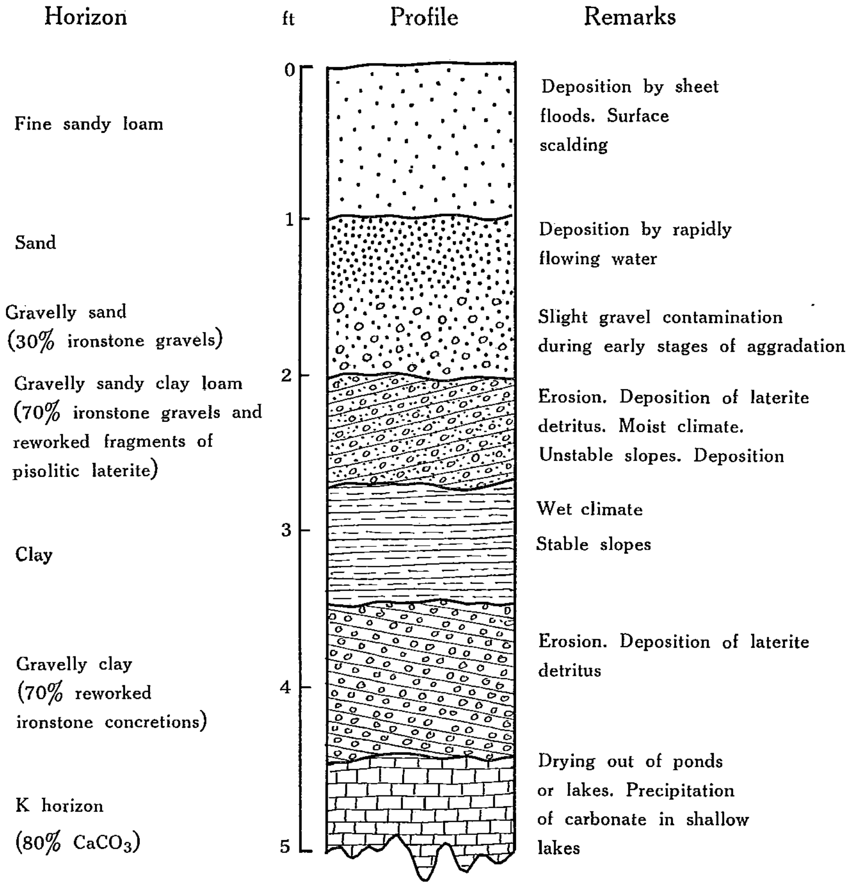

Fig. 16.—A polygenetic soil profile.

by a renewal of slightly drier conditions (II). These have continued into the present phase (I), which is characterized by a slowing down of erosion and the deposition of a greater proportion of fine particles than previously. This reconstruction is only one of several possible interpretations of the erosional–depositional sequence in a specific locality, but it does show that climatic fluctuations have occurred in the survey area during Pleistocene and Recent times.

V. Geomorphology and the Land Systems

In Table 8, the land systems have been grouped according to four parameters: relief, lithology, relation to the Koolpinyah surface, and, where relevant, drainage.

TABLE 8

GEOMORPHOLOGY AND THE LAND SYSTEMS

Relation to Koolpinyah Surface or Weathered Zone	Lithology	Relief	Land Systems
Stable or moderately stripped Koolpinyah surface	Ironstone gravels and laterite	Level to gently undulating lowlands	Kay, Keating, Kysto
Partially dissected Koolpinyah surface and weathered zone	Ironstone gravels, laterite, quartz gravels, sands	Low hills and broad valleys, depressions, and undulating lowlands	Keefers Hut, Kosher, Jay, Krokane
Erosional-depositional surfaces within Koolpinyah weathered zone	Deep sands	Level lowlands	Queue
		Broad valleys	Knifehandle
Erosional surfaces rising above, or cut below, Koolpinyah weathered zone	Sandstones, siltstones, greywacke	Hills and strike ridges	Baker
		Low erosional remnants	Bend, Rumwaggon
	Granite (fresh)	Hills	Currency
	Granite (weathered)	Rolling to undulating lowlands	Cully
	Quartzites	High plateaux	Buldiva
Quaternary alluvium	Sands	Plains	Effington
	Silts	Plains	Fabian, Flatwood
	Sands or silts	River channels and active flood-plains	McKinlay
Quaternary estuarine and littoral deposits	Clay	Swampy plains	Copeman, Pinwinkle
	Clay	Plains	Cyperus
	Clays and muds	Tidal flats	Littoral

Relief was assessed primarily from stereoscopic examination of air photographs of two different scales (1 : 16,000 and 1 : 50,000), and checked by some 500 Abney-level readings at different sites in the field, and by more detailed levelling of 30 slope profiles on eight land systems.

Level terrain has slopes less than 1%, a local relief from interfluve summit to alluvial flat of 20 ft or less, and little or no apparent relief on the air photographs. Gently undulating land has slopes up to 5%, with a local relief up to 40 ft; undulating land has slopes to 15% and relief to 30–60 ft; rolling land has slopes to 25% and relief to 40–70 ft. Hilly country includes mesas, scarps, granite domes, strike ridges, and strongly dissected uplands. Relief is up to 100–200 ft, and slopes up to 20–40% are common. Erosional remnants include low gravelly rises with slopes to 3% and relief to 15–20 ft, and worn-down strike ridges with relief to 30–50 ft, but with knife-edge ridge crests, in contrast to the convex summits of the rolling or undulating terrain.

(*a*) *Stable or Moderately Stripped Koolpinyah Surface*

The unmodified Koolpinyah surface consists of extensive level to gently undulating lowlands, overlain by ironstone gravels in a matrix of sands and loams, with occasional outcrops of mottled-zone and ferruginous-zone laterite. Gradients usually range from ½ to 2%, but where incipient dissection and stripping are occurring, they may attain 5%.

Where the weathering profile is shallow, lithological variations in the underlying folded metasediments are reflected in a banded pattern of groves and glades parallel to the strike (Kysto land system).

(*b*) *Dissected Koolpinyah Surface and Weathered Zone*

A number of erosional landscapes have been etched into the Koolpinyah weathered zone. They range from a composite landscape of low hills and broad valleys, with remnants of the Late Tertiary surface occupying the interfluves, to undulating lowlands from which the weathered zone has been almost entirely removed (Keefers Hut and Jay land systems).

Krokane land system consists of shallow closed depressions, and sometimes represents an early stage of stripping. Kosher land system is confined to the dissected margins of the Koolpinyah surface, and has a lithology varying from ironstone gravels and ferruginous laterite outcrops to deep ferruginous sands.

(*c*) *Erosional–Depositional Surfaces within the Koolpinyah Weathered Zone*

Shallowly etched into the Koolpinyah surface are extensive level lowlands (Queue land system) characterized by deep sands that appear to be secondary, having been derived from Late Tertiary laterites and subsequently laid down by water. Broad valleys (Knifehandle land system) eroded in these sand plains have slopes up to 3·5% and a local relief to 30 ft.

(*d*) *Erosional Surfaces rising above or cut below the Koolpinyah Weathered Zone*

Where the removal of both the Bradshaw and the Koolpinyah weathered zones is almost complete, the resultant landscape is hilly or rolling. Remnants of the former weathered zone or zones persist in undulating Bend, Cully, and Rumwaggon land systems, but on rugged Baker, Buldiva, and Currency land systems, stripping has been virtually complete. It is probable that many of the higher granite hills and strike ridges protruded as inselbergs above the original Koolpinyah surface, and represent the exhumed irregular weathering front (Mabbutt 1961) of the Miocene Bradshaw surface.

(*e*) *Quaternary Alluvium*

Cut into the Koolpinyah surface are alluvial plains that vary in width from 5 miles to 50 yd. East of the South Alligator River and in scattered localities in the west, bed-loads and flood-plains are dominantly sandy, whereas silts and clays are dominant on the western alluvial plains. Multiple channels are common in the east; single channels are a feature of the west. The alluvial plains have therefore been split into two broad regional groups on the basis of texture and channel type.

(*f*) *Quaternary Estuarine and Littoral Deposits*

Recent emergence of the shore-line is reflected in the level estuarine clay plains that penetrate well into the dissected lowlands formed by the Koolpinyah surface. These plains are flooded for considerable periods each year, and since impeded drainage is their chief characteristic, they have been classed according to whether they are seasonally well drained (Cyperus land system), ill drained (Copeman and Pinwinkle land systems), or liable to tidal flooding (Littoral land system).

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PART VII. SOILS OF THE ADELAIDE–ALLIGATOR AREA

By A. D. L. HOOPER*

I. INTRODUCTION

In 1946, the first of the land system surveys involving correlated soil–geomorphology–vegetation investigations was carried out in the Katherine–Darwin region (Christian and Stewart 1953). Prior to this date, soil surveys were of a very limited and broad reconnaissance nature (Prescott 1938*a*, *b*; Prescott and Skewes 1941; Marshall 1945). The results of soil investigations of the 1946 survey, complemented by subsequent field observations and the semi-detailed survey of experimental farms at Katherine by Litchfield (1952, 1954), were published in a comprehensive memoir by Stewart (1956). Where definite correlation has been possible, the names of soil families proposed by Stewart have been adopted for families described in the present report (Table 9).

The soils of the Tipperary area in the south-west of the Katherine–Darwin region were described by van de Graaff (1965), who gave much greater definition to families of red earth soil groups, but combined several other associated families of Stewart (1956). Other soil reports in land system surveys of similar areas in northern Australia (Rutherford 1964; Sleeman 1964) have been correlated with the soils of the Adelaide–Alligator area, but some families have become broad in definition apparently due to reliance on great soil group morphology as the main criterion of classification. Stewart (unpublished data) has recently redefined some of his original families in a survey of the Ord–Victoria area, giving greater emphasis to parent material relationships.

Section II is supplementary to Table 9 and illustrates the classification of some soil families in which profile features other than those used in the notation have been used to show obvious differences in the soils. Table 9 sets out all the soil families with a brief profile description and the correlation of these soils with families recognized in previous reports. Soil profiles representative of each family are described in Appendix I.

The Adelaide–Alligator area, however, lends itself easily to a broad geographic subdivision in which the main soil families are related in broad catenae or toposequences. Apart from some transitional zones, groups of soils appear to be confined to these geographic zones, which are described in Section III.

II. SOIL CLASSIFICATION

(*a*) *General*

All soil profiles were coded according to Northcote (1965) and like units of soils were established primarily from individuals showing the same notation, which has been retained wherever possible (Table 9). The soil families used in this report are

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TABLE 9

SUMMARY DESCRIPTION, CLASSIFICATION, AND CORRELATION OF SOILS

Major Group	Family	Summary Description	Principal Profile Form (Northcote 1965)	Approximate Equivalent Soil Names: Others in Northern Australia	Approximate Equivalent Soil Names: Great Soil Groups (Stephens 1962)
Uniform coarse-textured soils with no pedologic organization	Dune sands	Weakly coherent dune or beach ridge sands	Uc1.21		
	Kapalga	Deep (60 in.) grey acid sands	Uc1.21	Deep light grey sands (Stewart 1956)	
	Howard	Moderately deep (48 in.) greyish sands over grey acid clay D horizons	Uc1.21, 1.22		Alluvial soils
	Nourlangie	Moderately deep (48 in.) greyish sands over grey alkaline clay D horizons, with $CaCO_3$	Uc1.21, 1.22		Alluvial soils
Uniform coarse-textured soils with pedologic organization	Baroalba	Deep yellow sand to sandy loam; acid	Uc5.11, 4.2	Pago (Stewart unpublished), Kalyeeda (Rutherford 1964)	Alluvial soils
	Murrabibbi	Moderately deep to shallow (24 in.) black loam over grey or yellow sand with mottled clay D horizons; acid	Uc5.13 ?, 2.12		
	Cockatoo	Deep red sands to sandy loams; acid	Uc5.21	Cockatoo (Stewart 1956; Rutherford 1964; van de Graaff 1965), K (Litchfield 1952)	Brown soils of light texture
	Cahill	Moderately deep to shallow red sand to sandy loam; nodular and stony	Uc5.21, 5.22	Coralie (van de Graaff 1965)	Brown soils of light texture
Uniform coarse- or medium-textured soils with no pedologic organization	Skeletal soils	Shallow (<24 in.) stony yellow sand to loam on bed-rock	Uc1, Um1		Skeletal soils

Uniform medium-textured soils with pedologic organization	Mary	Deep olive-brown silts; acid	Um5.3	S (Litchfield 1952)	Alluvial soils
	Frances	Deep olive-brown silts; with $CaCO_3$ pan	Um5.3	N (Litchfield 1952)	
Uniform fine-textured soils with no pedologic organization	Saline muds	Deep, permanently wet, gleyed saline mud	Uf1.41		
Uniform fine-textured soils with pedologic organization (plastic)	Dashwood	Black peaty swamp clays; acid	Uf6.32	Dashwood (Stewart 1956)	Acid swamp soils
Uniform fine-textured soils with seasonal cracking, with pedologic organization (smooth-faced peds)	Adelaide	Black self-mulching alkaline clays with $CaCO_3$ nodules	Ug5.28		Grey soils of heavy texture
	Wildman	Black massive clays over alkaline saline estuarine mud	Ug5.4	Wildman (Stewart 1956)	Grey soils of heavy texture
	Carmor	Black massive or weakly self-mulching clays with amorphous $CaCO_3$ over alkaline estuarine mud	Ug5.4, 5.28		Grey soils of heavy texture
	Counamoul	Black massive clays, acid, over buried acid riverine, dune, or lateritic sands or mottled sandy clays	Ug5.4		Grey soils of heavy texture
	Cairncurry	Black massive mottled clays over acid gypsic swamp clays	Ug5.4		Acid swamp soils
	Carpentaria	Grey gleyed saline clays	Ug5.4, 5.2, 5.1	Salt flat soils (Stewart 1956), Carpentaria (Sleeman 1964)	Solonchak
Gradational soils, non-calcareous, with earthy fabric in B horizon	Berrimah	Deep red sandy loam; soft A horizon, with or without A_2; clay B horizon; acid; minor nodules	Gn2.11, 2.14	Berrimah (Stewart 1956)	Red earth
	Katherine	Deep red silty loam; A horizon, without A_2; clay B; acid; no nodules	Gn2.11	M4 (Litchfield 1952), Katherine (Stewart 1956)	Red earth

TABLE 9 (*Continued*)

Major Group	Family	Summary Description	Principal Profile Form (Northcote 1965)	Approximate Equivalent Soil Names	
				Others in Northern Australia	Great Soil Groups (Stephens 1962)
Gradational soils, non-calcareous, with earthy fabric in B horizon (*continued*)	Hotham	Moderately deep red loamy A horizon; nodules in clay B; acid to neutral	Gn 2.11, 2.12, 2.14, 2.21, 2.22	Berrimah (Stewart 1956), Wonorah (Stewart 1954)	Lateritic red earth
	Munmarlary	Moderately deep yellow to brown sandy A horizon; red clay B with nodules and stones; acid to neutral	Gn2.11, 2.12, 2.14, 2.21, 2.22, 2.24	I (Litchfield 1952)	
	Basedow	Deep brown to yellow sandy A horizon; red sandy clay loam B; acid	Gn2.11, 2.21, 2.24		
	Woolner	Deep yellow-brown sandy A horizon; mottled clay B; acid to neutral	Gn2.41, 2.42, 2.44		
	Magela	Deep yellow sandy A horizon; yellow to red mottled sandy clay loam B; acid	Gn2.41, 2.44	Chunuma (Stewart unpublished)	Red earth
	Batten	Deep or moderately deep yellow loamy hard-setting A horizon, with A_2: reddish brown hard clay B; acid	Gn2.24, 2.25, 2.65, 2.74, 2.75	L1 (Litchfield 1952), Batten (Stewart 1954), Elliott (Stewart 1956)	Yellow earth
	Elliott	Deep or moderately deep yellow-brown loamy hard-setting A horizon, no A_2; clay loam to clay B; acid to neutral	Gn2.61, 2.62, 2.81, 2.82	L (Litchfield 1952), Elliott (Stewart 1956; van de Graaff 1965)	Yellow earth
	Koolpinyah	Moderately deep yellow to yellow-brown loose sandy A horizon; sandy clay loam B with nodules; acid	Gn2.21, 2.61, 2.81	Koolpinyah (Stewart 1956), Florina (van de Graaff 1965)	Yellow earth

	Cullen	Deep or moderately deep yellow to grey sandy A horizon; loose loamy B; stony, acid	Gn2.81, 2.91	H (Litchfield 1952), Cullen (Stewart 1956)	Yellow earth
	Masson	Moderately deep yellow sandy loose A horizon; pink sandy clay B; stony	Gn2.81, 2.24		Yellow earth
	Angelara	Moderately deep brown silty A horizon; clay B; stony, alkaline	Gn2.43		Lithosol
Gradational soils, non-calcareous, with smooth ped fabric in B horizon	McKinlay	Deep yellow loamy A horizon; mottled clay B; alkaline	Gn3.53, 3.73, 3.93	Transitional soils (Baseden and Martin 1965)	Yellow earth
	Stapleton	Deep yellow well-developed A_2 horizon; mottled structured clay B; alkaline	Gn3.86, 3.96	S3 (Baseden and Martin 1965), Argada (Stewart 1954)	Solodized solonetz
	Moline	Deep yellow mottled alkaline structured clay; B horizon with pH $>7\cdot0$ at or below 14 in.	Gn3.56, 3.76, 3.96	S2–S3 (Baseden and Martin 1965)	Solodized solonetz
Gradational soils, non-calcareous, with rough ped fabric in B horizon	Marrakai	Deep yellow-grey silty A horizon; mottled clay B with pH $<6\cdot5$	Gn4.51, 4.52, 4.54, 4.61, 4.31	Marrakai (Stewart 1956; van de Graaff 1965)	Meadow podzolic
	Woolwonga	Deep grey alkaline calcic clay B horizon with nodules, pH $>7\cdot0$	Gn4.53		?Meadow podzolic
Duplex (texture-contrast) soils with yellow clayey mottled subsoils, and hard-setting surface horizons	Jim Jim	Deep grey acid sandy A horizon; massive alkaline calcic clay B	Dy3.53, 3.63, 3.73		Meadow solonetz
	Margaret	Deep yellow acid silty A horizon; alkaline structured (columnar) clay B	Dy3.13, 3.23, 3.33	Miranda (Sleeman 1964), S1 and S2 (Baseden and Martin 1965)	Solodized solonetz
Duplex (texture-contrast) soils with dark clayey whole-coloured subsoils, and hard-setting surface horizons	Cooinda	Deep black acid shallow peaty A horizon; pedal heavy clay B	Dd1.11		Acid swamp soils

based on characters thought to be of agronomic importance as defined by the United States Department of Agriculture (1951). This grouping in many cases transcends Northcote's (1965) notation by forcing the grouping of similar principal profile forms and the separation of those where factors such as texture of subsoils, stoniness, drainage, pH, or sometimes colour are not accounted for in the notation.

Uniform, gradational, and duplex (texture-contrast) soils are all widely represented in the survey area. No organic soils were observed.

(*b*) *Soils with Uniform Texture Profiles*

Uniform soils were observed on recent flood-plains and levees, at the foot of sandstone hills or ridges, and on the upper surface and margins of the Koolpinyah surface. These are predominantly coarse-textured (Uc) soils (Table 9) derived from arenaceous parent materials and without pedologic organization in the profile (Uc1). Within this group, family units have been established by further subdivision into soils with contrasting (?polygenetic) D horizons, either acid (Howard family) or alkaline (Nourlangie) in reaction. Both of these soils are nearly always closely associated spatially on valley flood-plains and shallow drainage-ways, particularly on the Koolpinyah surface. Uniform coarse-textured soils showing profile development (Uc5) in colour or weak textural change are confined to older terraces of the present rivers, high level sand plains, and their marginal slopes.

Medium-textured soils (Um) were observed only on recent flood-plains and levees, and fine-textured soils (Uf) only on inland and swampy zones of the coastal plains or under mangrove or the littoral fringe.

Cracking clay soils (Ug5) occupy the rest of the coastal plains with a uniform notation of Ug5.4 in soils with massive surfaces, or Ug5.28 where some self-mulching (i.e. pedality) occurs. Family units within these groups are based on pH and associated special features in the profile, viz. alkaline soils (Wildman), alkaline with carbonate nodules and self-mulching (Adelaide), alkaline with amorphous carbonate (Carmor), acid with gypsum (Cairncurry), or acid with underlying sands or sandy clays (Counamoul).

(*c*) *Soils with Gradational Texture Profiles*

Gradational, non-calcareous soils, particularly of the earth type (Gn2), are the dominant soils of the area occupying most of the Koolpinyah surface, considerable areas of the lower slope zones in the hill country, and on alluvium of flood-plains and older levees.

Further subdivision of the Gn2 soils has been made on the texture classes covered by the gradation, degree of stoniness or amounts of ironstone nodules in the profile, the colour of the A horizons where this is regarded as an indicator of both process and drainage, and the presence of mottles. For example, the clay B horizon of Berrimah family is matched by the Hotham family which is essentially a shallow phase of Berrimah but has some differences which show co-variance; it is less deep, with generally light clays in the B horizon, and has high amounts of ironstone nodules in lower horizons. Katherine family has silty surface textures and no nodules.

Lighter-coloured A horizons are typical in soils of the sloping margins of the plains, and an apparent multiplicity of Northcote's (1965) notation between Gn2.1, Gn2.2 in these families is due to the colour of the B horizon, where no family status has been given to soils with a value/chroma of 5/6 or 4/6 where the hue is 5YR or less. Similarly, the presence or absence of an A_2 horizon shows no significant co-variant properties on the soil profile, and is therefore not a classification characteristic for these soils. The B horizons in this group may be clay, with nodules or weathered rock material (Munmarlary family) or mottled (Woolner), or sandy clay loam (Basedow) with mottles (Magela).

The "yellow earth type" soils are widespread on lower margins of the lateritic surface, on slopes in the hill country, and on alluvial plains. They have major differences between each area. On the Koolpinyah surface, Koolpinyah family has loose or soft sandy surfaces and commonly high amounts of nodules or laterite; on the dissected southern margins of the Koolpinyah surface, the Cullen soils are yellow-grey with similar loose surfaces and stony with light mottling. Gradational textures in Koolpinyah family are often weak, particularly in the transition zone to the associated (uniform-textured) Baroalba family where rare profiles with a notation of Uc4.2 have been recorded. On the other hand, the yellow earths of the foothills and alluvial plains (Elliott and Batten families) have massive loamy surfaces which are of hard consistence in the dry state.

Soils with a smooth ped fabric in the B horizon (Gn3) are confined to the lowest hill-slope units and the flood-plains. They are all alkaline in the B horizon and may have a morphology similar to Elliott family, as in McKinlay family, or typical of solodized solonetz soils (structured B horizons and an A_2 horizon which may be bleached) as in Stapleton family. Strongly bleached dome crests of columnar structure which have shown an intermediate texture between the loamy surface soil and the clay B horizon, giving a primary profile form of (Gn), typify Moline family in this group.

Weakly pedal clay B horizons with a rough ped fabric (Gn4) are represented in Marrakai (acid) and Woolwonga (alkaline) families, typical of poorly drained sites on the alluvial flood-plains.

(*d*) *Soils with Contrasting Texture Profiles*

Duplex profiles observed in the area fall into either the yellow subsoil (Dy) or dark subsoil (Dd) group. The Dy soils are developed in treeless areas of the alluvial flood-plains throughout the survey area. Margaret family soils (Dy3.1, 3.2, 3.3) have a typical solodized solonetz morphology in contrast to Jim Jim family (Dy3.5, 3.6, 3.7) which has a massive alkaline clay B horizon. Cooinda soils (Dd1) are located only in paperbark swamps and frequently have very peaty surface horizons.

In Table 9 the principal features of all soil families are summarized and the observed range of Northcote's (1965) notation is given for each family. Descriptions of generalized soil profiles representing the families defined in this survey are given in Appendix I. Where possible the families of the Adelaide–Alligator area are correlated (Table 9) with other soil families described from neighbouring areas of northern Australia, but in many cases the correlation is weak. The approximate equivalent great soil group name is included to indicate the relationship of these soils in the manner of previous soil reports.

TABLE 10

DISTRIBUTION OF SOIL FAMILIES IN THE LAND SYSTEMS OF THE ADELAIDE–ALLIGATOR AREA

Total area (sq miles) of land system with each soil

Soil Association and Family	Dissected Foothills, Granite Hills, and Buldiva Plateau						Koolpinyah Surface									Alluvial Flood-plains				Recent Coastal Plains				Total Area (sq miles)
	Rugged Terrain			Rolling to Hilly			Stripped and Eroded, Rolling			Intact Surface, Stripped Margins			High-level Sand Plain and Margins			Sandy		Silty						
	Baker	Buldiva	Currency	Cully	Bend	Rumwaggon	Jay	Keefers Hut	Kysto	Kay	Keating	Kosher	Queue	Knifehandle	Krokane	Effington	McKinlay	Flatwood	Fabian	Cyperus	Copeman	Pinwinkle	Littoral	
Shallow stony Gn, Uc, and Um soils and rock																								
Skeletal and outcrop	725	25	15	30	410	205	45	20	20									<5	<5					1495
Angelara					30	70																		100
Cullen	40	<5	5	15			135																	195
Yellow loamy Gn soils from weathered parent rock on slopes and recent flood-plains																								
Masson			<5	50																				50
Elliott	85		<5	10	130	140	80	80	35								15	270	35					880
McKinlay						35												30	10					75
Batten					60	70																		130
Stapleton					35	50												55	10					150
Red loamy Gn and Uc soils on laterite and derived soils on margins																								
Munmarlary		<5			80	35	140	80	60	20		25		30										470
Cahill	115	5			65			110	20	390		40		20										765
Hotham								50	45	305	5	25		50	15									495
Berrimah										70	10	45		20										145
Woolner							110				45	10												165
Yellow sandy Uc and Gn soils																								
Koolpinyah							25	135	40	35	115	205		50	20							15		640
Murrabibbi												45			5	5						15		70

Red sandy Uc and Gn soils																							
Cockatoo	< 5			< 5					10		10	200			5								225
Basedow									10	10	25	20											65
Coarse-textured alluvial and colluvial Uc and Dy soils on eastern rivers, plains, and margin																							
Kapalga				< 5					45	< 5	25	5	40	15									130
Baroalba								20			40	15	75	20	35	15							220
Magela															20	20							40
Howard		< 5	30				20			10	10		50	5	5	5	25						160
Nourlangie			5				20			10	10		5	20	5								75
Jim Jim													5	20	5	30							60
Fine-textured alluvial Um and Gn soils of western rivers																							
Marrakai				15						5		5		20	20	30	75	45					215
Woolwonga						20					10		15			20							65
Mary				< 5												40		< 5					40
Frances																5							5
Katherine																30							30
Moline					35											20		20					75
Margaret					70											15	30	80					195
Black Ug clays																							
Adelaide																			60				60
Wildman																			410	100	95		605
Carmor																			490	40	5		535
Counamoul																			60		20	5	85
Black Ug and Dd peaty swamp soils																							
Cairncurry																			25		115		140
Dashwood																			30	20			50
Cooinda																					75		75
Saline Uf clays and beach ridge Uc sands																							
Carpentaria																			30			165	195
Dune sands																			60			35	95
Saline muds																						40	40
Miscellaneous land																							
Water and channels									15	5		5		15	20	25	55	20	60	40		25	285

III. Soil Geography

(a) General

In Table 10 the area of distribution of each soil family is arranged into four broad geographic zones. These zones are derived from the types of country detailed in Part VI and are the dissected foothills, granite hills, and Buldiva plateau; the Koolpinyah surface; the alluvial flood-plains; and the coastal plains.

In each of these zones the soil families that are consistently related within, and in some cases confined to, the zone are grouped together. In this context overlapping areas, i.e. land systems with soil components of two or more adjacent land systems, have distinct genetic connotations. Keefers Hut, Jay, and Kysto land systems have (Table 10) soils derived from weathered sandstone rocks (Elliott family) typical of the dissected foothills and large areas of soils dominant on the Koolpinyah surface (Munmarlary, Cahill, Hotham, Woolner, and Koolpinyah families). The geomorphic relationships of these two groups of soils in these land systems suggest that these land systems were formerly part of an extensive lateritic surface now dissected and in which the laterites and their associated soils form remnants on hill crests or mesa-like areas.

Laterite types and their distribution are detailed in Parts V and VI. Laterite is an important feature of the soils in some areas, particularly on the Koolpinyah surface where it is normally associated with shallow sandy gravelly soils and lowers the agronomic value of the areas in which it occurs.

The high-level mesas of the Bradshaw surface (Wright 1963), with massive laterite cap rocks and associated deep-weathering profiles, are not represented in the Adelaide–Alligator area. In the dissected foothills (Bend land system) laterite occurs sporadically on hill crests in several forms. It is here associated with Cahill and Munmarlary families. Laterite outcrops, however, were not always seen with these soils and their occurrence may in places be representative of a late stage of laterite disintegration.

In Bend land system (unit 4) and Keefers Hut land system (unit 4) laterite blocks may be present as relict features outcropping in Elliott soils. The laterites in this case appear to be neither actively forming nor contributing to soil formation by weathering and disintegration.

The major area of laterite distribution is in the land systems of the Koolpinyah surface. On the higher parts of the surface in Kay and Keating land systems, laterite outcrops form conspicuous features in areas of Koolpinyah and Munmarlary soils. Berrimah, Hotham, and Cahill soils of the intact surface (unit 1 of Kay land system) rarely, however, have laterites. Hotham and Cahill soils have high amounts of loose ironstone nodules presumably due to a concentration as "lag gravels" by a washing out of finer fractions under high-intensity wet-season rains. The nodules are also locally concentrated in soil debris exposed on tree roots by windfall. They rest abruptly on weathered and mottled Cretaceous sediments in many areas, particularly in the north of the area.

On the lower components of the Koolpinyah surface (Knifehandle, Kosher, and Krokane land systems), Woolner, Koolpinyah, and Munmarlary soils are often associated with arcuate outcrops of laterite marking distinct breaks in slope at low levels. The B horizon of the Woolner family (described in detail in Appendix I) shows strong affinities with the hardened vesicular laterite common in Koolpinyah soils in a location downslope of the Woolner soils.

Laterite outcrops are also sporadic along the outer margins of Queue land system (units 1 and 3). This is mostly a detrital laterite of strongly weathered quartzose sandstone and rounded quartz stones, and a similar deposit in a soft condition has been observed underlying the Cockatoo soils in road cuttings and deep bores in Queue land system (unit 1) and under Basedow soils in unit 3 of Queue land system.

In Buldiva land system (unit 2), Cockatoo soils have also been described associated with Cahill and Munmarlary soils and laterite outcrops. This land system is small in the Adelaide–Alligator area and the soil association in unit 2 has been observed in only a few areas. The distribution of these soils and the nature of the land system unit are very similar to those described for the Junction soil complex in the Ord River area by Burvill (1944).

As suggested above, laterite is associated with a relatively limited number of soil families of the total soils described in the Adelaide–Alligator area. Some soil sequences have been observed where laterite is absent or very restricted in occurrence. It is these sequences that show most clearly the distinctive geographic zonation of this area.

(*b*) *Soils of the Dissected Foothills*

Skeletal soils dominate in most of the units of Baker, Buldiva, and Currency land systems of the rugged high country, sandstone plateau areas, and rugged granite intrusives where they form very shallow coarse sandy deposits in between rock outcrops. Although these soils are also dominant in Bend and Rumwaggon land systems, they are invariably associated with other soils that indicate the lesser slope and lower relief characteristics of these land systems. Elliott soils are present on most slopes below 5% and are dominant or subdominant in land systems where colluvial slope or valley floor units occur below crests with skeletal soils (Baker, unit 4; Bend, unit 2; Rumwaggon, unit 1). They are represented in many cases by a shallow stony phase and the transition zone between Elliott and skeletal soils is often vague. The soil surface is frequently stony (up to Class IV or V (United States Department of Agriculture 1951)), with a sporadic thin sandy layer or with a hardened flaky surface caused by raindrop impact.

Rumwaggon land system represents a lower, more eroded version of Bend land system with up to 50% of its area as alluvial flats. Elliott soils are located on hill crests (Rumwaggon land system, unit 1), replacing the Cahill soils typical of Bend land system and skeletal soils typical of both Bend and Baker land systems. The increase in dominance of the more developed Batten soils and Stapleton soils on lower slope units is a marked feature in unit 3 of Rumwaggon land system.

A catenary relationship in topographic position and degree of profile development can be observed in the sequence Elliott–Batten–Stapleton–Moline–Margaret soils. An increasing trend to texture contrast with dominance of a clay B horizon in Moline and Margaret soils, a change in reaction from acid (Elliott) to alkaline (Stapleton, Moline, Margaret), and a change in dominant metal cation from calcium in the B horizon of Elliott soils on upper slopes to magnesium in Stapleton and sodium in Margaret soils show this relationship.

Elliott family is common throughout the Katherine–Darwin region (Stewart 1956) and most other areas described in northern Australia, but the distinction between this soil and Batten family has not always been made. Stewart (1956, p. 58) accounted for the yellow colours of Elliott soil as being due to a lower content of iron oxides in hydrated forms with iron concentrations in mottles, concretions, or nodules owing to poor drainage above an impermeable lower B or C horizon. These iron oxides form largely as mottles which become cemented in the dry season and indicate current segregation (G. A. Stewart and G. D. Smith, quoted in van de Graaff 1965, p. 74). Rounded nodules are also commonly present and may be due to both subsequent transport of these cemented mottles owing to erosion and to forms inherited where laterite remnants may be present. In Elliott soils of alluvial flood-plains (Flatwood land system), segregation of iron and manganese marks seasonal high water-table levels.

The higher rainfall of the Adelaide–Alligator area (compared with the Tipperary area) would compound the leaching effect of percolating drainage water and account for the predominantly grey-coloured A_2 horizon in Batten and Stapleton soils common to this area.

Recent research in the Adelaide–Alligator area has also recognized the polygenetic nature of many skeletal and Elliott soils (Appendix I). The underlying shale strata in this instance may be both acid and alkaline. The latter form, where exposed to the surface on gently rolling topography in valley areas, forms Angelara family and probably contributes sodium and magnesium ions on the formation of alluvial solodized solonetz soils (Moline and Margaret families). McKinlay family is apparently polygenetic with an Elliott profile morphology, derived from sandstones, over these alkaline shales, and has recently been observed by the author also in the Ord River area.

It is possible therefore that the catena of Elliott–Batten–Stapleton may be complicated by the occurrence of alkaline shales in Stapleton family and not detected in auger sampling. Differences in soil drainage between the impermeable shale-derived clays and the more porous, often stony, sandstone-derived clays (the true B or B–C horizons in an Elliott soil) may also be significant in the development of A_2 horizons and the amounts of iron nodules present, and also in the distribution of termitaria on these soils.

(*c*) *Soils of the Koolpinyah Surface*

Low undulating or level topography forming broad salients between the major rivers characterizes this type of country. Shallow, generally narrow valleys are cut into the surface and rounded or elliptical internal drainage depressions, often in linear groups, are widespread.

Under the present monsoonal climate, characterized by intense rainfall over part of the year (November–March) followed by extreme desiccation for 6–7 months, rapid soil formation by chemical weathering is inhibited, and wasting is the dominant regime. Selective removal of finer fractions leads to the development of coarse, mostly gravelly soils on the upper surface (Stephens 1946). Sandy, extremely leached soils with associated laterite outcrops dominate on lower slopes, usually in a well-defined sequence. A pinkish white sandy surface deposit is a characteristic feature of the surface of all soils on the higher areas of the plains.

In Figure 17, some of the major soils are illustrated with reference to their characteristic site distribution. This figure also shows the principal soils of the catena characteristic of the Koolpinyah surface, but not completely in the order in which these soils may be observed in a traverse from Kay land system through Keating to the lower-level Kosher, Krokane, or Knifehandle land systems. Berrimah, Hotham, and Cahill soils are regarded as the initial high-level phase of this catena, and, although dominant, the Cahill soil is not shown in Figure 17 because of the extreme profile degradation of this soil.

The deep red Berrimah soils occupy a small area in Kay land system and appear as an associated soil in several other land systems. Some minor occurrences of a sandy form of Berrimah family, still within the limits as defined in the profile (Appendix I), have been found on lower slopes near areas of high water-table (Kosher land system, unit 1; Knifehandle land system, unit 2). In unit 2 of Keating and unit 3 of Kosher land systems, Berrimah soil is generally confined to low spurs existing as remnants of the higher-level surface in a stripped and eroded landscape, and is located under groves of open forest or woodland which occur sporadically on higher sites in these areas. The overwhelming dominance of Hotham and Cahill soils is a significant indicator of the prevailing process of soil wastage. The widespread occurrence of Cahill soils, ranked third in total area in Table 10, is partially over-emphasized by the classification that has included many shallow, very gravelly soils, or dense "lag" masses of concretions ($\frac{1}{8}$–$\frac{3}{4}$ in. diam.) and nodules with little or no soil matrix.

The gradational soils with lighter-coloured A horizons and red clay B horizons represented by the Woolner soil profile in Figure 17 also include Munmarlary and Basedow soils and occupy the second phase of the catena. These soils are found where ground slopes have increased often by as little as 0·25% but where little change can be observed in vegetation. The tall open forest of *E. miniata* and *E. tetrodonta* may change to woodland, but species or composition changes are very slight. This is well marked in unit 1 of Keating land system and less well marked in units 2 and 3 of Kosher or unit 1 of Knifehandle. Most of the vesicular laterite exposed on bare shrubby areas within unit 3 of Kosher is similar in the shape and organization of concretions and hardened iron-rich zones to the Woolner B horizon, and occurs nearly always downslope of these soils. Koolpinyah soil, strongly depleted of iron and clay and resting on hardened laterite or with exposed laterite, is a dominant soil in a wide variety of sloping sites. Its dominance on the upper surface is related mainly to sloping sites mapped within these land systems, or to areas where stripping has removed all traces of the higher-level soils and the topography consists mainly of low undulating domes with little or no level crest surface, often the case in unit 1 of Keating land system.

Baroalba and Kapalga soils, or gravelly phases of these families, on sandy wash slopes in Knifehandle, Krokane, and Kosher land systems, often succeed Koolpinyah soils. In units 1 and 4 of Kosher land system these soils are characteristic of valley-like depressions separated by long low spurs of Berrimah, Hotham, and Cahill soils

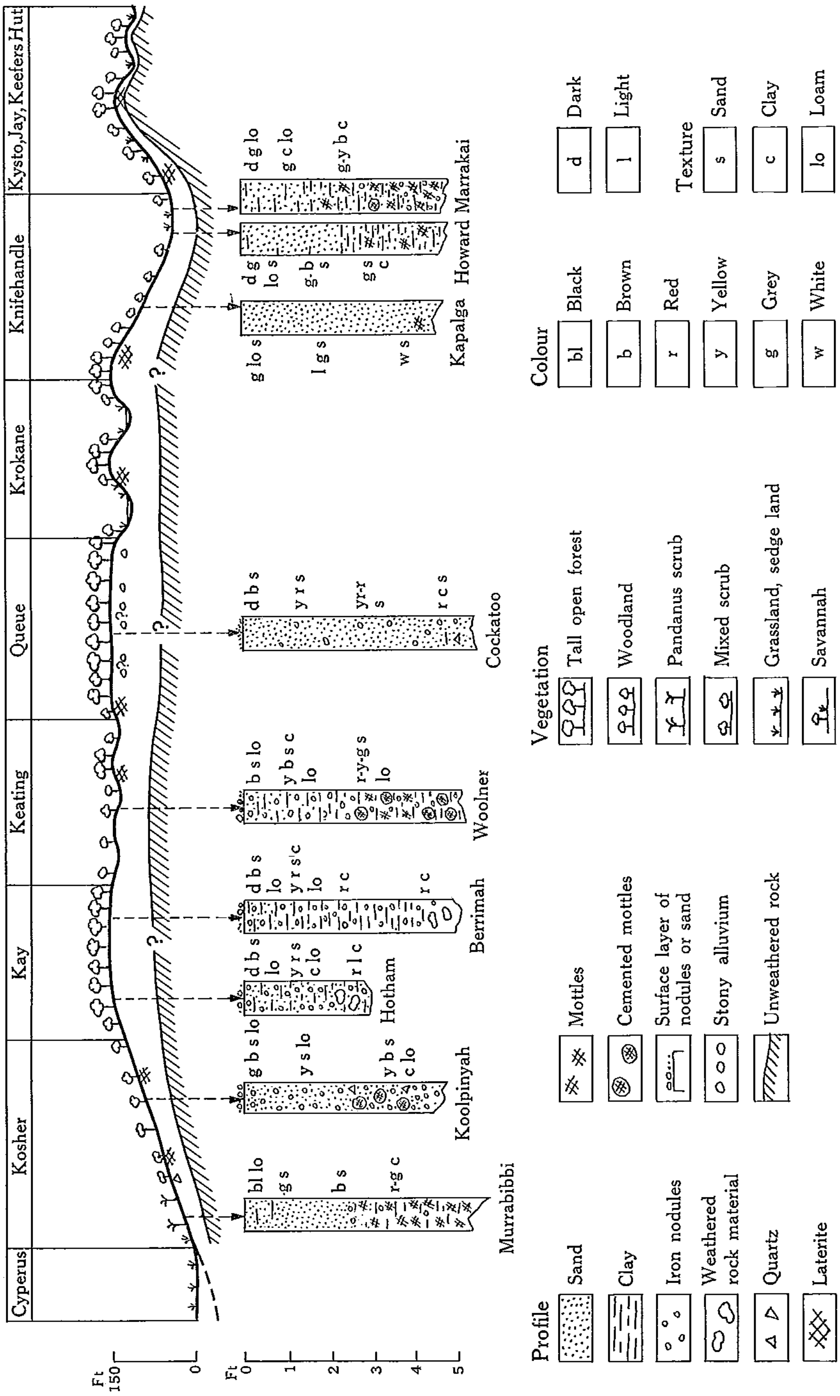

Fig. 17.—Diagrammatic cross-section of the Koolpinyah surface showing characteristic distribution of some dominant soils and vegetation.

on higher areas nearer to the upper (Kay or Keating land system) surface (unit 3 of Kosher), and Koolpinyah soils on lower sites of the spurs as in Kosher (units 2 and 3).

The final phase of the catena varies. On the margin of the coastal plains (unit 4 and part of unit 1 of Kosher land system) Woolner soils often pass into Murrabibbi soils with no laterite outcrops or associated sandy soils. In Knifehandle and Krokane land systems and on the margins of Effington land system, Koolpinyah, Kapalga, and Baroalba soils react quickly to poorer drainage conditions, and clay horizons beneath the sandy surface material become well developed to form the Howard and Nourlangie soil families.

As stripping and dissection of the Koolpinyah surface increase, the major soils become confined to limited remnant crest zones or adjacent wash slopes, and parent rock becomes exposed to initiate a new cycle of soil formation. Skeletal, Cullen, and Elliott soils are found dominant or subdominant on slopes or on alluvial flats within the transitional Kysto, Keefers Hut, and Jay land systems.

In comparison with this sequence is the catena developed on the high-level sand plains of Queue land system. The lower slope members of this catena are similar to those of the lower slopes subtending the Koolpinyah surface, and indicate once again the importance of process in the genesis of the present soils in this area (Fig. 17).

Cockatoo soils, exclusively dominant in unit 1 of Queue land system, are deep sandy soils which, wherever observed to depth, were underlain with an abrupt boundary by water-worn or rounded quartz stones of 2–3-in. diam. or ferruginized rounded gravels of quartz-rich rocks. Internal drainage depressions within Queue land system are often linear and connected by sandy dry channels or spillways with Baroalba soils, suggesting an alluvial origin. This contrasts with the many isolated depressions of other land systems on the Koolpinyah surface which appear, at least in some cases, to be genetically related to underlying dolomitic strata (see Part VI). The detrital laterite cropping out on the margins of unit 1 of Queue land system and in unit 3 may form a barrier to further erosion and as such is likely to be instrumental in maintaining their position as topographic highs in the present landscape. On the other hand, the origin of the red soils of Kay land system is more doubtful. It is ascribed in this report (Part VI) to cyclic weathering and erosion of the former high-level surface (Bradshaw surface of Wright 1963). However, recent African work on broadly similar areas shows striking comparison in the types of deposits of recent low-level plains of lateritic soils. Moss (1965) has described in detail some of these deposits, which he attributes to colluvial deposition of debris derived from the back-wearing of high-level laterite scarps.

Baroalba and Kapalga soils in unit 2 of Queue and in unit 2 of Knifehandle land systems grade, with increasing height of the water-table, to the Howard soils as described above. These soils may be polygenetic but could be related to the deposition of clay, in sheet wash from the upper surface, within the existing sand layers. Where these soils are subject to ponding of water in the wet season, carbonate deposits have formed in the clay horizon (Nourlangie family). Marrakai soils of the alluvial flats in the lateritic plains are generally located in central zones of the flats where seasonal streams in grassed drainage-ways have deposited silty materials.

(*d*) *Soils of the Alluvial Flood-plains*

Soils developed on the alluvium of the flood-plains and valleys fall into three broad categories in which soil characteristics are mainly determined by the type of parent material and drainage.

East of the South Alligator River, the major creeks rise in the arenaceous rocks of the Arnhem Land plateau (Buldiva land system) and reflect this origin in dominantly coarse sand bed-loads and soils. Braided channels and sand-bars are a feature of the creek channels.

Alluvial flats on the Koolpinyah surface have dominantly sandy soils similarly derived from arenaceous parent materials. Some of these soils are also common on the higher stable river flats of the eastern river system. Streams are small and rarely show well-defined channels.

On the large alluvial plains, levees, and terraces of the Mary, McKinlay, Margaret, and Adelaide Rivers ("the western rivers"), the soils are dominantly fine-textured and are derived from a wide variety of parent rocks in the dissected foothill country. The main rivers are deeply incised into the valley fill deposits and are flanked by well-developed levees. Sandy bed-loads occur irregularly on the floors of the incised channels.

These categories are discussed in more detail below. In the eastern rivers area represented by Effington and McKinlay (unit 1) land systems, Baroalba soils dominate over most of the area, with Marrakai soils in the same relationship as in the alluvium derived from the Koolpinyah surface. On higher sites, subject to seasonal water-table fluctuations, Magela soils occur and generally grade to higher levels with typical Cockatoo soils on terrace sites. The braided channels of unit 1 of McKinlay land system show a dominance again of Baroalba soils, with Jim Jim soils present in minor levee back plains or low-lying central zones between the channels and the margin of the higher country, an environment essentially similar to that of solodized solonetz soils of the western rivers.

The western rivers area is dominated by an entirely different group of soils, apart from the ubiquitous Marrakai family confined to moist depression sites. Mary soils are dominant in low-lying recent flood-plains and levees of all land systems (McKinlay, Fabian, Flatwood), but, as these sites comprise a relatively small total area, Mary soils rank very low in distribution as represented in Table 10. Higher flood-plain sites with characteristically high seasonal water-tables are dominated by McKinlay and Elliott families. These soils occupy large areas of Flatwood land system on flat to gently undulating recent flood-plains, or slightly raised older terrace sites, under a woodland or savannah vegetation. Surface wash is common, the soil surface is always smooth, and scalded bare areas are common. Both families have characteristic D horizons of cemented vesicular mottles and concretions of iron and manganese, often in multiple layers, in the profile.

The families of solonetzic soils (Moline and Margaret) have been found covering large areas of generally shallow basins or wide open grassy flats (unit 5 of McKinlay or unit 1 of Fabian land system) and extending into the hill country in narrow valley floors (e.g. unit 2 of Rumwaggon land system). The soil surface, generally burnt bare of its grass cover in the dry season, is characterized by small mounds of fine dusty surface soil presumably built by burrowing worms around a central core of grass, locally termed "debil-debil". The size of these mounds sometimes correlates with the depth of the A horizon. Where the A horizon is less than 9 in. deep, small ($\frac{1}{2}$–3 in. high) mounds occur, and when the A horizon is 9–15 in. deep or more, the mounds are 3–6 in. and often up to 12 in. in height. Very shallow A horizons show a smooth soil surface.

The gradational texture profile of Moline and Stapleton soils, which show marked properties of typical solodized solonetz soils, may be due to strong leaching of the domed area of the columnar structure. Concretions, which form commonly over the domes in Margaret family by a concentration of iron-rich waters that saturate the A horizons of these soils in the wet season, occur also sporadically in the same position in Moline and Stapleton soils, and may be derived from the physical or chemical weathering of iron-rich materials on soils of the higher country.

(*e*) *Soils of the Coastal Plains*

The low-lying estuarine plains of the main rivers are extensive, uniform, and flat. At the inland margins of the plains, the northward-flowing rivers distribute into a disconnected series of long deep billabongs or wide shallow swamps flanked or choked by dense forests of *Melaleuca.* Tongues of sandy alluvium penetrate this zone in the eastern rivers area, where also a black sandy loam veneer over clay (Cooinda family) is typical in the green meadow lands on small, seasonally dry zones in the swamps (units 1 and 2 of Pinwinkle land system). Separating these wooded swampy zones and meadow lands also in the eastern rivers area, are bare areas of the inland plains (unit 4 of Pinwinkle land system). The clay soils are underlain in this case by sandy deposits (Counamoul family).

In the west, a veneer of silty alluvium borders the major billabongs (river channels in the wet season) to a distance of up to 15 miles from the mapped border of McKinlay and Cyperus land systems. All main rivers, except the Mary, re-form seaward of this zone and rapidly widen into meandering estuarine channels, fringed with mangrove, which carry influxes of sea water in the dry season. A mosaic pattern of low-lying swampy ground with many channels and billabongs fringes, and is often connected to, the main river channels, and sea water may penetrate these swampy zones. These are separated from the higher country by wide plains with extensive swampy zones which, however, generally dry out completely in the dry season and may carry only isolated drainage channels. Often fringing the Koolpinyah surface, particularly in embayments, are more extensive swamps of *Melaleuca* or sedges, with almost permanent water derived from seepage from the high-level surface. In the Mary River plains, a long history of instability is evidenced at present by numerous abandoned channels and meander cut-offs without a major outlet to the sea, and large areas of *Melaleuca* swamp.

Under this estuarine environment and seasonal flooding which apparently covers the plains, dense heavy clays have been formed which show a common property of shrinkage and cracking in the dry season into coarse polygons between 6 and 12 in. across and with cracks from $\frac{1}{2}$ to 4 in. wide. In swampy localities and on the inland zones where organic material or higher sand fractions are present in the clays, cracking is much less frequent and sometimes not present at all. A thin transition zone often underlies the black clay A horizon where cracking penetrates in the dry season, and surface material falling into these cracks becomes mixed as irregular large black mottles. The horizons below this transition zone are mainly grey, saline, estuarine muds over the greater part of the plains.

The Wildman family occupies the dominant position among the soils of the swampy areas of the plains (unit 1 of Copeman, unit 2 of Cyperus, units 1 and 2 of Pinwinkle land systems), and is subdominant on the "higher" plains area in unit 1 of Cyperus land system because of the intensely complex nature of this area. Where the plains dry rapidly in the dry season (unit 1 of Cyperus land system), and especially near old river channel sites, Carmor soils (with carbonate) are dominant. The minor Adelaide soil (Table 10) is closely associated with Carmor soils and is confined to river levee sites with a minor gilgai microrelief. On the margin of the Koolpinyah surface, Koolpinyah and Murrabibbi soils share dominance (unit 3 of Pinwinkle land system), extending into the fringing swamps, and elsewhere Counamoul soils, with, in this case, the same D horizon as Murrabibbi soils, may occupy quite considerable marginal zones (up to 400 yd wide).

Cairncurry and Dashwood soils are located primarily in very swampy sites, the Cairncurry soil under *Melaleuca*. Cairncurry soil with its distinctive red mottled A horizon and dense gypsic A–C or D horizon is often found on "dry" plains areas, but in nearly all cases where samples were taken at depth in these soils peaty swamp deposits were found, and the soil thus forms a useful indicator of former conditions.

On the littoral fringe (unit 1 of Littoral land system) wide bare flats of salt-saturated clays of Carpentaria family, periodically flooded by tides, are dominant. These flats are fringed on the seaward side and on river banks up to 30 miles from the coast by dense mangrove communities (unit 2 of Littoral land system) on saline muds. Long dune ridges cut through the plains marking former strand lines, and these are often margined by soils of Counamoul family. In the coastal dune complex (unit 3 of Littoral land system), soils of similar (Counamoul) morphology have been described from inter-dune swales, but where these are saline they have been included with Carpentaria family.

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PART VIII. VEGETATION OF THE ADELAIDE–ALLIGATOR AREA

By R. Story*

I. Introduction

(a) *General Remarks*

The following points should be noted:

(1) Where only the generic name is given it refers to the genus in general, or to one particular species if only one is listed in Appendix II.

(2) The available common names of the plants mentioned are listed in Appendix II.

(3) *E.* is used throughout for *Eucalyptus.*

(4) Trees, shrubs, and grasses are listed alphabetically if they are equally common, otherwise the most common come first.

The vegetation of the Adelaide–Alligator area is part of the much larger complex that has been described by Christian and Stewart (1953) for the Katherine–Darwin area and by Specht (1958) for Arnhem Land. This material has been consulted and drawn upon where appropriate for the writing of the Adelaide–Alligator report, as has that of Blake (1953, 1954) which gives information on the floristics and ecology, particularly of the eucalypts.

The Adelaide–Alligator area is about 800 miles from the equator, and the tropical climate is reflected by the character of the vegetation, e.g. in the rain forest by buttresses, lianes, broad leaves, tropical genera, and a rich flora, and elsewhere by the abundance of *Pandanus,* palms, cycads, and tall grass, including bamboos along many of the larger creeks. As stated by Christian and Stewart (1953), rain forest is found only in moist or sheltered spots near the coast, for the unbroken winter drought imposes conditions that are too harsh for it elsewhere, and most of the area is covered by grassy eucalypt forest or woodland, with an understorey of mainly deciduous non-eucalypt trees. The severe climate is reflected also in the eucalypts. About half of the 18 species recorded were deciduous, which is a most unusual feature of the genus.

Of the grasses under the eucalypts, annuals cover about two-fifths of the ground, and perennials three-fifths. Independently of their life history they fall into three other categories — tall, mid-height, and short — which cover the ground in the approximate ratio of 2:2:1. On the whole the grasses are in smaller and more fragmented communities than the woody growth, and not as closely tied to differences in the environment. Their occurrence in the land systems is given in Tables 11 and 12.

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(b) *The Environment*

(i) *Climate*.—Towards the coast the severity of the winter drought is tempered by the sea and by the earlier onset and later ending of the rainy season. The response in the vegetation is shown in the patches of rain forest that have already been mentioned, in patches of semi-deciduous forest, and by clumps and scattered individuals of non-eucalypt trees that are rare or absent in the drier country to the south (e.g. *Alstonia, Canarium, Eugenia, Parinari*). No corresponding change could be detected in the ground cover, but as it was at best dormant and at worst extensively and freshly burnt, there may well have been differences that went unobserved.

TABLE 11

NUMBER OF OBSERVATIONS IN WHICH PERENNIAL OR ANNUAL GRASSES WERE DOMINANT

Land System	Perennials	Annuals
Baker	30	15
Buldiva	1	5
Bend	48	22
Cyperus	N.a.*	N.a.
Copeman	N.a.	N.a.
Cully	16	2
Currency	5	1
Effington	9	9
Fabian	6	0
Flatwood	17	4
Jay	5	7
Kay	8	18
Keating	7	2
Keefers Hut	7	16
Knifehandle	11	7
Kosher	21	19
Krokane	10	5
Kysto	9	8
Littoral	N.a.	N.a.
McKinlay	27	3
Pinwinkle	N.a.	N.a.
Queue	1	7
Rumwaggon	24	9
Total	262	159

* N.a., not applicable.

(ii) *Fire*.—The area is burnt almost completely every dry season, as it has undoubtedly been ever since human occupation and perhaps even before that, for the dense dry tall grass and the eucalypts, especially the seedling eucalypts, make up a vegetation that for inflammability must have few equals in the world. F. H. Bauer (unpublished data) draws attention to Leichhardt's remarks on the fires in or near this area, "Again and again he remarked on the extensive deliberate burning of the open grassy forests and plains by the blacks." The effects cannot at present be assessed because of the lack of unburnt areas for comparison.

(iii) *Animals.*—Grazing by buffaloes is very heavy, causing greater disturbance to the vegetation than that of any other grazing animals, but it is localized because the buffaloes remain close to water. They are concentrated on the estuarine plains of Cyperus, Copeman, and Pinwinkle land systems, on the alluvial flats of Fabian, Flatwood, Rumwaggon, and Effington, and on other land systems where springs and billabongs are found, being most plentiful in remote places where they have not been thinned by shooters. At the time of the survey, nearly all of the estuarine plains had been heavily puddled by their hoofs. Tulloch, in an unpublished report, draws attention to the heavy grazing in these places, and the consequent lack of any reserve

TABLE 12

NUMBER OF OBSERVATIONS IN WHICH TALL, MID-HEIGHT, OR SHORT GRASSES WERE DOMINANT

Land System	Tall	Mid-height	Short
Baker	35	17	4
Buldiva	5	2	2
Bend	33	31	2
Cyperus	N.a.*	N.a.	N.a.
Copeman	N.a.	N.a.	N.a.
Cully	8	9	2
Currency	5	1	2
Effington	6	7	6
Fabian	1	7	1
Flatwood	8	12	4
Jay	10	4	1
Kay	12	6	10
Keating	2	6	2
Keefers Hut	13	8	5
Knifehandle	7	6	3
Kosher	0	13	18
Krokane	3	7	4
Kysto	8	9	3
Littoral	N.a.	N.a.	N.a.
McKinlay	10	11	6
Pinwinkle	N.a.	N.a.	N.a.
Queue	5	2	0
Rumwaggon	11	24	5
Total	182	182	80

* N.a., not applicable.

feed: "Towards the end of the dry season a food shortage frequently develops, for much of the high black soil is almost devoid of vegetation; in some areas fires are a regular occurrence, and each year destroy vast quantities of feed, not only on the sub-coastal plains, but also throughout large areas of the northern portion of the Northern Territory. If the wet season is late in arriving, this shortage can be very serious, and many animals will die." Their influence on the alluvial and estuarine areas is difficult to assess, as is the influence of burning elsewhere, and for the same reason, that no part is undisturbed. Changes do seem to have occurred since the original survey by Christian and Stewart (1953), for several of the plants they list from the estuarine plains, which were presumably important, were either not seen on the present survey or were uncommon (*Imperata*, *Oryza*, *Eleocharis*, and *Phragmites*). Details are given in Table 13. In the surroundings, also heavily trampled, the vegetation is usually of short annual grasses with much *Stylosanthes* in sandy areas (Kosher land system) and with *Hyptis* locally abundant.

Cattle numbers were far behind those of the buffalo and the vegetation is at present virtually unaffected by them except on the more developed stations, where some denudation is apparent near yards and watering points. Wild pigs and brumbies are fewer still. Of the various species of termites represented, those which build the so-called "magnetic" termitaria are probably best known. Their termitaria are up to 5 ft high and shaped rather like an erect hand, the long horizontal axis being aligned north and south. On the whole, however, grass-cutting termites are not important. They forage only within a few yards' radius of the termitarium, are uncommon except in savannah or grassland (Effington, Flatwood, Fabian land systems, unit 2 of Rumwaggon and unit 4 of Kosher), and are localized even there. It is noteworthy that they are abundant throughout the drier Tipperary area (Speck 1965, p. 87). Indigenous grazing animals are a rarity and have little effect. It is doubtful if more than 50 wallabies were seen during the whole field period, in spite of the large areas visible from the helicopter; the buffaloes, on the other hand, could be observed by the thousand.

(iv) *Edaphic Factors*.—Rocky hills with skeletal soils (Baker and Bend land systems, unit 1 of Rumwaggon) support a characteristic and mostly deciduous woodland of *E. bleeseri*, *E. clavigera*, *E. dichromophloia*, and *E. foelscheana*, but two modifications were noted which were related to certain rocks. These were that *E. alba* dominated the vegetation on chert, and that *E. tectifica* occurred only on siltstone. Regardless of the lithology, non-eucalypt trees of many kinds are common where the country is broken by clefts and gorges or where large boulders occur.

On the level well-drained Koolpinyah surface of Kay and Queue land systems, tall open eucalypt forest is the rule, uniform and dense and dominated by *E. miniata* and *E. tetrodonta*. On adjoining slopes, or where the level surface is stripped, these trees become shorter and more open, and indeed subordinate in places to the non-eucalypts.

Black cracking clays subject to waterlogging or prolonged flooding (Pinwinkle, Cyperus, and Copeman land systems) support paperbark forest, sedge land, or herbaceous swamp vegetation. Solodized solonetz soils which are intermittently flooded support grassland or open savannah. They occur on the alluvial flood-plains of Effington, Flatwood, Fabian, and Rumwaggon land systems.

(*c*) *Diagnostic Characters of the Vegetation Types*

For the purposes of this report, 15 vegetation types are distinguished, some grading into one another like the tall open forest and the woodland, others with no close affinities like the mangrove scrub. Overall, they cannot be fitted to any logical floristic or ecological arrangement. As a makeshift, woody types are taken

TABLE 13

DIFFERENCES IN THE VEGETATION IN THE KATHERINE–DARWIN, TIPPERARY, AND ADELAIDE–ALLIGATOR AREAS

Species	Katherine–Darwin	Tipperary	Adelaide–Alligator
Acacia shirleyi	Exploitable thickets	Scattered stands	Not recorded
Bauhinia spp.	Common in deciduous parkland	Common in deciduous parkland	Not recorded
Callitris sp.	Small areas	Small areas	Negligible
Casuarina cunninghamii	Universally prominent on major streams	Characteristic along perennial streams	Not recorded
Eucalyptus camaldulensis	On Daly River system, and prominent in deciduous parkland	Characteristic along perennial or ephemeral streams	Rare
E. microtheca	Common in deciduous parkland	Occasional in fringing forest	Not recorded
Nauclea orientalis	Universally prominent on major streams	Characteristic along perennial streams	Rare
Aristida spp.	One of main grasses in open forests	Cracking clay; annual species characteristic in open forest	Rare
Arundinella nepalensis	Deciduous parkland	Deciduous parkland	Negligible
Bothriochloa intermedia	Coastal plains, prominent in deciduous parkland	Restricted areas	Not recorded
Chionachne cyathopoda	Dense masses near fringing forests		Not recorded
Dichanthium fecundum	Dominant in deciduous parkland	Restricted areas	Not recorded
Hymenachne amplexicaulis	Coastal plains		Rare
Imperata cylindrica	Coastal plains	Some dense stands in fringing forests	One record
Ischaemum arundinaceum	Dominant in parts of coastal plains		Rare
Iseilema spp.	Deciduous parkland		Not recorded
Leersia hexandra	Coastal plains		Not recorded
Ophiuros exaltatus	Deciduous parkland		Not recorded
Oryza spp.	Dense on main part of coastal plains		Rare
Phragmites karka	Wet places, coastal plains		Not recorded
Plectrachne pungens	One of main grasses in open forests and palm scrubs	Characteristic of open forests	Uncommon
Sehima nervosum	One of main species in open forests	Characteristic in mixed open forest	Not recorded
Stylosanthes spp.	Some round Darwin		Abundant in *Pandanus* scrub near coast

first, with the eucalypt-dominant types first among them, and herbaceous types are taken last. The list, in order, is as follows:

(1) Tall open forest — evergreen eucalypts, *E. tetrodonta* and/or *E. miniata* dominant, height over 40 ft, visibility up to about 100 yd (Katherine–Darwin equivalent tall open forest).

(2) Woodland — eucalypts usually dominant, some deciduous, no canopy, height under 40 ft, visibility 100–300 yd (Katherine–Darwin equivalent low open forest).

(3) Stunted woodland — mainly deciduous eucalypts and non-eucalypts, no canopy, height under 20 ft, visibility about 200 yd (Katherine–Darwin equivalent orchard communities).

(4) Mixed scrub — mainly evergreen non-eucalypts, with *Pandanus* and shrubs, height 25 ft, visibility 60 yd (Katherine–Darwin equivalent in part dwarf *Melaleuca* communities).

(5) *Pandanus* scrub — as for mixed scrub, *Pandanus* dominant (Katherine–Darwin equivalent *Pandanus* scrub).

(6) Leguminous–Myrtaceous scrub — shrubs dominant and dense, height up to about 8 ft (Katherine–Darwin equivalent Leguminous–Myrtaceous scrub).

(7) Paperbark forest — *Melaleuca leucadendron* dominant, height 50 ft, broken or unbroken canopy (Katherine–Darwin equivalent fringing forest and tall *Melaleuca* communities).

(8) Mangrove scrub — unbroken canopy, height 20 ft, visibility 50 yd or less (Katherine–Darwin equivalent in part communities of the littoral).

(9) Rain forest — rich flora of evergreen non-eucalypt trees, unbroken canopy, height up to 100 ft.

(10) Semi-deciduous forest — rich flora of non-eucalypt trees, height below 40 ft, broken canopy (Katherine–Darwin equivalent monsoon forest).

(11) Savannah — scattered trees, height under 40 ft, visibility over 400 yd (Katherine–Darwin equivalent parkland).

(12) Grassland — tall, mid-height, or short grasses, heights 6 ft, 3 ft, and 1 ft respectively (Katherine–Darwin equivalent *Sclerandrium–Leptocarpus* swamp communities and *Themeda–Eriachne* grassland).

(13) Sedge land — Cyperaceae or Restionaceae dominant, height 2 ft (Katherine–Darwin equivalent in part communities of the lagoons).

(14) Herbaceous swamp vegetation — (Katherine–Darwin equivalent in part communities of the lagoons).

(15) Samphire — *Arthrocnemum* dominant (Katherine–Darwin equivalent in part communities of the littoral).

(d) Comparison with the Vegetation of the Katherine–Darwin Region and of the Tipperary Area

Some of the general observations made on the vegetation of the Katherine–Darwin area and the Tipperary area (Speck 1965) do not apply to the warmer and

TABLE 14

RELATION OF VEGETATION TYPES TO LAND SYSTEMS

Areas in sq miles

Land System	Woodland	Tall Open Forest	Sedge Land	Grassland	Savannah	Stunted Woodland	Paperbark Forest	Herbaceous Swamp Vegetation	Mixed Scrub	*Pandanus* Scrub	Bare Ground	Leguminous–Myrtaceous Scrub	Mangrove Scrub	Samphire	Rain Forest or Semi-deciduous Forest	Total
Baker	869			48	48											965
Buldiva	12			10	5										3	30
Bend	413	41		124		247										825
Cyperus			980					245								1225
Copeman			40					160								200
Cully	112			28												140
Currency	18			2												20
Effington				30	72		18									120
Fabian	33			154	22					11						220
Flatwood	108			27	378					27						540
Jay	443	28		28	56											555
Kay		765			45		45					45				900
Keating	96	86			22		11									215
Keefers Hut	205	103		52	26				129							515
Knifehandle	162			72					108			18				360
Kosher				132					157	183		53				525
Krokane		39		45	16		39	16								155
Kysto	96	108		12	24											240
Littoral	14		54								54		94	54		270
McKinlay				93	81		68			14	14					270
Pinwinkle				17			272				51					340
Queue		237					13									250
Rumwaggon	284			71	107	248										710
Total	2865	1407	1074	945	902	495	466	421	394	235	119	116	94	54	3	9590

wetter section covered in this report. Some of them were judged to be untrustworthy (e.g. species hard to recognize) and have been ignored but the most striking, which are likely to be differences in fact, are given in Table 13.

II. Description of the Vegetation Types

In the description that follows, the vegetation types are discussed in a general way with respect to their land system relationships. More detailed information is given in Table 14.

(*a*) *Tall Open Forest* (*1410 sq miles*)

E. miniata and *E. tetrodonta* are the dominant trees. They usually grow together in about equal proportions, and, with lesser amounts of *E. terminalis*, *E. papuana*, *E. clavigera*, and *Erythrophleum*, form a discontinuous thin canopy that admits enough light for most grasses to thrive below it. Other tall trees are rare and are nearly always correlated with some difference in the habitat. They are not normal constituents of the community. Smaller trees, on the other hand, are common everywhere, many branching from near the base and having the form of robust shrubs rather than trees (Speck 1965, p. 92). They vary little from place to place, being characterized by the abundance of *Livistona* and *Pandanus* and by a selection from about 15 other genera, *Acacia* included but nowhere dominant as it is in the drier parts of Australia. Large numbers of their own seedlings, and seedling eucalypts, give a false impression of an undergrowth of low shrubs which are in fact rather uncommon. Cycads have a curiously limited distribution, west of the Adelaide River except for a few outlying patches some miles to the east of the river.

The forest is widespread and, for a community so large and with its components often widely separated, is remarkably uniform. It is between 40 and 60 ft high, with visibility varying between 30 and 200 yd and averaging about 50 yd. There are about 125 trees to the acre that are over 6 in. in diameter, and about 75 from 3 to 6 in.

The characteristic non-eucalypt woody species are as follows (all are below canopy height except *Erythrophleum*): *Erythrophleum chlorostachys*, *Livistona humilis*, *Pandanus*, *Planchonia careya*, *Terminalia ferdinandiana*, *Petalostigma quadriloculare*, *Xanthostemon paradoxus*, *Acacia cunninghamii* sens. lat., *Gardenia megasperma*, *Buchanania obovata*, *Cochlospermum gillivraei*, *Grevillea heliosperma*, *Bossiaea phylloclada*, *Grevillea pteridifolia*, *Acacia mangium*, *Grewia*, *Cycas media* (restricted), and *Maytenus cunninghamii*.

The grass cover is the only really variable component of the tall open forest. Sometimes it is mixed, sometimes in distinct communities of all sizes, and the most likely explanation is that patchy burning has been the cause, for the communities appear uncorrelated with any habitat differences or with any effect of grazing.

The annuals are dominant. Most of them are tall sorghums which form a dense and stalky community about 6 ft high, in the dry season tangled and partly fallen and without any trace of greenness. The short annual grasses, also important, dry out and disintegrate even more quickly than the sorghums after the end of the growing season. The commonest annuals are *Sorghum*, *Thaumastochloa major*, *Schizachyrium obliqueberbe*, *Setaria*, *Eragrostis*, *Eriachne ciliata*, and *Pheidochloa gracilis*.

The perennials dominate only about a quarter of the ground cover. They are mainly mid-height or tall grasses. Some retain a little greenness at the leaf bases during the dry season, but the proportion of this fresh feed to useless dry matter is extremely small. The commonest of those recorded were *Alloteropsis semialata*, *Chrysopogon* spp. (*C. fallax*, *C. latifolius*, *C. pallidus*), *Heteropogon triticeus*, *Coelorachis rottboellioides*, and *Eriachne triseta*.

Of the non-grass herbs, small species of Cyperaceae are plentiful. Other species nearly always present, but thinly scattered, are *Borreria*, *Striga curviflora*, *Gomphrena canescens*, *Bonamia pannosa*, *Pachynema junceum*, and *P. complanatum*.

Some areas heavily trampled by buffaloes have a very poor ground cover, for practical purposes bare. Others are equally sparsely covered but for no apparent reason. Litter is fairly plentiful except in recently burnt areas.

The forest covers nearly all of Kay and Queue land systems. It is slightly less dense on the deeper soils of Queue, but taller; it is more open and shorter on eroded surfaces (Keating land system) with more subdominant eucalypts and other trees; and it often lacks *E. miniata* on the sloping sandy ground that borders the main units of Kay and Queue land systems (units 3 of Kay and 2 of Queue). Its prevalence on the Koolpinyah surface is well illustrated in Jay land system (unit 1), where it covers the lateritized remnants on the tops of the rises, giving way abruptly to a lower and more open woodland on the stripped country downslope.

Its strike-aligned parallel bands (usually but not always on very slight rises) are the diagnostic character of Kysto land system, in which it alternates with a wide variety of woodland types. The difference is often too subtle to be easily recognized on the ground, for although the dividing line between Kay and Kysto land systems, or between tall open forest and woodland, may happen to be sharp, it is not necessarily so.

In Knifehandle and Keefers Hut land systems it is sometimes associated with dense undergrowth in a narrow band a few hundred yards wide next to Kay or Queue land systems, sometimes sufficiently to show up as a dark margin on the aerial photos. This form is mentioned in the tabular descriptions of unit 4 of Keefers Hut land system, but is elsewhere too small to be considered.

(*b*) *Woodland* (*2875 sq miles*)

In many of its characters the woodland has close affinities with the tall open forest, and the difference between the two is indefinite and largely arbitrary. *Erythrophleum*, *Livistona*, and *Pandanus*, for example, are common throughout, together with a selection from the same small trees and shrubs that have been listed; and *E. miniata* and *E. tetrodonta* are fairly frequent, though seldom co-dominant as is the rule in the tall open forest. Signs of the change may be seen most easily in the eucalypts, for the non-eucalypt trees and shrubs are only slightly more numerous, and the grasses (except in stony places, where spinifex is fairly frequent) change only in the relative proportions of the different species. A little *Ampelocissus* occurs on rocky slopes.

Trees of all kinds range in size from 20 to 40 ft, with visibility varying greatly even in the same area. Eucalypts are usually dominant but are smaller and more widely spaced than in the tall open forest, and include several or more of the following species. Those marked with an asterisk are deciduous, some invariably, others only when they grow on skeletal soils: *E. alba*,* *E. bleeseri*, *E. clavigera*,* *E. confertiflora*,* *E. dichromophloia*,* *E. ferruginea*,* *E. foelscheana*,* *E. grandifolia*,* *E. latifolia*,* *E. miniata*, *E. papuana*,* *E. patellaris*, *E. phoenicea*, *E. tectifica*, *E. terminalis*, and *E. tetrodonta*.

Three broad subdivisions of the woodland may be recognized. Although the extremes are distinct the intergrades are large and vague, and for this reason no formal classification is attempted.

A rather tall and dense form with *E. miniata* dominant but with *E. tetrodonta* rare or absent is found on Keating, Baker, and Bend land systems, mostly on those parts that are north of Adelaide River and within about 10 miles of the Stuart Highway, and the same form occurs on Cully and Currency land systems. A similar form, but with *E. miniata* and *E. tetrodonta* both present, borders the road leading from Jim Jim to Pine Creek.

The second form is mixed, with abundant non-eucalypt trees and shrubs which are in some places dominant. *E. tetrodonta* is plentiful but *E. miniata* is rare. This form is widespread in Jay land system and with minor differences is found also in unit 1 of Keefers Hut and Knifehandle land systems, where it forms the gradation to mixed scrub that is referred to in the tabular descriptions of these units.

The third form is low and open and almost wholly deciduous. Eucalypts are dominant, sometimes as a mixture of many species in equal proportions, sometimes with one or two species abundant and others widely scattered. Non-eucalypts are not as common as in the other forms of woodland but all of the species are nevertheless represented. This form is on Baker, Bend, and Rumwaggon land systems, mostly in the Margaret, Mary, and McKinlay catchments as far north as the latitude of Batchelor.

In terms of tall, mid-height, and short grasses the woodland as a whole is fairly uniform, for these grasses were recorded more or less throughout in the proportions of 5:5:1. If, however, the observations are considered according to the dominance of annual and perennial species, two subdivisions are apparent. In one, which comprises Jay, Keefers Hut, and Knifehandle land systems, annuals and perennials are in more or less equal proportions; in the other, which comprises Baker, Bend, Cully, Currency, and Rumwaggon land systems, the proportion of annuals to perennials is about 2:5. These differences could not be correlated with any consistent difference in the habitat.

(*c*) *Stunted Woodland* (*495 sq miles*)

This is an open type of vegetation dominated by gnarled, crooked, and dwarfed specimens of the deciduous eucalypts of the woodland. Their general height ranges from 8 to 20 ft, and visibility averages about 200 yd. It may be distinguished from the woodland by the shortness of the trees and the absence of the evergreen eucalypts, and also by the rarity, if not the absence, of *Cycas*, *Grevillea pteridifolia*, *Livistona*, and *Pandanus*, which were not recorded. After the eucalypts, *Erythrophleum* and *Xanthostemon* are the commonest trees. Shrubs are sparse, except for occasional clumps of *Calytrix achaeta*, and grasses extremely so. All the shrubs and grasses of the tall open forest and woodland were recorded except for minor gaps which are probably ascribable to a density of sampling inadequate for any really accurate evaluation of the cover. Only a little spinifex was seen, though this is a grass one would expect to be plentiful in view of the obviously arid environment. *Themeda* was fairly frequent, another surprising feature, for *Themeda* is a mesic type of grass.

Stunted woodland is found on stony skeletal soils on low rounded erosional hills in Rumwaggon and Bend land systems.

(*d*) *Mixed Scrub* (*395 sq miles*)

Mixed scrub is dominated by non-eucalypts. It grades into woodland (the mixed form) or into *Pandanus* scrub, but may be distinguished from the woodland by its lower and denser habit (visibility 30 to 60 yd, height 25 ft), by the greater proportion of shrubs (mostly evergreen), and by the frequent occurrence of *Melaleuca nervosa*, *Grevillea pteridifolia*, *Acacia*, *Tristania*, *E. papuana*, and *Calytrix achaeta*. *Pandanus* is common but not dominant as it is in the *Pandanus* scrub. Other slightly less common trees and shrubs are *Livistona*, *E. polycarpa*, *Grevillea heliosperma*, *Eugenia*, *Hakea*, *Verticordia*, *Petalostigma pubescens*, and *Banksia*. The ground cover is richer and more variable than in the woodland. It includes all the species that have been listed there, similarly uncorrelated, as far as could be ascertained, with any habitat factors; and it contains also a number of plants that seem to be dependent on a sandy and somewhat moister habitat. Ground cover plants recorded on most sample areas were *Chrysopogon*, small Cyperaceae, *Ectrosia*, *Eriachne triseta*, *Paspalum*, Restionaceae, *Schizachyrium*, *Themeda*, and a number of rather brightly flowering herbaceous plants (*Drosera*, *Mitrasacme*, *Stylidium*, *Utricularia*).

Melaleuca nervosa may dominate areas of any size up to a square mile or so, and *Grevillea pteridifolia* is another common dominant over smaller areas. The other woody plants are usually mixed, and tend to grow in clumps rather than in unbroken communities. The type as a whole is common on sandy slopes in Kosher, Kay, and Knifehandle land systems (units 3, 4, and 5 respectively).

(*e*) Pandanus *Scrub* (*235 sq miles*)

As has been stated, this vegetation type is dominated by *Pandanus*, and merges with the mixed scrub. In parts *Pandanus* forms almost pure dense thickets with a tangled ground cover of fallen leaves; where it is mixed with other trees the scrub is more open, and tends to be clumpy. The most common subordinate trees are *Parinari*, *Eugenia*, *E. papuana*, *Melaleuca nervosa*, *Alstonia*, and *Ficus*, with lianes fairly frequent. Ground cover in the thickets is of patches of *Hyptis*, a little *Stylosanthes*, short Cyperaceae, and thinly scattered short grasses, mostly annual. Typical species are *Stylosanthes* (often dominant), *Dactyloctenium*, *Urochloa*, *Cynodon*, *Eleusine*, *Ectrosia*, *Thaumastochloa*, and *Schizachyrium*. In the more open parts *Hyptis* as a rule is absent, and the rest of the ground cover is thicker.

Pandanus scrub occurs mainly on the gravelly red and yellow earths of Kosher land system, but is common also in smaller patches on the alluvial flats of Fabian, Flatwood, and McKinlay land systems. It is often much disturbed by buffaloes.

(*f*) *Leguminous–Myrtaceous Scrub* (*115 sq miles*)

Calytrix achaeta, *Verticordia cunninghamii*, *Acacia*, and *Bossiaea* form distinct but small areas of scrub up to a few acres in size, mainly on gravelly soils in Kosher land system, and varying in height from 2 to 10 ft according to the species. Smaller areas occur on level laterite pavements (unit 4 of Kay, unit 5 of Knifehandle land systems). The ground cover is sparse, mainly of the short annuals that are listed under the *Pandanus* scrub, with a little spinifex, *Eriachne ciliata*, and *E. triseta*. Thinly scattered eucalypt and non-eucalypt trees occur on most patches. The equivalent in Specht's (1958) account of the Arnhem Land vegetation is *Acacia–Calytrix* scrub.

(*g*) *Paperbark Forest* (*465 sq miles*)

Melaleuca leucadendron is almost the only tree to be found over large areas of the coastal plains. It forms extensive forests (up to 80 sq miles) and is diagnostic of Pinwinkle land system. These forests are virtually pure, including only a little *Barringtonia* along the channel margins. They can endure prolonged waterlogging, and with a run of above-average rainy seasons some of them would remain wet from one year to the next. In such places the trees usually have a mass of fibrous adventitious roots above the stagnant water at the base of the stem. Other patches occur on higher ground or where flooding is intermittent; here the trees have no exposed roots, and a few lianes and other tree species occur (*Acacia auriculiformis*, *Morinda*, and *Terminalia melanocarpa*).

The canopy is about 50 ft above the ground, visibility from 70 to 100 yd, and the density of the trees about 80 or 90 to the acre, in places opening out into a savannah (where the trees tend to be low and bushy) and in others becoming very much denser, with about 150 trees to the acre. The only epiphyte noted was a fairly common small orchid.

The ground cover varies considerably. In swampy places is an assortment of water-weed, varying according to the light that comes through the canopy. Common constituents are *Caldesia*, various Cyperaceae (*Fuirena*, *Eleocharis*), *Commelina*, *Ludwigia*, *Nymphoides*, *Phylidrum*, and *Utricularia*. In drier areas is a sparse cover of short Cyperaceae and short annual and perennial grasses (*Brachiaria*, *Digitaria*, *Echinochloa*, *Eleusine*, *Eragrostis japonica*, *Paspalidium*, *Panicum*, *Pseudoraphis*, *Sporobolus*).

Paperbark forest is common also along the larger streams but usually in a more mixed form, the fringing forest of Christian and Stewart (1953). It has an admixture of other species of *Melaleuca* and other unrelated trees, most of them non-eucalypts. The ground flora also becomes richer and includes some patches of mid-height and tall perennial grasses. Apart from the dominant *Melaleuca*, the plants most often recorded were *Acacia auriculiformis*, *Bambusa*, *Barringtonia*, *E. papuana*, *E. polycarpa*, *Eugenia*, *Ficus*, *Metrosideros*, *Pandanus*, *Parinari*, *Syzygium*, *Terminalia grandiflora*, *T. melanocarpa*, *Tristania*, *Eugenia armstrongii*, *Morinda*, *Chrysopogon*, *Sorghum*, *Vetiveria*. *Nauclea* was recorded as a rarity only and *Casuarina cunning-*

hamiana was not recorded, but they are, or were, universally prominent in the Katherine–Darwin area as a whole (Christian and Stewart 1953, p. 66). This mixed form of paperbark forest often edges the billabongs which are concentrated in Krokane land system and scattered in level country generally; and here each species tends to occupy its own narrow zone parallel to the billabong margin. Pure forest, if present, is confined to the centre of the depression.

(*h*) *Mangrove Scrub* (*95 sq miles*)

The mangrove scrub is nearly all in Littoral land system, from which five species were recorded. One of these, which was not determined, grows in rocky places along the coast, well within reach of the daily tides. The other four grow in mud, in belts along the shore or inland in patches where the tide can reach and as a border along the salt-water creeks. The canopy is thick and unbroken, and the floor bare except for a dense growth of pneumatophores. *Aegialitis annulata* is small and shrubby, with hollow petioles and salt-encrusted leaves. It grows along the edges of the scrub, usually next to a zone of the taller and well-known *Avicennia marina.* Towards the middle of the patches the bulk of the scrub is made up of *Ceriops tagal,* a robust and stubby tree. The fourth species, which could not be determined, is tall and straggly, and scattered among the *Ceriops* and *Avicennia.*

Upstream where the salt water ends, this scrub gives way to the freshwater mangrove, *Barringtonia gracilis,* mostly in narrow and open communities.

(*i*) *Rain Forest* (*a few sq miles*)

According to Webb's (1959) classification, this is complex mesophyll vine forest. It is without eucalypts and has an unbroken but rather uneven canopy averaging about 80 ft in height, with scattered emergent trees to 100 ft. Below the canopy a rich flora of trees, shrubs, lianes, epiphytes, and undergrowth grows in dim light and dense disorder, limiting visibility to a few yards and making progress slow and difficult. Most leaves are large and many are compound, and plank buttressing is conspicuous. Characteristic plants are the figs and occasional slender palms that grow up into the canopy. Litter in all stages is plentiful. No grasses were recorded except for a little of the cosmopolitan forest genus *Oplismenus.* Mosquitoes and green ants are a continual harassment, as they are in most of the wooded areas, but of the other insect life and larger native animals little is known. Some wallabies were seen, and occasional great mounds of litter marked the nesting sites of the brush turkey (*Megapodius freycinet*). Only the buffaloes have any bad effect on the forest, and where they can enter it the change is striking. They destroy undergrowth, litter, and the smaller woody plants to leave only the canopy and supporting columns, with a scattering of robust shrubs. Most of the rain forest is now in this condition, for the patches are usually on Kosher land system not far from the coastal plains which are the buffalo grazing grounds.

Only a few of the component species could be determined.

With increasingly dry conditions the forest becomes lower and more open, and grades into the next vegetation type. There is no abrupt break between the two.

(*j*) *Semi-deciduous Forest* (*a few sq miles*)

In Webb's (1959) classification this is deciduous vine thicket. In its ideal form it is usually under 30 ft high, a rather dense forest with occasional breaks in the canopy and, during the dry season at least, with a well-lit floor, as most of the trees are deciduous. In common with the rain forest, lianes are abundant (*Opilia*, *Stephania*, *Flagellaria*, *Smilax*) and the litter is deep enough to provide suitable conditions for the brush turkey, but the profusion of species, the large leaves, the buttressing, and the dense undergrowth that are characteristic of the rain forest are all missing. Trees with swollen stems are fairly frequent (*Gossampinus*, *Sterculia*, *Brachychiton*), as Webb has stated, and scattered eucalypts (*E. papuana*, *E. polycarpa*) occur near the edge, where the forest often merges with mixed scrub. In this forest type also, only a few of the component species could be determined. Nearly all the semi-deciduous forest is in Kosher and Littoral land systems.

(*k*) *Savannah* (*905 sq miles*) *and Grassland* (*950 sq miles*)

(i) *General.*—For the purposes of this report, savannah is defined as a vegetation of scattered trees over grasses. Grassland differs in being without trees.

Almost all the savannah is found on alluvial flats throughout the area, equally on the larger flats that make up Rumwaggon, Fabian, Flatwood, and Effington land systems and on the small flats that occur as units in most of the other land systems. It differs from woodland in being a much more open type of vegetation with visibility 400 yd or more, and the change from the one to the other is often abrupt and clear. Grassland patches are an integral part of it; and, conversely, even large areas of grassland are nearly always, so to speak, contaminated with at least some scattered trees. For this reason and because no satisfactory geographic or floristic dividing line, arbitrary or not, could be established between the two types, they are grouped under this one heading, and only the two components (trees and grasses) are considered separately.

(ii) *The Trees.*—These consist of a few widespread and constantly recurring species, mainly eucalypts, of which the commonest are *E. papuana*, *E. polycarpa*, *E. alba*, *E. latifolia*, and *E. clavigera*. *E. apodophylla* is another savannah species, but it was recorded only from the headwaters of the McKinlay, Margaret, and Adelaide Rivers, and in patches in the extreme north-west. It and *E. polycarpa* occur only in this vegetation type, but the others are found also in woodland and, in a very different habitat, on rocky hills with skeletal soils.

These trees occur usually in mixtures, more rarely as monotypic communities of any size. *E. papuana* especially is sometimes all but pure for several square miles at a stretch. As a co-dominant with *E. polycarpa* it makes up probably more than half of all the savannah. *E. alba* is generally in the south-west, and is sporadic. *E. latifolia* usually forms part of a relatively dense savannah.

The following are the main non-eucalypt trees: *Pandanus*, *Melaleuca nervosa*, *Livistona*, *Tristania*, *Melaleuca symphyocarpa*, *Grevillea pteridifolia*, *Banksia*, and *Eugenia*. *Pandanus* is common in many vegetation types and habitats but specially favours the savannah. It tends to form small clumps of a dozen stems or so, often together with one or two of the other non-eucalypt trees, but the clumps are widely separated and do not interfere with the open and park-like aspect of the vegetation as a whole. *Tristania* also tends to form clumps, not with more *Tristania* but through sheltering smaller trees of other species. *Melaleuca symphyocarpa* is a gregarious slender tree about 7 ft high which forms occasional rather dense small patches and strips of about an acre. *Grevillea pteridifolia* and *Banksia* were found growing together with a little *Tristania* on Effington land system: the *Tristania–Grevillea–Banksia* community of Christian and Stewart (1953). In this survey area these communities are too small to be considered as a separate vegetation type.

(iii) *The Grasses*.—As a whole, the grasses of the savannah and grassland are distinct from those of the other vegetation types. The sampling indicated that perennial mid-height grasses predominate, perennials covering roughly five times as much ground as annuals, and mid-height grasses covering about as much as tall and short grasses combined. It may be taken for granted, even when pure grass communities are mentioned, that Cyperaceae are frequent throughout. They are small and leafy, unlike the robust species of the sedge land.

For clarity of description, the grasses of these two vegetation types are subdivided into communities, which are discussed under sections 1–6 in the paragraphs that follow.

(1) *The Mid-height Grass Communities*.—The commonest grass is probably *Eriachne burkittii*. It forms almost pure communities, and in this form dominates the ground cover over many square miles in all land systems where savannah and grassland have been recorded, being particularly common in slight depressions and broad shallow channels. On slightly higher ground it often gives way to *Themeda*, also in large and almost pure communities. This alternation of the two communities and the correlation with drainage is a characteristic feature of the savannah and grassland on the alluvial flats in the south-west of the area, and although it was sometimes difficult to observe from the ground, it stood out clearly from the air.

(2) *Grasses of Channels and Bush Clumps*.—Near the edges of channels and billabongs some other grasses occur, including several of the taller ones. *Sorghum plumosum*, *Vetiveria*, *Sclerandrium truncatiglume*, *Pseudopogonatherum*, *Panicum delicatum*, *P. trachyrachis*, and *P. effusum* are characteristic. The small clumps of *Pandanus* and *Tristania* also tend to have a grass flora of their own, commonly a mixture that includes *Sorghum plumosum*, *Vetiveria*, *Coelorachis*, and *Heteropogon triticeus*.

(3) *The Short Grass Communities*.—These occur in certain definite areas, mostly in Fabian and McKinlay land systems near Clark's Crossing, in Kosher land system (units 3 and 4), and thinly along the edge of Cyperus land system. The grasses are probably secondary, for these parts are heavily grazed by buffaloes. The main components are *Pseudoraphis*, *Cynodon arcuatus*, *C. dactylon*, *Eragrostis japonica*, *Paspalum*, *Chloris*, *Ectrosia*, *Echinochloa*, *Brachiaria miliiformis*, and *Digitaria ctenantha*. Important non-grasses are *Stylosanthes* and the ubiquitous Cyperaceae.

(4) *Mixed Grasses*.—Much of the ground cover is under a mixture of the grasses already mentioned and the following: *Chrysopogon fallax*, *C. setifolius*, *C. pallidus*,

Alloteropsis, *Eriachne obtusa*, *E. triseta*, *Panicum delicatum*, *Sclerandrium grandiflorum*, annual *Sorghum*, *Ischaemum*, *Pseudopogonatherum*, *Capillipedium*, *Heteropogon contortus*, and *Eriochloa*. The *Chrysopogon* spp. have starchy underground parts, and some of the other perennials have them swollen and succulent; these, particularly the *Chrysopogon* spp., are dug up for food by the native fauna, whether birds or marsupials it was not possible to say. Annual *Sorghum* is patchy, and was recorded mainly from sandy well-drained flats on Effington land system. Moist sandy areas, on the other hand, supported a great variety of grasses with small and rather brightly flowering herbs between them (*Drosera*, *Mitrasacme*, *Stylidium*, *Utricularia*).

(5) *Grasses of the Coastal Plains*.—The grasses considered here are those found on the higher and better-drained parts of the coastal plains and do not include the hygrophilous grasses, which are dealt with under herbaceous swamp vegetation.

Among those recorded were *Ischaemum*, *Heteropogon contortus*, and *Panicum trachyrachis*. These were the only ones that formed communities in the generally accepted sense. *Ischaemum* and *Panicum* were almost pure in two separate areas of a few square miles each, and in a third area *Panicum* and *Heteropogon* were growing together on a slightly gilgaied flat of about the same size, in the hollows and on the rises respectively. No other grassland areas were seen.

(6) *Grasses of the Arnhem Land Plateau*.—Outliers of the Arnhem Land plateau (Buldiva land system) have a distinct grassland community dominated by spinifex, with scattered individuals and small mixed communities of *Eriachne*, *Micraira*, annual *Sorghum*, *Schizachyrium*, and short Cyperaceae.

(*l*) *Sedge Land* (*1075 sq miles*)

Sedges are the characteristic and dominant vegetation of Cyperus land system. They are up to 24 in. high and wiry or robust, and on nearly all the slightly higher and better-drained parts form a dense unbroken cover. They become mixed and diffuse in the lower and more waterlogged parts, and in this form extend into Copeman land system where they merge with the hygrophilous swamp vegetation. As the total number of species on the coastal plains is without doubt much greater than the number collected on survey, it would be pointless to say more than that *Cyperus*, *Eleocharis*, *Fuirena*, and *Scirpus* are among the genera represented. Individual grasses and widely scattered patches of *Sesbania* were recorded, but they were rare, and other non-sedges were inconsiderable.

Trampling by buffaloes is incidental, for the sedge lands do not provide any appreciable grazing.

(*m*) *Herbaceous Swamp Vegetation* (*420 sq miles*)

By the time the field work began, the whole area occupied by this vegetation type had been accessible to the buffaloes for several months and was heavily trampled, with the rank growth known by repute and from the work of Christian and Stewart (1953) shortened to a few inches. The components vary according to the depth of water and the period of flooding. Deep water has floating plants, e.g. water-lilies and algae, and swampy areas support a richer vegetation of the same species together with grasses, scattered sedges, and abundant non-graminoid herbs, many of which dry out to papery unrecognizable fragments as the water recedes. The following were recorded: *Caldesia, Commelina,* Cyperaceae, *Hymenachne, Ludwigia, Nymphoides, Oryza, Paspalum, Phylidrum, Pseudoraphis, Scleria, Utricularia.* In slightly drier parts *Phyla* was common, with an admixture of *Echinochloa, Elytrophorus, Euphorbia* sp., *Ipomoea aquatica, Panicum delicatum, P. trachyrachis,* and *Sporobolus virginicus.*

As in the sedge land, the species recorded represent only a fraction of the total.

This vegetation type covers most of Copeman land system in a patchwork of communities broken by strips of sedge land and open water. The open water (unit 4 of Copeman land system) often forms a discontinuous band along the edges of the swamps and is characteristic also as a border on a smaller scale along either side of old river channels, as shown in Figure 18.

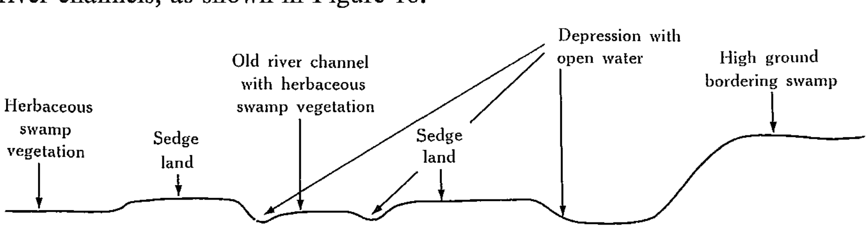

Fig. 18.—Relation of swamp vegetation to relief.

The swamps are the home of thousands of waterfowl. In some places the water is infested with a snail-borne parasite allied to bilharzia, which attacks the vascular system of birds (Bearup and Langsford 1966). It attacks human beings also, but causes only temporary skin irritation for it cannot live in the human bloodstream. No leeches were seen in the swamps, but leeches do exist in other places in the Northern Territory.

(*n*) *Samphire* (*55 sq miles*)

Samphire (*Arthrocnemum*) grows on clay salt flats of Littoral land system, usually in pure communities alternating with areas of bare soil and areas of sedge. A few additional chenopods and sporadic tufts of *Sporobolus virginicus* and *Diplachne fusca* were the only other species recorded.

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PART IX. GRASSES OF THE ADELAIDE–ALLIGATOR AREA AND THEIR UTILIZATION

By R. Story*

I. General

The purpose of this Part is to give a generalized picture of the types of grazing in the area, with respect to the grasses and the topography. To this end, the land systems are considered in terms of plains, slopes, and hills, and the grasses of the vegetation types are lumped into four broad subdivisions. Topography and grasses are then combined to give eight types of country, each with a roughly similar grazing potential. The eight groups (pasture lands) are shown on the small pasture lands map that accompanies this report, and are summarized in Table 15.

II. The Grasses

The broad subdivisions are described below.

(*a*) *Woodland and Forest Grasses*

These are the grasses found in the tall open forest, the woodland, and the stunted woodland. Generally, about half the cover is of annuals and half of perennials, most of them tall or mid-height. Short grasses are scattered but seldom dominant. The main species are annual *Sorghum*, *Alloteropsis*, *Chrysopogon* spp., *Heteropogon triticeus*, *Coelorachis*, *Thaumastochloa*, *Schizachyrium*, and *Setaria* spp.

(*b*) *Scrub Grasses*

Like the woodland and forest grasses, these are a mixture of annuals and perennials, but most of them are mid-height or short. The main species are *Schizachyrium*, *Ectrosia*, *Thaumastochloa*, *Eriachne*, *Themeda*, *Chrysopogon*, *Eleusine*, *Urochloa*, *Dactyloctenium*, and *Cynodon*.

(*c*) *Alluvial Grasses*

These grasses are found in the savannah and grassland. They are mainly mid-height perennials (five times as much perennial as annual cover, and as much mid-height as tall and short combined) and are made up of the following main species: *Themeda*, *Eriachne burkittii*, *Alloteropsis*, *Chrysopogon* spp., *Panicum* spp., *Sorghum plumosum*, *Vetiveria*, *Coelorachis*, *Ectrosia*, *Pseudoraphis*, *Eragrostis japonica*, *Paspalum* spp., *Pseudopogonatherum*, and *Sclerandrium* spp.

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TABLE 15

CHARACTERISTICS OF PASTURE LANDS

Pasture Land No.	Main Grass Communities	Topography	Relative Grazing Value	Constituent Land Systems	Area (sq miles)	Proportion of Grass Communities* (%) (a)	(b)	(c)	(d)	(e)
1	Woodland and forest grasses	Level to slightly hilly	Good wet season; poor dry season	Kay	900	85	5	5	5	
				Keating	215	85		10	5	
				Kysto	240	85		15		
				Queue	250	95			5	
2	Woodland and forest grasses	Hilly	Good wet season; poor dry season	Baker	965	90		10		
				Bend	825	85		15		
				Cully	140	80		20		
				Currency	20	90		10		
				Jay	555	85		15		
3	Woodland and forest grasses and scrub grasses	Hilly	Good wet season; fair dry season	Keefers Hut	515	60	25	15		
				Knifehandle	360	45	35	20		
4	Alluvial grasses	Flat	Flooded wet season; fair dry season	Effington	120			95	5	
				Fabian	220	15	5	80		
				Flatwood	540	20	5	75		
				McKinlay	270		5	90		5
5	Woodland and forest grasses and alluvial grasses	Flat and hilly	Good wet season; fair dry season	Rumwaggon	710	75		25		
6	Woodland and forest grasses and alluvial grasses	Flat, with depressions	Good wet season; fair dry season	Krokane	155	25		55	20	
7	Scrub grasses	Gentle slopes with rounded summits	Meagre but good; dry and wet seasons	Kosher	525		100			
8	Swamp grasses	Flat	Flooded wet season; fair dry season	Cyperus	1225				100	
				Copeman	200				100	
				Pinwinkle	340			5	80	15
Non-range country	Spinifex	Flat or rugged	Extremely poor	Bulvida	30					100
				Littoral	270					100

* Community (*a*), woodland and forest grass; (*b*), scrub grasses; (*c*), alluvial grasses; (*d*), swamp grasses; (*e*), useless.

(*d*) *Swamp Grasses*

A specialized group grows under very wet conditions, that is, flooded for the duration of the rainy season at least, and sometimes permanently. Those recorded in the wettest areas were *Hymenachne*, *Oryza rufipogon*, *Paspalum* spp., *Scleria oryzoides*, and *Pseudoraphis*. In better-drained areas were *Echinochloa colonum*, *Elytrophorus*, *Heteropogon contortus*, *Ischaemum* sp., and *Sporobolus virginicus*.

III. Types of Grazing Country (Pasture Lands)

(*a*) *Pasture Land 1 (1605 sq miles)*

This pasture land, which covers large areas of the Koolpinyah surface, has mainly woodland and forest grasses on level to slightly hilly country. It is rankly grassed and provides good and abundant feed in the early growing season, but this falls off very rapidly in growth rate and quality, and although seeds are produced in great abundance their value as feed is offset by the development in most of them of extremely sharp awns just when they are needed to supplement a ration declining in quality. The nutritive value that can be found in the dry season is in the green leaf bases of some of the perennial grasses (*Alloteropsis*, *Coelorachis*, *Heteropogon triticeus*), and probably in the remnants of the smaller annual grasses, but these quickly disintegrate and the annual fires in any case put an early end to them. The animals then have to live on leaf bases and a meagre supply of roughage until the next season's growth begins. Browse plants and non-grass herbs are rare. The alluvial flats stay damp for longer than their surroundings and their grasses stay greener, but they make up only about 6% of this pasture land, and the sparse drainage and consequent lack of billabongs and springs cause large tracts to be waterless in the dry season. All these characters, and the relative stability of the level country, point to its use for wet-season grazing.

The land systems included here are Kay, Queue, Keating, and Kysto. All four are on the Koolpinyah surface. Kay is mostly gravelly and Queue mostly sandy, and both are intact and level; Keating and Kysto are both slightly eroded, Keating into irregular rises and hollows, Kysto into slight strike-aligned ridges and swales.

(*b*) *Pasture Land 2 (3380 sq miles)*

In its ground cover this pasture land is similar to pasture land 1, its main difference being in topography, which is hilly and therefore more vulnerable to erosion. It has a definite system of drainage channels, and a higher proportion of alluvial flats (14%). It may be inferred that in the dry season it is better watered and has somewhat better feed.

The component land systems are Baker, Bend, Currency, and Jay. Baker and Currency (on mixed lithology and granite respectively) are rugged, the rest have lower relief and more gentle slopes. Of these, Bend is on mixed lithology, Cully on granite, and Jay derived from the stripping of the Late Tertiary weathered surface. They differ mainly in the pattern of dissection.

(*c*) *Pasture Land 3* (*875 sq miles*)

Pasture land 3 is similar to pasture land 2 except for having fewer woodland and forest grasses and correspondingly more scrub grasses (30%), which are more leafy and provide slightly better-quality winter feed. Two closely related land systems are involved, Keefers Hut and Knifehandle. Both are derived from the stripping of the Koolpinyah surface and are rolling to hilly, Keefers Hut being predominantly gravelly and Knifehandle predominantly sandy.

(*d*) *Pasture Land 4* (*1150 sq miles*)

Flats and grassland with scattered trees are the characteristics of this pasture land, which comprises Effington, Fabian, Flatwood, and McKinlay land systems. The flats are alluvial and the grasses are the alluvial grasses listed in Section II(*c*). Fuller information on the various communities and their interrelationships is given in Part VIII. Grazing is at present heavier here than on pasture lands 2 or 1. The grasses are exploited preferentially by any buffaloes or cattle that happen to be in the vicinity, and by the termites that are always there. Termites forage only when the floods have receded, but cattle are less restricted and buffaloes scarcely at all, and in spite of the level surface, trampling of the soft ground and consequent damage to ground cover are in places severe and result in gullying and sheet erosion. As stated in Part VIII, marsupials or birds also take their share of grazing by digging up the storage organs of *Chrysopogon* spp.

Billabongs and seepy areas supply water and a little green feed during the dry season; this is still small, but relatively high by comparison with the first two pasture lands. Water, feed, and wet-season damage all suggest that pasture land 4 could be best used as a reserve for the dry season.

(*e*) *Pasture Land 5* (*710 sq miles*)

A combination of alluvial grasses with woodland and forest grasses is the distinguishing character of pasture land 5. The communities are inseparable at the scale of working used for this report, but in fact are quite separate, the alluvial grasses being on alluvial flats and the woodland and forest grasses on a maze of low ridges that intersect them. The pasture land is in effect a combination of pasture lands 2 and 4, but the grazing on the ridges is a little poorer than usual because of the prevalence of stunted woodland, which usually has a very sparse ground cover. Billabongs on the flats ensure a fairly good supply of water well into the dry season.

Rumwaggon land system is the only one represented.

(*f*) *Pasture Land 6* (*155 sq miles*)

In several respects this pasture land is similar to pasture land 5: it consists of only one land system, Krokane, and contains similar grasses, also in separate communities. The topography, however, is different. The woodland and forest grasses are on level plains, which are in all their characters identical with Kay and Queue land systems, and are part of Krokane only because of practical difficulties in mapping them. The other grasses are mostly alluvial, in wide shallow depressions that are sometimes isolated and sometimes joined by sandy spillways. Swamp grasses occur in some of the deeper billabongs with permanent water.

The dry-season feed in the billabongs is, relatively speaking, good, or it would be if it were spared during the rainy season. Most of it, however, is grazed heavily and continuously by buffaloes, and ruderals are common.

(*g*) *Pasture Land 7* (*525 sq miles*)

Pasture land 7 is mainly of scrub grasses on gentle slopes and rounded summits, with sandy or gravelly soils. While over most of the Adelaide–Alligator area the grasses appear to be totally uncorrelated with the woody communities under which they grow, in pasture land 7 the correlation is close. The trees tend to be in thickets, and the ground cover is densest in the open spaces between them. Short annuals are dominant, the mid-height grasses being thinly represented by *Eriachne triseta* and a few other less common species. The non-grasses include small Cyperaceae and much *Stylosanthes humilis*, also much *Hyptis* (avoided by stock) where grazing has been heavy and continuous. Both *Stylosanthes* and *Hyptis* are introduced. The quantity of the feed produced here is probably less than in any other pasture land but the quality is good, and with summer spelling would remain fairly good during the dry season as well. Water is scarce in the pasture land itself, but as a rule is available close by on the coastal plains, which often adjoin it.

A characteristic feature is a strip of open short grassland, from 50 to a few hundred yards wide and just upslope from the coastal plains. It is usually dotted with termitaria and, perhaps in consequence, badly denuded. Nearly all of the pasture land is heavily grazed by buffaloes.

The only constituent land system is Kosher.

(*h*) *Pasture Land 8* (*1765 sq miles*)

Pasture land 8 is synonymous with swamps, with Cyperus, Copeman, and Pinwinkle land systems, and with the buffalo grazing grounds. The grasses are the swamp grasses, usually in a thorough mixture with sedges and water-weeds, and rarely in purer communities that include small patches of *Ischaemum*, *Panicum trachyrachis*, and *Heteropogon contortus* on higher ground. The whole of it is flooded during the rainy season, and much of it remains under water for several months of the dry season as well. It is grazed continually by the buffaloes as soon as they can find a footing. Over half is under sedges and of little grazing value.

(*i*) *Non-range Country* (*300 sq miles*)

Littoral land system is of salt flats and produces virtually no feed. Buldiva land system is largely spinifex, with wisps of edible grasses, and is on precipitous and broken country. The two land systems are of negligible pastoral value.

IV. Utilization

(*a*) *Introduction*

Little is known of the pastures in the survey area. This section is compiled from information from the Northern Territory Administration (Commonwealth of Australia 1960, 1961*a*, *b*, 1962, 1963; Department of Territories 1964, 1965, and undated; Northern Territory Administration, Agricultural Branch 1965), by extrapolation from results at Katherine (Norman 1963, 1965, 1966), and from observations made during the survey. Katherine results are from a pasture mainly of perennials, including some species not recorded from the survey area. Rainfall also is less, and the period of useful pasture growth is shorter (Christian and Stewart 1953). The survey information is at best from dormant and otherwise from burnt pastures, and is sketchy; and the striking, discontinuous, and sometimes apparently fleeting differences mentioned in Part VIII make for a complex and unstable composition. In view of these facts, the views put forward are broad and generalized.

(*b*) *Advantages and Limitations of the Native Pastures*

The impression gained round Katherine and in the survey area is that a heavy yield of native herbage is produced. In fact the tall rank growth is deceptive, for basal cover is poor and much of the growth is of light hollow culms. It has been found at Katherine that a mixture of *Cenchrus* and *Stylosanthes* (Townsville lucerne) can produce five times the weight per acre of the native pastures, which yield about 1200 lb of dry matter per acre per year.

On native pasture without supplementary feed, cattle gain or maintain weight (except for a slight time lag) only during the wet season, roughly from late November to late May. The wet season may be considered to have begun after 2 in. of rain have fallen in a fortnight, which is the amount and intensity needed to bring the dormant pasture to life. The pasture's first response, which takes place during that fortnight, is a quick rise in protein and phosphate content. The value is short-lived, for the content starts dropping from the end of the fortnight, at first sharply, then slowly and steadily until the onset of the early storms that herald the next wet season, when a further sharp drop occurs, probably caused by the battering and leaching of the rain and by increased activity of microorganisms.

Growth starts slowly, the rate becoming appreciable not during but after the first fortnight referred to. It ceases about 4 weeks after the last rains.

In terms of yield (that is, amount per acre), dry matter, nitrate, and phosphate more or less coincide at a maximum round mid March. The general result is that the pasture is scanty but good at the beginning of the wet season and abundant but poor later.

Figure 19 shows the severe setback which experimental cattle suffered each dry season at Katherine. It varies according to the weight of the cattle, but over 3 years represents an average waste each season of over 60% of the beef that would have been produced if the gain had remained steady. The lean dry period is usual in regions of summer rainfall, but the change reflected in the Katherine figures is exceptionally abrupt.

For practical purposes, the lean and useful periods are each 6 months long.

A point in favour of the pastures is their cheapness. A second is that if they allow any gain in weight at all, it is a rapid one; and when they cannot give a gain in weight unaided they can at least do so if the cattle are given a little high-protein supplement, except during the period of early storms when no amount of protein supplement will prevent liveweight loss. In short, the native pastures on their own are adequate for 6 months, with added protein they are adequate for an additional 5, and for 1 month they are inadequate.

Ways in which the grazing in the survey area probably differs from that at Katherine are the following:

(1) The longer wet season will bring about an earlier start to growth, but may cause more leaching of the mature feed towards the end of the season.

(2) Higher humidity in the dry season could lead to lower quality of standing feed.

(3) Continuing available soil water in low-lying areas would extend the growing period of species well into the dry season if they had been grazed and had hence not completed their growth cycle.

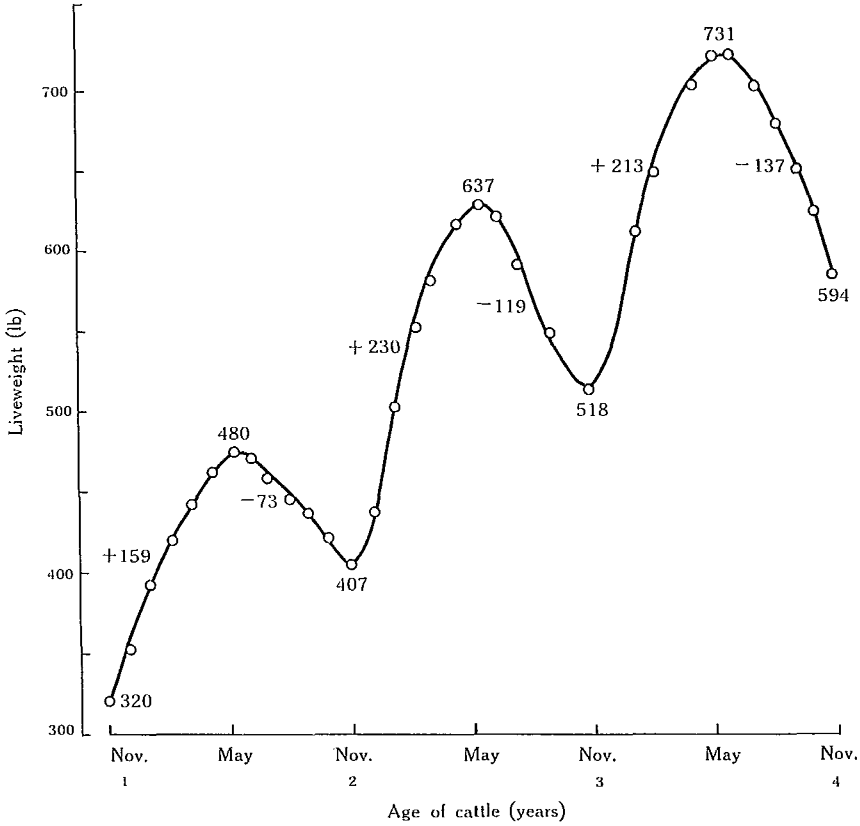

Fig. 19.—Seasonal liveweight changes in cattle 1–4 yr old (after Norman 1966).

(*c*) *Controlled Grazing*

Cultural and grazing treatments applied in attempts to improve the situation have so far been ineffective.

Paddocking has been done on only a few properties in the area, and the cattle stocking rate is extremely low. This ensures that the stock have unrestricted and fairly good-quality feed in summer, and can select the best constituents from the poor-quality pasture in winter. They can travel at will to obtain the best feed and to avoid seasonal grass fires, as in fact they do. No imminent change from the present situation can be foreseen, for the indications are that returns from the native pastures are so low that subdivision does not pay.

If paddocking and grazing control are aimed at, however, pasture lands 1–3 would best be utilized in the wet season when the pasture is relatively good and grass fires do not occur. The other pasture lands (4–8) are better in the dry season, for in the moister soil of the alluvial flats the dominant perennial grasses retain a little basal green growth, and combine with swamp grasses and *Stylosanthes* (Townsville lucerne) to provide a fairly good dry-season ration. The persistence of *Stylosanthes* in the face of heavy grazing and trampling is an encouraging feature of sandy open areas towards the coast, and of pasture land 7 in particular. It is of proved value in providing supplementary dry-season protein, and can fairly easily be established where tall annual *Sorghum* is dominant (Stocker and Sturtz 1966). Pasture lands 4–8 have the additional advantage in winter of providing refuge from fire in the areas of short grass, swamps, and billabongs that are either within them or close at hand.

The mean stocking rate for the Darwin Gulf region is 4–6 beasts to the sq mile, which represents only about 4–6% utilization when applied to the Katherine pastures discussed in this section. If the stock can be carried on sown pastures during the dry season, 10–20 acres of native pasture at Katherine and Tortilla Flat (inside the survey area) are enough to carry a beast and remain stable.

Heavy grazing brings about an increase in short herbage, but it is not known what this means in terms of carrying capacity and palatability. The commonest plants on heavily grazed areas are *Eragrostis japonica*, fine Cyperaceae, *Thaumastochloa*, *Schizachyrium*, *Dactyloctenium*, *Eleusine*, *Cynodon*, and *Echinochloa*, with *Pseudoraphis* on alluvial flats as well.

(*d*) *The Buffalo*

The poor condition of the few cattle seen during the survey (July–August) made it clear that the experimental and analytical work that has been discussed has plenty of practical application. The contrastingly good condition of the many hundreds of buffaloes, on the other hand, made it equally clear that they should be considered as a race apart, with entirely different requirements. They thrive where mud and shallow water provide the wallows and aquatic vegetation so suited to their habits, and graze wherever they can find a footing, at times submerging completely in search of sunken water-weeds. However, they are not confined to the swamps, and if water is within reach they will graze in quite rugged country. There is evidence that they can utilize coarse fodders more efficiently than cattle, which are often thin to the point of emaciation while the buffaloes in the same area appear sleek and well fed. The net carcass weight is about 45%, in some strains over 50%. In short, they are enterprising, adaptable, and thrifty feeders, and where they are domesticated they have been found to be valuable animals (Cockrill 1966). Their milk contains 7–9% butterfat, twice the average content of cows' milk, and dairy strains give 4–5 pints. One drawback, if they are used for milk production, is that they are seasonal breeders, which brings about alternating gluts and scarcities of milk. They are easily tamed even when fully grown, and become most docile.

The fact that the buffalo is a useful dual-purpose animal in Asia does not necessarily mean that it can play the same part in the Northern Territory. Nevertheless, as a producer of meat it is promising, and the main obstacle to the advancement of the buffalo industry appears to be little more than habit and prejudice in favour of beef in the rest of Australia. Except for the work of Tulloch,* of the Northern Territory Administration, no serious attempt has been made to explore the possibilities of its domestication.

An analysis of road development in the buffalo area has been published by the Bureau of Agricultural Economics (1964), and ecological studies by Tulloch have been outlined in the annual reports of the Northern Territory Administration. This information will no doubt enable the industry to be appraised soon from all its important aspects.

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APPENDIX I

Description of Soil Families

By A. D. L. Hooper*

I. General

The soil profiles used to illustrate the characteristics of families described in this report are broad and often grossly generalized. The depths of horizons given in the description indicate maximum observed depths rather than a mean for the family, and only in a small group of texture-contrast and polygenetic soils are these depths limiting or diagnostic in the classification. In keeping with the use of Northcote's (1965) notation, the characters of the A–B solum only are diagnostic, C horizons were often not observed within the 5-ft profile described.† Contrasting lower layers, designated D horizons, are, however, important in some polygenetic soils. Because of a variability of minor horizons, e.g. A_2, in most families the descriptions refer only to the A and B horizons. General terms such as shallow, moderately deep, and deep refer to solum depths of 24 in., 48 in., and 60 in. respectively.

Soil colour names are those used in the Munsell soil colour charts and apply to the moist condition unless otherwise stated. Both textures and colours indicate the range observed in individual profiles. Terms used for moisture, consistence, structure, mottles, and cementation are those defined by the United States Department of Agriculture (1951).

Fabric is as defined by Northcote (1965), but it was found necessary to subdivide the earthy fabric into two groups, one as defined by Northcote, the other as sandy earth fabric where the soil body is composed primarily of sand grains with only a thin clay coating over grains and lining interstitial spaces and pores.

Nodules are used to describe both ironstone concretions formed by centripetal accretion, which are mostly rounded or weathered, and rolled fragments of ferruginous material. They are always indurated and brittle. Their size is invariably between $\frac{1}{8}$ and $\frac{5}{8}$ in. diam. unless stated and amounts are expressed as high (more than 40% of soil volume), medium (20–40%), and low (10–20%), or rare if below 10%. Cemented mottles, mostly ferric, occur frequently and are distinct from nodules in having diffuse margins and are only weakly cemented. Soil reaction is used only where this is a classification characteristic and is expressed in field pH units determined by colorimetric methods. The presence of carbonate (expressed as $CaCO_3$) was determined by testing with 2N HCl in the field.

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† Where practicable at each sample site auger holes (4 in. diam. or 2 in. in harder soils) were put down to 5 ft, or to cemented or rocky layers if these occurred at depths shallower than 5 ft. A small pit was dug to 12 in. over most auger holes and on very stony or gravelly sites a shallow trench (about 12 in.) was examined only.

II. Soils with Uniform Texture Profiles

(*a*) *Coarse-textured Soils with Little or No Pedologic Organization*

Dune sands are a minor unit occurring on unconsolidated or weakly consolidated beach ridges, dunes, or former strand lines under *Pandanus* or a mixed woodland complex. They are deep, brownish, speckled, and gritty.

Kapalga family occurs on the margins of the Koolpinyah surface in Queue land system and often tongues out into flat valley floors. It is typical of the marginal areas of internal drainage depressions; vegetation is mixed woodland with shrubs; drainage is excessive.

A–B, 0–60 in.—Dark grey or greyish brown sand to sandy loam in a shallow A_1 horizon of 1–3 in. (increasing in depth and becoming black, loamy on lower slope sites and valley floors) grading to greyish brown, brown, or pale brown sand before 12 in. and continuing through white, light grey, or pale brown sand to 60 in.; dry, loose, single-grained; sandy fabric; sometimes moist or wet at 50–60 in. with few discrete reddish mottles and clayey sand to sandy loam textures.

C.—Not observed.

Howard family soils are a common feature of alluvial flats within the Koolpinyah surface; vegetation is dominantly *Eriachne* grassland with scattered *Pandanus, Melaleuca,* and *Grevillea,* or a sedge meadow vegetation; drainage is free on the surface soils but poor in the clay D horizon and dry-season water-tables are frequently at 2–3 ft in the profile.

A, 0–48 in.—Dark greyish brown or brown sand or loamy sand, melanized to 1–6 in., grading to light yellowish brown or light reddish brown, or grey-brown sand; dry, loose; single-grained, or moist, very friable with an abrupt boundary to

D, 48–60 in.—Light brownish grey to grey sandy clay with common yellow or reddish mottles weakly cemented or with low amounts of rolled manganese and iron nodules; moist or wet; very firm, sticky and massive; pH 5·0–6·5.

Howard family also includes soils with black loamy surface horizons in lower valley floor sites where magnetic termitaria are often present.

Nourlangie family occurs on sites similar to, and in a complex with, the Howard family under a grassland of *Ectrosia* and *Aristida,* with scattered *Melaleuca.* Drainage is apparently more free (in the clay horizon) than in Howard family but site factors suggest a ponding of water during the wet season.

A, 0–27 in.—Dark grey or very dark grey loam or sandy loam; soft or hard, melanized 1–4 in., grading to light greyish brown to brown sand; dry, soft or loose; single-grained with rare nodules; abrupt boundary to

D, 27–60+ in.—Grey sandy clay; dry, very hard, or moist, very firm; massive with abundant amorphous $CaCO_3$ and low to medium amounts of rolled nodules; lightly mottled reddish to yellowish brown; pH 7·5+.

(*b*) *Coarse-textured Soils with Pedologic Organization*

Baroalba family is dominantly on lower slopes of the Koolpinyah surface and alluvial flood-plains under eucalypt savannah (*E. tetrodonta*) or mixed scrub of *Grevillea, Pandanus,* and *Melaleuca.* Drainage is imperfect and water-tables are commonly high.

A–B, 0–60 in.—Black to brown loamy sand or sandy loam to 1–6 in., grading to light brown, yellowish brown, or brownish yellow sand or sandy loam; dry, loose; single-grained; sandy fabric; or to light sandy clay loam, often moist or wet, very friable; mottled (grey, yellow, and red) or with low to medium amounts of nodules, weakly cemented or indurated.

C.—Horizons not observed.

Murrabibbi family is a distinct unit of the lower slopes of the Koolpinyah surface most commonly developed in the *Pandanus–Melaleuca* fringe bordering Cyperus land system; drainage is imperfect, ground-water permeability is rapid in lower layers, and water-tables are generally up to 6 ft throughout the dry season. These soils grade, with increasing clay textures in the surface soils, into the Counamoul family of Cyperus land system, and both families share a common D horizon in many cases.

A–B, 0–36 in.—Black or very dark brown loam or sandy loam; massive; dry, hard; earthy fabric, over grey-brown, pale brown, or light yellowish brown sand to sandy loam; dry, loose or slightly hard; massive or single-grained with a sandy earth fabric to approximately 20 in., and followed by a dark yellowish brown, yellowish brown, or grey-brown horizon with moderate to high amounts of nodules and which, in some cases, may be sandy clay loam in texture giving a gradational texture profile (Gn2.41).

D, 36–120 in.—Very strongly mottled red and grey with minor yellowish brown clay to medium clay, sometimes sandy with low amounts of nodules; moist, firm or wet, slightly sticky and plastic; massive; earthy fabric; has been recorded to below 10 ft and continuing.

Cockatoo family (Burvill 1944) occurs characteristically on the crest of the sandy Koolpinyah surface of Queue land system, with minor occurrences on lower margins of the surface on the eastern rivers. Vegetation is tall open forest or woodland; drainage is very free.

A, 0–30 in.—Brown or dark reddish brown loamy sand or sandy loam, grading at <12 in. to yellowish red sand or sandy loam; dry, loose; single-grained with a sandy earth fabric, the solum composed of fine to coarse sand-size rounded quartz grains with thin clay coatings; few or rare nodules.

B, 30–60 in.—Red sandy loam or clayey sand; dry, loose or soft; sometimes moist and very friable; low amounts of nodules with incorporated rounded sand grains.

C or D.—Abrupt boundary to rounded water-worn quartz stones and ferruginized rock material often at great depth (15+ ft), or hardened detrital laterite.

Cahill family is widespread on crest zones of the Koolpinyah surface, ridges capped with remnant laterite, or on colluvial slopes below laterite breakaways under woodland or mixed scrub; drainage is very free, permeability rapid. The shallow to moderately deep stony phase of this family (depths of horizons in brackets) is very common and many profiles less than 24 in. deep have been observed on ridge crest sites.

A, 0–24 in. (0–15 in.).—Dark greyish brown to brown loamy sand to sandy loam, at 1–4 in. grading to strong brown or yellowish red sandy loam or light sandy clay loam; dry, loose or soft; massive; earthy fabric; moderate to high amounts of nodules or fragments of ferruginized parent rock material; nodules often form a dense surface veneer with light red sand.

B, 24–48 in. (15–36 in.).—Yellowish red sandy loam to light sandy clay loam with high amounts of nodules and rock material; pH 6·0–7·5.

C, 48+ in.—Strongly weathered rock, mottled zone, or cemented nodular laterite in restricted valley sheet deposits.

(*c*) *Coarse or Medium Soils with No Pedologic Organization*

Skeletal soils occupy the largest area of any unit in the Adelaide–Alligator area, with an estimated total of 1495 sq miles (Table 10). They occur on hill slopes and crests where slopes exceed 5% under a stunted woodland and invariably have a surface stone cover of at least class 4 or mainly class 5 (United States Department of Agriculture 1951). They are shallow yellow sandy loams to loams, forming a matrix in high amounts (generally over 60%) of coarse angular stones and boulders of sandstone and quartz. Buried clay horizons have been observed, and subsequent study has shown them to be weathered shales overlain by sandstone detritus from creep deposits where the resistant sandstone forms topographic highs in alternating sandstone and shale strata (M. A. J. Williams 1966, personal communication).

(*d*) *Medium-textured Soils with Pedologic Organization*

Mary family occurs on recent river flats and levees under savannah; drainage is free, permeability slow.

A, 0–30 in.—Olive-brown to brown silty loam grading to dark brown; dry, hard; massive or platy with an earthy fabric; rare iron staining on root traces in surface layer.

B, 30–60 in.—Brown to yellowish red clay loam; dry, hard; massive; earthy fabric, rare mottles; pH 6·5–7·0.

Frances family occurs in close association with Mary soils on levee back slopes or small embayments on recent river flats. Drainage is imperfect and water is ponded during the wet season.

A, 0–30 in.—Olive-brown to brown clay loam; dry, hard; massive or platy.

B, 30–60 in.—Reddish yellow to yellowish red or grey mottled clay loam or light clay; dry, very hard and cemented; with abundant amorphous $CaCO_3$.

(*e*) *Fine-textured Soils with No Pedologic Organization*

Saline muds occur under mangroves on the levees of tidal creeks and along the strand line, and are deep, strongly gleyed, sticky muds with a characteristically strong smell of hydrogen sulphide.

(*f*) *Fine-textured Soils with Pedologic Organization* (*Plastic*)

Dashwood family (Stewart 1956) occurs in swampy depressions, in *Melaleuca* swamp forests, and in areas of the inland alluvium–coastal plains transition zone; drainage is poor.

A, 0–14 in.—Black silty clay or medium clay; firm when moist; hard when dry with a weak granular structure or massive.

A–C, 14–30 in.—Grey to dark grey medium to heavy clay; moist, firm massive; strongly mottled (brown, yellow-brown, and black).

C, 30–60 in.—Dark grey or olive-grey medium to heavy clay; massive, very firm and sticky; mottled (yellow).

(g) *Fine-textured Soils showing Seasonal Cracking, with Pedologic Organization Characterized by Smooth-faced Peds*

Adelaide family occurs in small areas of former levees on Cyperus land system under dense grassland. The soil surface may be gilgaied with low puffs and shallow depressions with an amplitude of less than 6 in. where observed. Adelaide soils are confined to the puffs and Carmor soils occur in the depressions. The soils have black granular heavy clay surfaces with rusty mottling over grey heavy clays; massive; moist, very firm with low amounts of nodular $CaCO_3$ between the A and C horizons.

Wildman family (Stewart 1956) occurs over wide areas of Cyperus and Copeman land systems on flat zones or low-lying depressions, and is distinguished on aerial photographs by a mottled vegetation pattern of sedges, grasses, and water-weeds; drainage is always poor and an apparently permanent water-table is present in the mud layer.

A, 0–30 in.—Very dark grey or black "silty" medium to heavy clay; dry, extremely hard, cracked; sometimes with a thin ($\frac{1}{8}$ in.) granular surface layer under root masses of grasses or sedges but more commonly massive breaking to medium-size blocky fragments; fine rusty or yellow mottling; large cracks extend between 6 and 24 in. depth, increasing with length of dry season.

A–C, 30–48 in.—Grey heavy clays, moist, very firm with large black or dark grey inclusions and some yellowish mottles.

D, 48+ in.—Pale olive, olive-grey, and grey wet heavy sticky mud often gleyed with bluish green hues.

Carmor family is characteristically located in the vicinity of abandoned river channels and meander cut-offs. Drainage is imperfect to poor; vegetation is dominated by grasses, with sedges, *Phyla*, and *Sesbania* common.

A, 0–36 in.—Very dark grey or black "silty" medium to heavy clay; dry, extremely hard; massive or with a thin blocky overlay, cracking between 12 in. and 36 in., often in blocks to 12 in. wide; lower A may be moist and very firm; strongly mottled (yellow-brown to olive-brown with rusty staining) and with amorphous $CaCO_3$.

A–C, 36–50 in.—Strongly mottled (strong brown-yellow), grey, massive, clay with black inclusions and moderate to high amounts of amorphous $CaCO_3$.

D, 50+ in.—Light olive-grey, olive, or light grey, medium to heavy clay, moist, very firm; abundant amorphous $CaCO_3$; common strong brown or yellow-brown mottling; shell fragments often present.

Counamoul family occurs mostly in narrow zones along the margins of the Koolpinyah surface, bordering dune lines where gilgai microrelief is sometimes seen, and in wider areas on the inland zones of the coastal plains. The D horizons may vary, e.g. strongly mottled red and grey sands and clays marginal to the Koolpinyah surface (as in Murrabibbi family), grey or brown river sands in inland zones, and coarse grey or brown dune sands near old dune lines or beach ridges. Vegetation is mixed, with grassland of *Cynodon* and *Oryza* in drier and wetter sites respectively, and a savannah of *Melaleuca* and *E. papuana* in the inland zone, with patches of *Barringtonia.*

A, 0–36 in.—Very dark greyish brown, dark grey, and black silty medium clay; massive or with a granular surface commonly mottled below 12 in. and with cracks 6–12 in. but often weakly developed in surface horizons; pH 5·0–5·5.

A–C.—Very dark greyish brown, olive-brown, or grey heavy clay, very thin and often absent.

D, 40–60 in.—Light and dark grey to yellowish brown sandy clays or sand, mottled red and grey clays or sandy clays; moist or wet, firm or very friable (in sands), often with iron–manganese nodular masses. High water-tables are common. Strongly weathered rock materials and quartz sometimes occur; pH 5·5–7·0.

Cairncurry family is located characteristically on the swampy margins of *Melaleuca* forests; drainage is poor with dry-season water-tables between 1 and 4 ft from the surface.

A, 0–36 in.—Very dark grey, grey, or black silty medium clay; dry, hard, and cracked 9–36 in., moist, very firm below; massive; strongly mottled (strong brown and red or pinkish red).

A–C, 36–48 in.—Grey to dark grey medium clay; moist, very firm; massive with common mottles and often abundant, fine, acicular crystals of gypsum.

D, 48–60+ in.—Olive-grey to greyish brown heavy clay; moist or wet, extremely firm or very sticky; strongly mottled red and yellow in moist horizons, yellow and grey in wet horizons.

Carpentaria family (Sleeman 1964) occurs on flats and back slopes of mangrove-covered levees in areas open to tidal flooding in Littoral land system. Salt encrustation is common on the surface and vegetation is generally absent.

A, 0–18 in.—Olive-grey, olive, or dark grey medium or heavy clay; dry, hard, cracked to 6 in. with a distinctive flaky or puffy granular (flocculated) surface.

C, 18+ in.—Light olive-grey, pale olive, medium to heavy clay; moist and firm over wet, very sticky gleyed muds.

III. Soils with Gradational Texture Profiles

(*a*) *Non-calcareous with Earthy Fabric in Subsoils*

Berrimah family (Stewart 1956) occurs predominantly on the crest of the Koolpinyah surface in the Darwin salient (Kay land system), with minor occurrences on outliers of the Koolpinyah surface and isolated pockets on marginal slopes. Vegetation is tall open forest; drainage is very free; permeability is rapid.

A, 0–36 in.—Dark reddish brown or dark brown sandy loam to sandy clay loam in a thin A_1 of 1–6 in., grading to yellowish red or red sandy clay loam or clay loam; dry, loose or soft; massive; rare nodules.

B, 36–60+ in.—Red or dark red sandy clay to light medium clay; moist, friable or dry, hard; earthy fabric; massive; clay skins are common; and cemented or indurated fine gravel-size rounded nodules increase to low to medium amounts in the lower B horizon; few yellowish mottles; B horizons may be of considerable depth (9–10 ft).

C.—Where observed was of mottled rock material.

Katherine family (Stewart 1956) occurs on the upper slopes and crests of old inactive river levees under savannah; drainage is very free.

A, 0–20 in.—Dark or very dark greyish brown silty loam grading at 1–3 in. to brown-red to yellowish red silty clay loam; dry, hard; massive or platy and grading below diffusely to

B, 20–60+ in.—Yellowish red or red clay loam to clay; dry, hard; massive; may be faintly mottled yellow-brown.

Hotham family is located on similar sites to the Berrimah soils but is also found on ridge crests or slopes of hills capped with laterite (as for the Cahill soils); vegetation is tall open forest or woodland with shrubs; drainage is very free.

A, 0–24 in.—Dark brown to dark yellowish brown loamy sand to loam in thin A_1 of 1–4 in. grading to yellowish red, reddish brown sandy loam to clay loam; dry, soft or loose; massive; medium amounts of nodules often in high amounts at surface and decreasing below until lower B horizon.

B, 24–48 in.—Yellowish red or red sandy clay to light clay; moist and friable or dry, soft to hard, sometimes cemented; medium to high amounts of nodules.

C.—Where observed was similar to that of Berrimah family.

Munmarlary family occurs in close association with soils of the Cahill family on colluvial slopes and margins of eroded areas of the Koolpinyah surface; vegetation is eucalypt savannah, or mixed scrub; drainage is very free. A moderately deep to shallow phase over laterite or rock is common.

A, 0–36 in.—Dark greyish brown to olive-brown loamy sand or sandy loam grading to dark yellowish brown to yellowish brown or brown sandy clay loam to clay loam; dry, soft on surface, loose below; massive; high amounts of nodules and/or stone-size angular parent rock fragments.

B, 36–60 in. (20–36 in.).—Yellowish red to red sandy clay or light clay; dry, soft to hard; massive, with high amounts of nodules and/or stones.

C.—Dense nodules and/or strongly weathered parent rock.

Basedow family occurs characteristically on the upper margins of the crest of the Koolpinyah surface under tall open forest or woodland; drainage is very free.

A, 0–36 in.—Dark greyish brown or brown grading to yellowish brown sandy loam or sandy clay loam below 2 in. and to strong brown or yellowish red before 36 in.; dry, soft or loose; massive; very porous, sandy earth fabric with low amounts indurated and rounded nodules. A surface veneer of fine sand is common.

B, 36–60 in.—Yellowish red or red sandy clay loam to sandy light clay; dry, loose or soft; massive, very porous continuing to below 60 in. High amounts of nodules are sometimes present at 50–60 in.

Woolner family occurs predominantly on the marginal slopes of the Koolpinyah surface under eucalypt woodland with shrubs; drainage is moderately free, permeability is rapid in surface horizons.

A, 0–30 in.—Dark greyish brown to dark yellowish brown loamy sand or sandy loam grading at 1–6 in. to brown (yellowish brown or strong brown) sandy loam to sandy clay loam; dry, soft or slightly hard; massive and very porous with a sandy earth fabric; low to medium amounts of nodules, rounded and indurated.

B, 30–60 in.—Yellowish red, rarely red, sandy clay to light medium clay; dry, hard or moist; firm, with abundant mottles of yellowish brown, yellow, and grey in distinct linear and concentric patterns, with clay skins dominant on red matrix (which also is less porous, more cemented) and with rounded quartz grains predominant in grey mottles which have a yellowish brown marginal zone; medium to high amounts of strongly cemented or indurated nodules may be present.

C.—Not observed, B horizons continuing and becoming impenetrable.

Magela family occurs on alluvial flood-plains or raised terrace areas on margins in the eastern rivers area under an open savannah of *Pandanus*, *Grevillea*, and *Tristania* over dense *Themeda* grass; drainage is imperfect.

A, 0–30 in.—Olive to dark greyish brown sandy or silty loam melanized to 1–6 in., grading to dark yellowish brown, yellowish brown, or olive-brown sandy loam or light sandy clay loam; dry, soft or loose; some weak rusty staining on root traces and organic wash mottles are present.

B, 30–60 in.—Yellowish brown to yellowish red sandy clay loam (or rarely sandy light clay); moist and very friable, weakly coherent; sandy or sandy earth fabric; strongly mottled, red-brown, grey, or yellow, low amounts of iron–manganese nodules and some cemented diffuse red mottles.

Batten family (Stewart 1954) is confined to the rolling terrain of Bend and Rumwaggon land systems, characteristically developed on lower slopes and in depressions. Vegetation is eucalypt savannah or woodland with shrubs; drainage is moderately free and run-off is rapid.

A, 0–30 in.—Brown to dark grey loam in hard-setting surface horizon of 1–6 in. depth, grading to an A_2 of grey-brown or brownish yellow (light grey when dry) clay loam (fine sandy or silty); dry, hard; massive; porous earthy fabric with numerous fine (1–2-mm diam.) pores or vesicles; fine, but distinct rusty staining or root traces and reddish brown mottles up to 20%; rare stones or nodules.

B, 30–50 in.—Brownish yellow, strong brown, or yellowish red light clay or light medium clay; dry, hard; massive; sometimes cemented and brittle with prominent, weakly cemented, red-brown mottles or indurated nodules and gossanous platy fragments of ferruginized shales and sandstone.

C, 50+ in.—Light grey or pale yellow clays with high amounts of ferruginized and strongly weathered rock fragments.

Elliott family (Stewart 1956) occurs in depressions and on colluvial foot slopes of Bend and Rumwaggon land systems, but also extends into Keefers Hut and Jay land systems and is characteristic of large areas of alluvial flood-plains in Flatwood land system. Vegetation and drainage are similar to those in Batten family and these two soils are closely related, the principal difference being the more sandy nature of the Elliott surface horizon and the lack of the bleached or light-coloured A_2 of the Batten soils.

A, 0–24 in.—Greyish brown to olive-brown sandy loam to sandy clay loam grading to olive-brown, yellowish brown sandy clay loam to clay loam; dry, hard; massive and porous with vesicles; rare nodules; common iron staining on root traces.

B, 24–48 in.—Yellowish brown to strong brown or brownish yellow to grey clay loam or clay, sometimes sandy; dry, hard; massive; weak earthy fabric with red-brown or yellowish brown cemented mottles.

C–D, 48+ in.—Clay horizons may extend to below 60 in. or be succeeded, particularly on alluvial sites, by massive, hard, red clays. The clay horizons on hill slopes are often derived from underlying shales similar to those under skeletal soils.

Koolpinyah family (Stewart 1956) is a characteristic soil of Kosher land system occurring on the crest margins and outliers of the stripped and eroded Koolpinyah surface; vegetation shows a wide range from tall open forest, woodland (often with shrubs or palms), *Pandanus* scrub, and semi-deciduous forest. Drainage is very free. Koolpinyah soils are very similar to Elliott soils (especially in colour) but textures are sandier in the A horizon and consistence is loose or soft in the dry state in contrast to the hard-setting nature of the Elliott A horizons. A shallow phase over laterite is very common.

A, 0–24 in. (0–10 in.).—Very dark greyish brown to dark yellowish brown loamy sand or sandy loam, grading at 1–6 in. to brown or yellowish brown sandy loam or light sandy clay loam;

dry, soft or loose; massive; very porous, sandy earth fabric; low to medium amounts of indurated rounded nodules, high amounts generally in shallow soils.

B, 24–48 in. (10–30 in.).—Yellowish brown, brownish yellow, or yellow sandy clay loam; dry, soft or moist, friable; massive; porous, sandy earth fabric with medium to high amounts of nodules and often with cemented red-brown mottles.

C.—Not observed, nodules or hardened nodular or vesicular laterite forms an impenetrable layer.

Cullen family (Stewart 1956) occurs on colluvial foot slopes in the dissected southern foothills, and in Jay and Cully land systems where quartzose parent materials are dominant under a mixed woodland with shrubs; drainage is very free.

A, 0–24 in.—Dark greyish brown to greyish brown loamy sand or sandy loam grading to grey, light grey, or yellow sandy loam; dry, soft or loose; massive or single-grained; sandy earth fabric; low to medium amounts of nodules and commonly quartz stones or weathered rock fragments.

B, 24–48 in.—Yellow, grey, or brownish yellow sandy clay loam; dry, loose or soft; moist, very friable; massive, with sandy earth fabric; medium to high amounts of nodules or quartz stones.

C.—Impenetrable stony layers.

Masson family is recorded on the crest areas of rolling topography in the granites of Cully land system.

A, 0–38 in.—Dark grey-brown sandy loam, melanized, over brownish yellow coarse sandy clay loam; dry, loose; single-grained and grading to

B, 38–40 in.—Pinkish white to yellowish red coarse sandy clay; dry, soft; massive, with abundant reddish cemented mottles; coarse quartz crystals from weathered granite are in high amounts throughout the profile below the A_1 horizon.

C.—Strongly weathered granite.

Angelara family soils are developed solely on laminated grey shales in small scattered localities in the southern foothills.

A–B, 0–48 in.—Olive-brown to dark yellowish brown silty clay loam to clay or medium clay, structureless immature soils with high amounts of platy fragments of shale in the profile, ferruginized at the surface and weakly weathered; alkaline in C horizons below 48 in.

Similar shales have been observed in the Moline area and analysis by the Agricultural Branch of the Northern Territory Administration (Baseden and Martin 1965) shows, in a shale sample with pH of 9·2, the exchange complex dominated by sodium (3·1 m-equiv. %) and magnesium (3·7 m-equiv. %).

(*b*) *Non-calcareous with Smooth Ped Fabric in Subsoils*

McKinlay family occurs on flat flood-plains or flood-plain margins, mainly in Rumwaggon land system; vegetation is *Themeda* grassland or open savannah.

A, 0–18 in.—Greyish brown to dark yellowish brown loam, melanized to 2–6 in., grading to brown or yellowish brown clay loam; dry, hard; massive; porous with vesicles; common rusty staining on root traces and rare cemented reddish mottles.

B, 18–50 in.—Olive-brown or dark yellowish brown clay to medium clay (often sandy) grading to yellowish brown or yellow clay; dry, very hard; weakly pedal and slightly mottled, grey and red-brown, weakly cemented; pH is 7·0+ below 18 in.

C.—Lighter-coloured and lighter-textured stratified colluvial or alluvial layers.

Stapleton family occurs on valley flood-plains and marginal pediment slopes under an open savannah or *Themeda* grassland; drainage is moderately free. Large (10+ ft) yellow termitaria and surface "debil debil" mounds are common.

A, 0–24 in.—Dark greyish brown to grey loam (silty or fine sandy); dry, hard, with incorporated organic matter and many fine vesicles over an A_2 of white, light grey, or pale yellow clay loam; dry, hard; massive and porous with vesicles; few yellow-brown to red mottles and low amounts of nodules; pH 6·0–6·5, or rarely 7·0.

B, 20–50 in.—Light grey, pale olive, or grey-brown clay loam to light clay grading to a yellow or yellowish brown mottled B_2 of light to medium clay; dry, very hard, weakly pedal in lower B_2 or B_3; mottled, red-brown or grey; low to medium amounts of nodules and cemented mottles; evidence of columnar structure in B_1 horizon; pH 8·0 in B_2.

C, 50+ in.—Yellow clay to clay loam; mottled.

Moline family occurs on flat flood-plain sites under *Themeda* grassland with scattered short *Melaleuca* and is very similar to the Margaret family, but has gradational textures with clay and high pH at depths of >14 in. in the profile and lacks the well-developed A_2 of the Stapleton soils. It apparently occurs as a complex with the Margaret soils.

A, 0–14 in.—Dark greyish brown to brown loam at 1–3 in., grading to pale brown clay loam; dry, hard; massive; porous with vesicles; rusty staining on root traces and low amounts of weakly or strongly cemented nodules principally in lower A horizon; pH 6·0–6·5.

B, 14–50 in.—Pale brown, light grey, yellow, or dark yellowish brown clay loam to clay, bleached domes of ?columnar structure with a pH of 7·5 or more, abrupt boundary to brown, yellowish brown, or olive-brown medium clay; strongly mottled grey and reddish brown; pH 8·0–9·0.

C, 50+ in.—Grey, greyish brown, or yellowish brown sandy clay or light clay.

(*c*) *Non-calcareous with Rough Ped Fabric in Subsoils*

Marrakai family (Stewart 1956) occurs widely in the survey area in restricted zones of flood-plain depressions, internal drainage depressions on the Koolpinyah surface, or near channels on levee banks where drainage is imperfect or poor and the subsoils remain moist throughout most of the dry season; vegetation is commonly savannah dominated by *Melaleuca* or *Eucalyptus polycarpa* over *Eriachne* grass or sedges.

A, 0–20 in.—Dark grey to olive-brown loam grading at 1–6 in. to grey or brown loam or clay loam; mottled, reddish brown, or yellow, or with light grey forming a sporadic bleach A_2; dry, soft or hard; massive or weak platy structure; very porous with vesicles; abundant fibrous roots.

B, 20–60 in.—Grey to yellowish brown clay to medium clay or rarely sandy clay; mottles, strong brown to reddish brown (which sometimes dominate and often are weakly cemented); massive or weakly pedal; moist, very firm; pH 5·0–6·5.

C–D, 60+ in.—Sands, nodules or clay of alluvial origin sometimes as high as 36 in. in profile.

Woolwonga family is common in sites similar to those of the Marrakai family and mainly occurs in the alluvium of the eastern rivers or derived from the Koolpinyah surface.

A, 0–18 in.—Dark grey to grey loam, melanized to 1–6 in., grading to dark grey to greyish brown clay loam (silty or fine sandy); dry, soft or hard; massive, or with a fine platy structure.

B, 18–40 in.—Grey to brownish grey sandy clay or light clay; dry, hard, and often brittle with low to high amounts of amorphous and nodular $CaCO_3$; common to abundant ($>20\%$) grey, yellow, and red mottles; low to medium amounts of nodules; pH 8·0–9·5.

C–D.—Lighter-textured alluvium or dense nodular layers often moist or wet at depths from 30 in.

IV. Soils with Duplex (Texture-contrast) Profiles

(a) With Yellow Clayey Mottled Subsoils, Hard-setting Surface Horizons

Jim Jim family occurs on flat or gently undulating flood-plains or drainage lines in the eastern rivers and Koolpinyah surface under *Eriachne*-dominant grassland and with imperfect or moderately free drainage.

A, 0–12 in.—Dark grey, very dark brown, or dark greyish brown sandy loam over grey or greyish brown loamy sand; dry, hard; massive on surface, loose, single-grained below; moderate amounts of rounded fine gravel-size nodules.

B, 12–50 in.—Grey sandy clay; dry, hard, or moist, very firm; massive; mottles (>20%) yellow-brown and red-brown, some cemented; medium amounts of amorphous $CaCO_3$.

C, 50+ in.—Grey alluvial sandy clays or clay loam, unmottled.

Margaret family occurs on flat flood-plains, generally shallow basin-like central zones under an *Eriachne* grassland; drainage is moderately free.

A, 0–12 in.—Dark greyish brown or olive-grey loam or fine sandy loam over olive-brown or grey sandy clay loam or fine sandy loam; dry, hard; massive; porous with vesicles; some rusty staining on root traces and low to medium amounts of rounded nodules, often cemented into a hard brittle layer capping and following the contours of the dome crest of the B horizon; pH 6·0–6·5.

B, 12–50 in.—Grey, yellowish brown to strong brown (or mottled with these colours in varying dominance) medium clay; dry, very hard with a smooth ped fabric; medium or coarse columnar structure often strongly bleached in dome crests of the B_1 horizon; B_2 horizons are blocky and mottled strong brown to yellowish red, some weakly cemented; pH 8·0–9·5.

B–C, 50+ in.—Similar-coloured but lighter-textured (sandy clay); massive.

(b) With Dark Clayey Whole-coloured Subsoils, Hard-setting Surface Horizons

Cooinda family occurs in the meadow-like grassy flats within *Melaleuca* forest of the inland coastal plains margins, and elsewhere sporadically on peaty dry zones of the *Melaleuca* swamps.

A, 0–8 in.—Black silty loam or silty clay loam; dry, hard, or moist, friable; massive or granular; earthy fabric with abundant plant remains and roots; abrupt boundary to

B, 8–60 in.—Black or dark grey heavy clays; massive or weakly blocky; moist, very firm or extremely firm, rare rusty mottling and acid reaction (pH 4·0 at 30 in.).

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Appendix II

List of Plants Mentioned with Available Common Names

Abrus precatorius L.	Crab's eyes
Acacia auriculiformis A. Cunn. ex Benth.	
A. cunninghamii Hook.	Curracabah, black wattle
A. mangium A. Cunn.	
A. shirleyi Maid.	Lancewood
Aegialitis annulata R. Br.	Mangrove
Alloteropsis semialata (R. Br.) Hitchc.	Cockatoo grass
Alphitonia excelsa (Fenzl) Benth.	Red ash
Alstonia actinophylla (A. Cunn.) K. Schum.	
Ampelocissus spp.	Native grape
Aristida spp.	Three-awn or wire grasses
Arthrocnemum spp.	Samphire
Arundinella nepalensis Trin.	Reed grass
Avicennia marina (Forsk.) Vierh.	Mangrove
Azolla spp.	
Bambusa arnhemica F. Muell.	Bamboo
Banksia dentata L.f.	
Barringtonia gracilis (Miers) R. Knuth	Freshwater mangrove
Bauhinia spp.	
Bonamia pannosa (R. Br.) Hall.f.	
Borreria sp.	
Bossiaea phylloclada F. Muell.	
Bothriochloa intermedia (R. Br.) A. Camus	Forest blue grass
Brachiaria sp.	
B. miliiformis (Presl) Chase	Green summer grass
Brachychiton paradoxum Schott	Currajong, bottle tree
Buchanania obovata Engl.	
Caldesia spp.	
Callitris sp.	Cypress pine
Calytrix achaeta F. Muell.	
Canarium australianum F. Muell.	
Capillipedium parviflorum (R. Br.) Stapf	Scented top
Casuarina cunninghamiana Miq.	River oak
Cenchrus ciliaris L.	
C. setigerus Vahl	
Ceriops tagal (Perr.) C. B. Rob.	Mangrove
Chara spp.	Stonewort
Chionachne cyathopoda (F. Muell.) F. Muell. ex Benth.	River grass
Chloris spp.	Rhodes grass
Chrysopogon fallax S. T. Blake	Golden beard grass
C. latifolius S. T. Blake	
C. pallidus (R. Br.) Trin. ex Steud.	Ribbon grass
C. setifolius Stapf	
Cochlospermum gillivraei Benth.	
Coelorachis rottboellioides (R. Br.) A. Camus	
Commelina lanceolata R. Br.	
Cycas media R. Br.	
Cymbopogon bombycinus (R. Br.) Domin	Citronella grass
Cynodon arcuatus J. S. Presl ex C. B. Presl	
C. dactylon (L.) Pers.	Couch grass
Cyperus spp.	Flat sedge, leaf rush
Dactyloctenium sp.	Button grass
Denhamia obscura Meisn.	
Dichanthium fecundum S. T. Blake	Blue grass
Digitaria spp.	Finger grasses
D. ctenantha (F. Muell.) Hughes	Comb finger grass
Diplachne fusca (L.) Beauv.	Brown beetle grass
Drosera spp.	Sundew
Echinochloa colonum (L.) Link	Awnless barnyard grass
Ectrosia leporina R. Br.	Hare's-tail grass, hare's-foot grass
Eleocharis spp.	Spike-rush
Eleusine indica (L.) Gaertn.	Barnyard grass, crow-foot, crab grass
Elytrophorus spicatus (L.) Greene	Broken spike
Eragrostis spp.	Love grasses
E. japonica (Thunb.) Trin.	Delicate love grass
E. schultzii Benth.	
Eriachne burkittii Jansen	Wanderrie grass
E. ciliata R. Br.	Wanderrie grass
E. mucronata R. Br.	Wanderrie grass

E. obtusa R. Br.	Wanderrie grass
E. triseta Nees ex Steud.	Wanderrie grass
Eriochloa procera (Retz.) C. E. Hubb.	Cup grass
Erythrophleum chlorostachys (F. Muell.) Baill.	Ironwood (N.T.)
Eucalyptus alba Reinw. ex Bl.	Poplar gum, Timor white gum
E. apodophylla Blakely & Jacobs	White bark
E. bleeseri Blakely	Smooth-barked bloodwood
E. camaldulensis Dehn.	Murray red gum, river red gum
E. clavigera A. Cunn. ex Schau.	
E. confertiflora F. Muell.	Apple gum
E. dichromophloia F. Muell.	Red-barked bloodwood
E. ferruginea Schau.	Rusty bloodwood
E. foelscheana F. Muell.	Cabbage gum (N.T.)
E. grandifolia R. Br. ex Benth.	Moreton Bay ash
E. herbertiana Maid.	Yellow-barked mallee
E. latifolia F. Muell.	Bloodwood, bastard bloodwood
E. microtheca F. Muell.	Coolibah
E. miniata A. Cunn. ex Schau.	Melaleuca gum
E. papuana F. Muell.	Cabbage gum, ghost gum, carbeen
E. patellaris F. Muell.	Weeping box
E. phoenicea F. Muell.	Ngainggar or scarlet gum
E. polycarpa F. Muell.	Grey bloodwood
E. tectifica F. Muell.	MacArthur River box
E. terminalis F. Muell.	Bloodwood, kulcha
E. tetrodonta F. Muell.	Darwin stringybark
Eugenia armstrongii Benth.	
E. bleeseri Schwarz	
Euphorbia sp.	Spurge
Ficus spp.	Fig
Fimbristylis spp.	Fringe-rush
Flagellaria indica L.	Supplejack
Fuirena umbellata Rottb.	Sedge
Gardenia megasperma F. Muell.	
Gomphrena canescens R. Br.	
Gossampinus malabaricus (DC.) Merr.	
Grevillea heliosperma R. Br.	
G. pteridifolia Knight	
Grewia sp.	
Hakea arborescens R. Br.	
Heteropogon contortus (L.) Beauv. ex R. & S.	Black spear grass, bunch spear grass
H. triticeus (R. Br.) Stapf	Giant spear grass
Hymenachne amplexicaulis (Rudge) Nees	
Hyptis suaveolens (L.) Poit.	Hyptis
Imperata cylindrica (L.) Beauv. var. *major* (Nees) C. E. Hubb.	Blady grass
Ipomoea aquatica Forsk.	Potato vine
Ischaemum arundinaceum F. Muell. ex Benth.	
I. rugosum Salisb. var. *segetum* Hack. ex DC.	
Iseilema spp.	Flinders grasses
Leersia hexandra Sw.	Swamp rice grass
Leptocarpus spp.	Twine-rush
Livistona humilis R. Br.	Palm
Ludwigia adscendens (L.) Hara	
Marsilea sp.	Nardoo
Maytenus cunninghamii (F. Muell.) Loes.	
Melaleuca argentea W. V. Fitzg.	Paperbark
M. cajaputi Powell	Paperbark
M. leucadendron (L.) L.	Paperbark
M. nervosa (Lindl.) Cheel	Paperbark
M. symphyocarpa F. Muell.	
M. viridiflora Sol. ex Gaertn.	Paperbark
Metrosideros sp.	
Micraira subulifolia F. Muell.	Mountain couch
Mitrasacme spp.	
Morinda citrifolia L.	
Nauclea orientalis (L.) L.	Leichhardt tree
Nymphoides indica (L.) O. Kuntze	Fringed water-lily
Ophiuros exaltatus (L.) O. Kuntze	Cane grass
Opilia amentacea Roxb.	
Oplismenus sp.	
Oryza rufipogon Griff.	Wild rice
Owenia sp.	Emu apple
Pachynema complanatum R. Br.	
P. junceum Benth.	
Pandanus spp.	Screw pine
Panicum spp.	Panic grass
P. delicatum Hughes	Panic grass

P. effusum R. Br.	Panic grass
P. trachyrachis Benth.	Panic grass
Parinari nonda F. Muell.	
Paspalidium sp.	
Paspalum spp.	Paspalum
Petalostigma pubescens Domin	Quinine bush
P. quadriloculare F. Muell.	Quinine bush
Pheidochloa gracilis S. T. Blake	
Phragmites karka (Retz.) Trin. ex Steud.	Reed
Phyla nodiflora (L.) Greene	Fog-fruit
Phylidrum lanuginosum Banks & Sol. ex Gaertn.	
Planchonia careya (F. Muell.) R. Knuth	
Plectrachne pungens (R. Br.) C. E. Hubb.	Soft spinifex
Pseudopogonatherum contortum (Brogn.) A. Camus	
Pseudoraphis spp.	Mud grass
Restio sp.	Cord-rush
Schizachyrium obliqueberbe (Hack.) A. Camus	Red spathe grass
Scirpus spp.	Club-rush
Sclerandrium grandiflorum S. T. Blake	
S. truncatiglume (F. Muell. ex Benth.) Stapf & C. E. Hubb.	
Scleria oryzoides J. & C. Presl	
Sehima nervosum (Rottb.) Stapf	
Sesbania sp.	Sesbania pea
Setaria spp.	Pigeon or bristle grasses
Smilax sp.	Sarsaparilla
Sorghum spp.	
S. plumosum (R. Br.) Beauv.	
Sporobolus virginicus (L.) Kunth	Sand couch, salt-water couch
Stephania sp.	
Sterculia quadrifida R. Br.	
Striga curviflora Benth.	
Stylidium spp.	Trigger-plant
Stylosanthes humilis H. B. & K.	Townsville lucerne
Syzygium sp.	
Terminalia sp.	
T. ferdinandiana Exell	
T. grandiflora Benth.	
T. melanocarpa F. Muell.	
Thaumastochloa major S. T. Blake	
Themeda australis (R. Br.) Stapf	Kangaroo grass
Tristania lactiflua F. Muell.	
Urochloa spp.	
Utricularia fulva F. Muell.	Tawny bladderwort
Verticordia cunninghamii Schau.	
Vetiveria sp.	
Xanthostemon paradoxus F. Muell.	
Xyris indica L.	

Index to Descriptions of Soil Families

(Principal profile form given in brackets)

MAPS

Fig. 1.—The stony mantle on this gentle slope reflects the intense heavy rainfall of the area, and severe over-grazing by buffaloes. The surrounding coastal plains (Cyperus land system) make an ideal habitat for them. Meanderings and cut-offs on the plains represent the Mary River, which has no definite dry-season channel in its lower reaches.

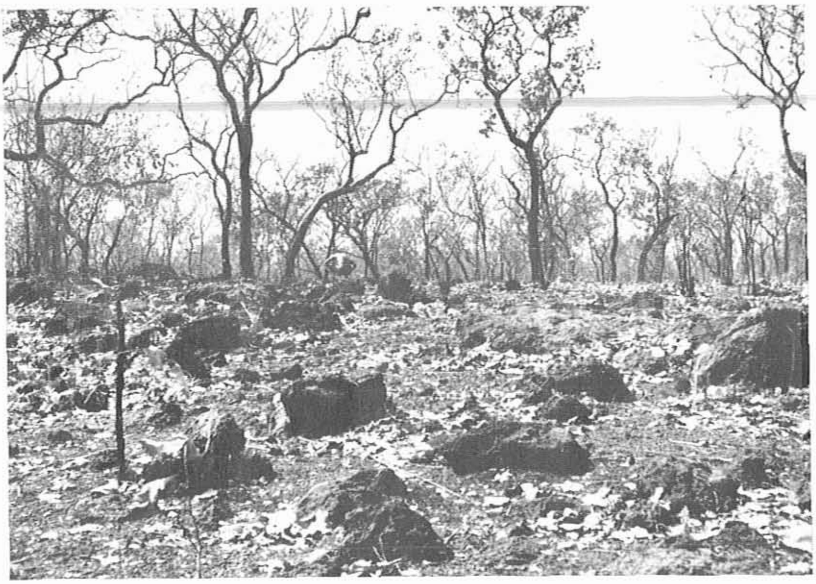

Fig. 2.—This laterite outcrop is on the Koolpinyah surface, which in intact or eroded form covers more than one-third of the survey area. Where the laterite is exposed the soils are thin and gravelly, and usually under eucalypt woodland in which *E. bleeseri* is the characteristic tree.

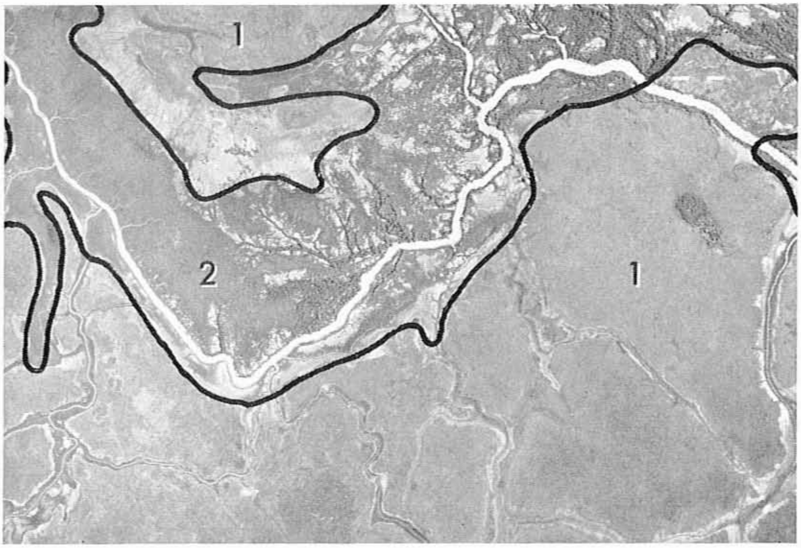

Fig. 1.—The two land systems shown are on the coastal plains, Cyperus (1) being higher and slightly better drained, and predominantly under sedges. Copeman (2) is lower and is flooded longer, sometimes permanently, with a vegetation of sedges, water-weeds, water-grasses, and paperbark, and with freshwater or salt-water mangroves or paperbark along the channels. The soils are deep heavy black cracking clays in both land systems.

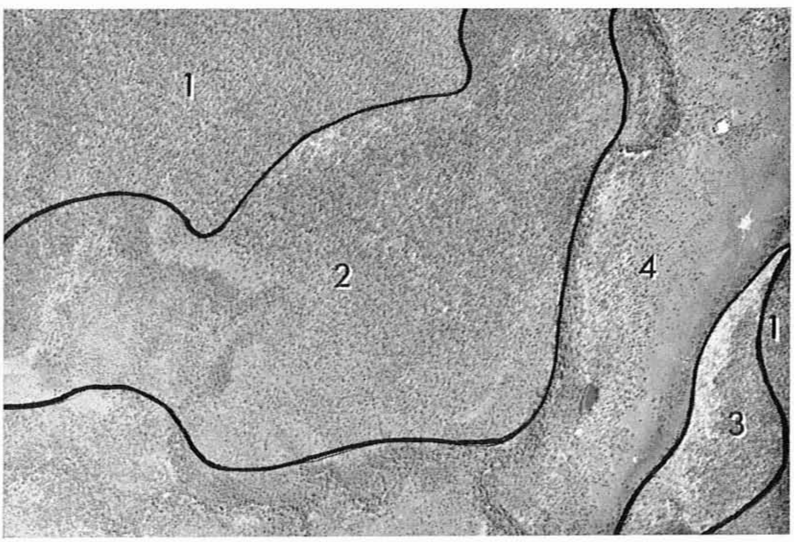

Fig. 2.—The dense vegetation on the upper left (Kay land system (1)) is tall open forest on the intact Koolpinyah surface. The wide border zone indicates an advanced stage of erosion marked by a definite slope, shallow gravelly and sandy soils, and mixed scrub or open woodland (Keefers Hut land system (2)). On the right of the river a narrow sloping zone is marked by deep sandy soils (Knifehandle land system (3)). Lowest in the series is Flatwood land system (4), alluvial, flat or nearly flat country of grassland and savannah with dense paperbark forest and *Pandanus* scrub bordering channels. Soils are deep and often texture-contrast.

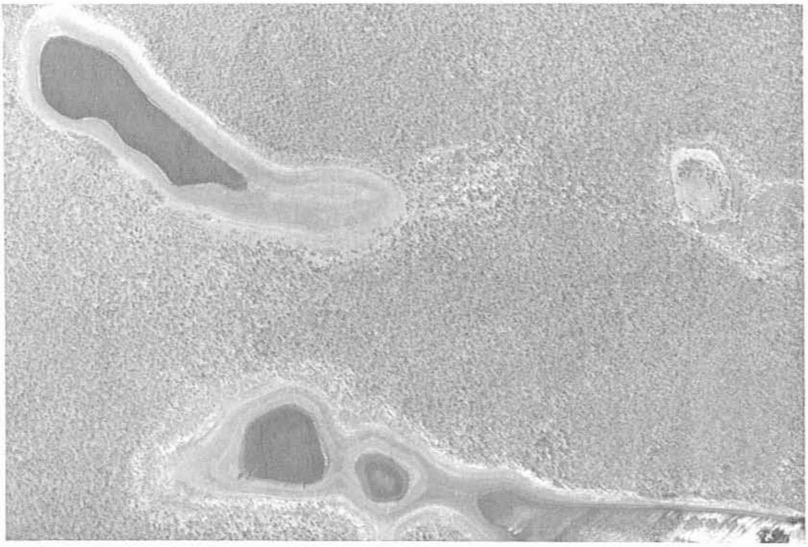

Fig. 1.—Drainage depressions like these (billabongs) are widely but rather patchily distributed over the Koolpinyah surface. It is not certain whether they are remnants of former river systems or the result of solution and subsidence of the underlying rock. They provide grazing and water for the buffaloes and refuge from the bush fires that occur in the dry season.

Fig. 2.—As a rule the coastal plains (Cyperus land system) are under deeply cracking clays, but towards the coast in Littoral land system they tend to be silty and to have finer cracks, as shown here. They are bare or under sedges or samphire.

Fig. 1.—Level Late Tertiary weathered surfaces and fairly deep red and yellow earths are characteristic of Kay and Queue land systems, the soils being predominantly gravelly in Kay and predominantly sandy in Queue. The timber is abundant but small and often unsound. *E. tetrodonta* and *E. miniata* are dominant, with a fairly dense lower storey of smaller trees. The ground cover is of tall or short grasses, sometimes, and for unknown reasons, in sharply defined small communities or very sparse.

Fig. 2.—Where the Koolpinyah surface has been dissected the country is undulating, the soil usually shallower, and the vegetation more open (woodland). This view is of Jay land system on the road to Oenpelli Mission.

Fig. 1.—Alternating patches of scrub and usually short grassland are characteristic of Kosher land system, most of which borders the coastal plains and is heavily grazed by buffaloes. The short grasses are probably secondary, and the introduced Townsville lucerne certainly is so. It does well on the sandy and gravelly soils that are the rule in this land system.

Fig. 2.—Parts of Cyperus and Copeman land systems which border Kay and geologically related land systems (in this case Kosher) are often marked by a long shallow depression, permanently waterlogged and under water-weeds and paperbark. The better-drained part is shown in the middle distance. The sequence is repeated in the background where another swampy border is faintly visible at the foot of more of Kosher land system. This whole complex is on the estuarine plains of the Adelaide River.

Fig. 1.—Flood-plain of the South Alligator River, showing the typical alluvial vegetation of alternating patches of grassland and savannah. Where grassland predominates, the flood-plains are in Fabian land system, otherwise in Flatwood.

Fig. 2.—This dense cover of mid-height sedges is characteristic of most of Cyperus land system. Buffaloes graze a few of the finer species among them, but for practical purposes the Cyperus sedges have no pastoral value. This view is of the estuarine plains of the South Alligator River.

Fig. 1.—Rumwaggon land system in the dissected foothills is a complex of ridges and alluvial flats. The ridges are under some form of woodland as shown here, usually on rocky skeletal soils. The alluvial flats (foreground) are sharply distinct. They are under grassland or savannah, often with texture-contrast soils.

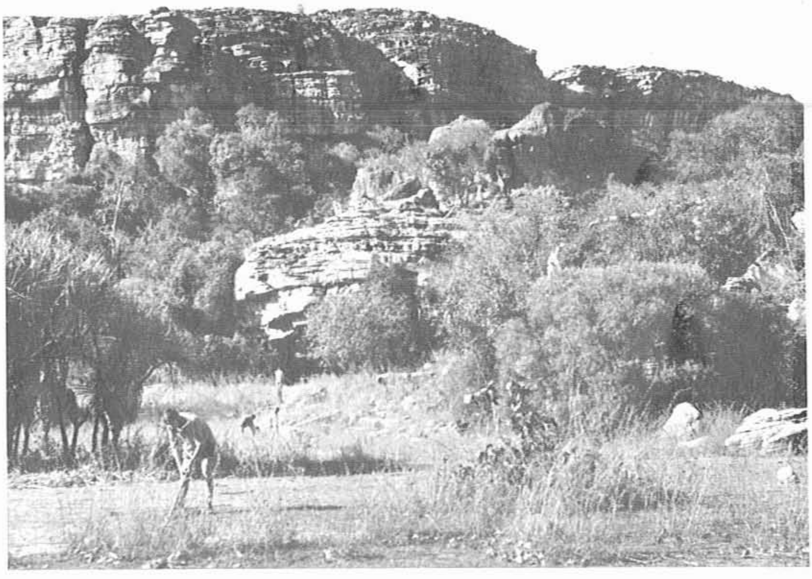

Fig. 2.—The eastern boundary of the survey area ends abruptly where the cliffs of Buldiva land system mark the beginning of Arnhem Land. Outliers of Buldiva land system occur within the area as well. They are of steep rugged quartzite hills, often under spinifex and scattered trees, and are practically valueless for grazing except at the foot, where sandy foot slopes support tall open forest over various grasses.

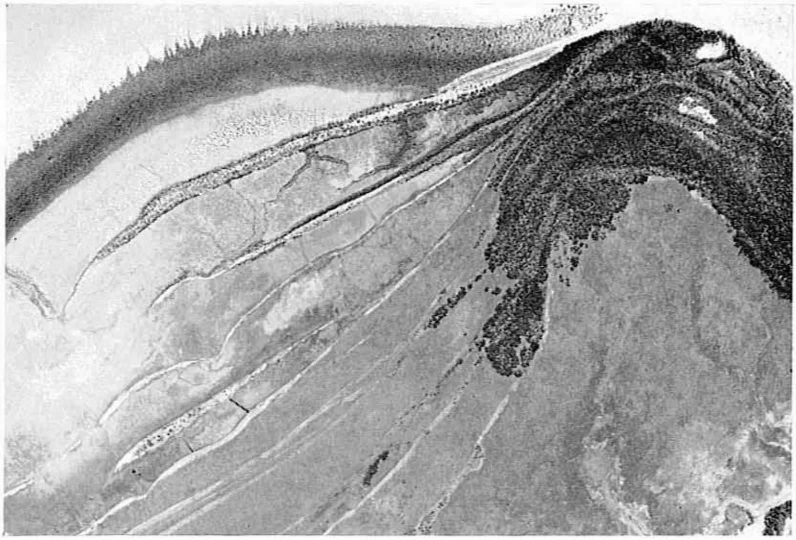

Fig. 1.—Coastal emergence is shown by this series of old dunes at Point Stuart. At the top right corner they are stabilized and under tall open forest and some rain forest patches, elsewhere they support scattered non-eucalypt trees and short grasses. At the top left is a zone of tidal mud flats under mangrove, different species showing as tonal differences in the photograph.

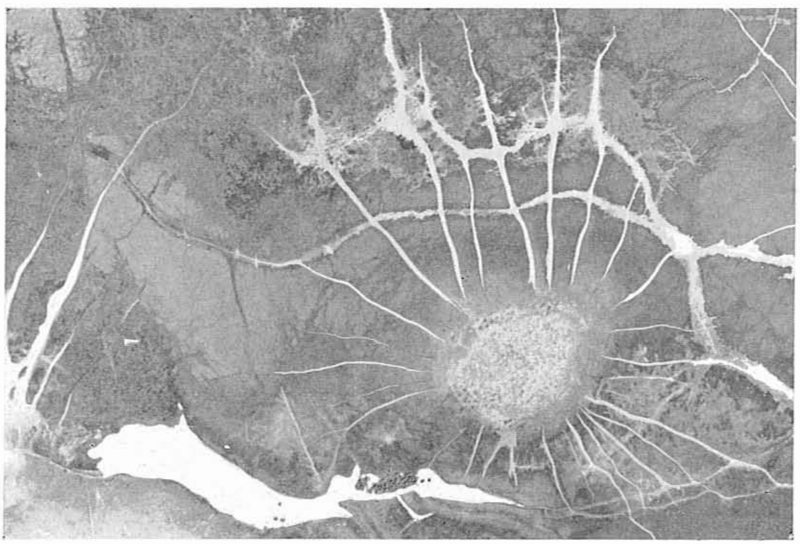

Fig. 2.—The rise in the centre is Floodmark Island, in the Mary River flood-plain. Such places provide a wet-season refuge for the buffalo, as is shown by the radiating tracks which also give some indication of the heavy stocking rate.