Lands of the Ord–Victoria Area, Western Australia and Northern Territory

Comprising papers by G. A. Stewart, R. A. Perry, S. J. Paterson, D. M. Traves, R. O. Slatyer, P. R. Dunn, P. J. Jones, and J. R. Sleeman

Land Research Series No. 28

Commonwealth Scientific and Industrial
Research Organization, Australia
1970

Printed by CSIRO, Melbourne

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PART I. INTRODUCTION TO THE ORD–VICTORIA AREA

By G. A. Stewart*

I. The Survey Area

(a) Location

The Ord–Victoria area lies astride the Western Australia–Northern Territory border (Fig. 1). The total area is 89,690 sq miles, of which approximately one-third is in Western Australia. It extends from long. 127°30′E. to 132°E. and from lat. 13°20′S. to 19°S. On its western boundary it adjoins the North Kimberley area

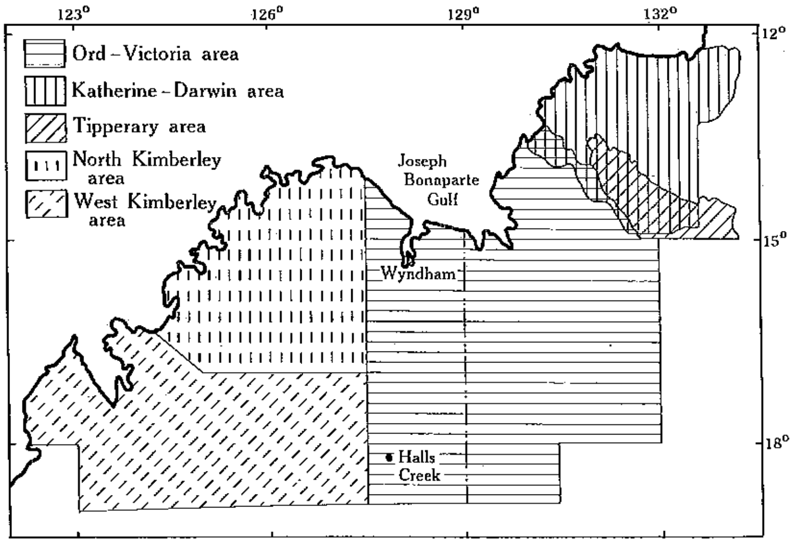

Fig. 1.—Location of the Ord–Victoria area in relation to other surveys in northern Australia.

(Speck *et al.* 1960) and the West Kimberley area (Speck *et al.* 1964). In the north-east, between lat. 13°55′S. and 15°S., the area is adjacent to the Tipperary area (Speck *et al.* 1965). The part of this area north of lat. 14°30′ was mapped approximately from partial air-photo coverage in the survey of the Katherine–Darwin region (Christian and Stewart 1953). Complete air-photo coverage was available at the time of this survey so that this part could be remapped more accurately.

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(*b*) *Towns and Communications*

At the time of the survey (1949, 1952) there were only two townships in the area—Wyndham, a port and meat-processing centre on Cambridge Gulf, and Halls Creek (Plate 4, Fig. 1), a former gold-mining town which is now a small centre for the cattle industry. The township of Kununurra was established in 1960 as a centre for the irrigation development (Plate 4, Fig. 2) in the lower Ord River.

Roads within the area were only graded earth or ungraded tracks, and were closed for long periods each wet season. In the years since the survey the roads have been improved considerably. Most cattle stations have bi-weekly to fortnightly plane services from Wyndham, Alice Springs, Darwin, or Katherine. Virtually all stations are linked by radio transceiver with the Flying Doctor Service for medical services and telegraphic communication.

(*c*) *Early Settlement and Development*

The first significant European exploration of the area was the 1875–79 expedition of Forrest. His glowing reports on parts of the area led to immediate pastoral interest in it, and cattle were overlanded from Queensland and New South Wales in 1884 by Buchanan for Ord River station and by the Duracks, who founded Argyle, Lissadel, and Rosewood stations. At the same time gold was discovered at Halls Creek and this provided a market outlet for beef. However, the Halls Creek gold rush lasted only until the mid 1890s (Traves 1955), after which gold production greatly diminished. At the time of the survey only a few people were engaged in gold-mining. With the decline of Halls Creek, cattle were marketed by exporting them live from Wyndham. About 1910, export of live cattle to the Philippines commenced and the export of store cattle by overland droving to Queensland also developed. The beef-cattle industry expanded until it occupied most of the area, and by 1920 the cattle population had reached approximately its present numbers. The Wyndham meat-works opened in 1918 and export of live cattle from Wyndham was terminated.

The cattle industry (Plate 3, Fig. 2) changed little between 1920 and the time of the survey. A brief description of the industry is given in Part VIII.

The development of irrigated agriculture on the lower Ord River in the 1960s is described in Part IX.

II. Survey Methods

The concepts and techniques of these surveys have been described by Christian and Stewart (1953, 1968). The basic feature is the mapping and description of land systems that are defined as "an area or group of areas throughout which there is a recurring pattern of topography, soils, and vegetation". The distinctive components of the recurring pattern are known as land units.

The technique of surveying large areas in a short time is based on the interpretation of aerial photographs, and a basic assumption is that patterns distinguishable on aerial photographs are a reflection of patterns of land characteristics and vice versa. The aerial photographs used in this survey were at a scale of 1 : 50,000, except for the north-east corner of the area where 1 : 30,000-scale photos were the only ones available.

The surveys are carried out by teams of scientists working very closely together in the field and in the laboratory. The members of the team for this survey were: G. A. Stewart, leader, soil scientist; R. A. Perry, plant ecologist; D. M. Traves, geologist (Bureau of Mineral Resources); S. J. Paterson, geomorphologist (1952 only); J. R. Sleeman, soil scientist (1952 only).

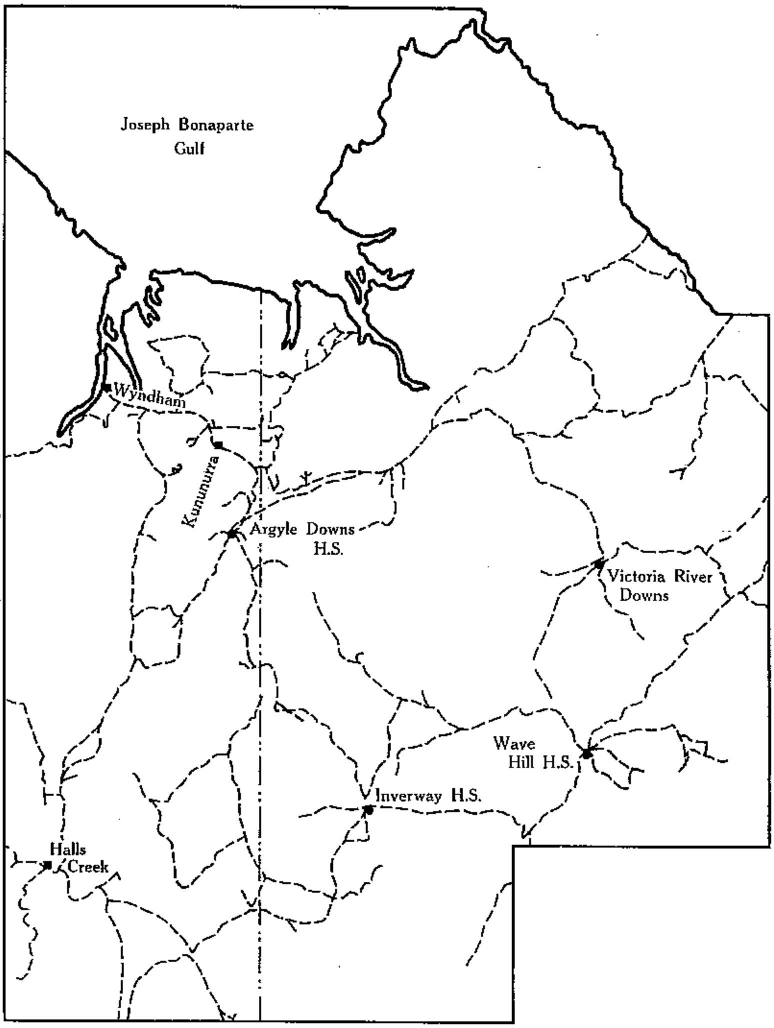

Fig. 2.—Traverse routes.

Field work was carried out in 1949 and 1952, each field season lasting 4 months. Brief notes were made while travelling along the traverse routes shown in Figure 2. More detailed examinations of rock outcrops, land forms, soil profiles, and plant communities were made at approximately 800 selected sites.

This report has been finalized many years after the field work was completed. It reflects the survey techniques that were used at that time, and most of the descriptive material was drafted shortly after field work was completed. It is less comprehensive than recent surveys reported in this series.

With the revision of the early draft material the report has been brought up to date editorially, the geology has been updated by the Bureau of Mineral Resources, and reference is made to recent agricultural research and development.

Since this report is relatively short, it does not contain a summarized description of the survey area. The general reader, or the specialist seeking a general introduction to the area, should read the introductory paragraphs of each part of the report together with the map and reference of pasture lands and land systems.

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PART II. LAND SYSTEMS OF THE ORD–VICTORIA AREA

By G. A. STEWART,* R. A. PERRY,* S. J. PATERSON,† J. R. SLEEMAN,‡ and D. M. TRAVES§

The lands of the Ord–Victoria area have been mapped and described in 50 land systems.

On the reference of the land system map the land systems are grouped in pasture lands which are described in Part VIII of this report. In the following pages the land systems are described in the same order.

The descriptions of land systems include three parts:

Information that applies to the whole land system at the top of the page, including a brief general description; a climatic reference to wettest and driest parts of the land system; a geological reference to the lithology, stratigraphic unit, and geological age; a geomorphological reference to the section or unit; and a brief statement on drainage patterns and drainage characteristics.

An illustrative block diagram that shows the relationship of the various land units within the land system.

Tabular description of the various land units, including qualitative estimates of the proportions of the various land units. Also reference is given to soil family names and plant community names and the interested reader can refer to more detailed information in Parts VI and VII on soils and vegetation.

Where pertinent, reference is also given to similar land systems in other surveyed areas in northern Australia.

Three land systems mapped in the part of the area north of 14°30′—Litchfield, Moyle, and Subcoastal Plain—were not traversed during this survey and their description is based on the descriptions given in the report of the Katherine–Darwin region.|| Another land system, Wingate, is mapped in that northern area, but was not sampled in the field in either this survey or the Katherine–Darwin survey. Its tentative description is based on recorded geological data, air-photo interpretation, and correlation with similar air-photo patterns in other surveyed areas in the northern part of north-western Australia.

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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.

(1) Pinkerton Land System (16,200 sq miles)

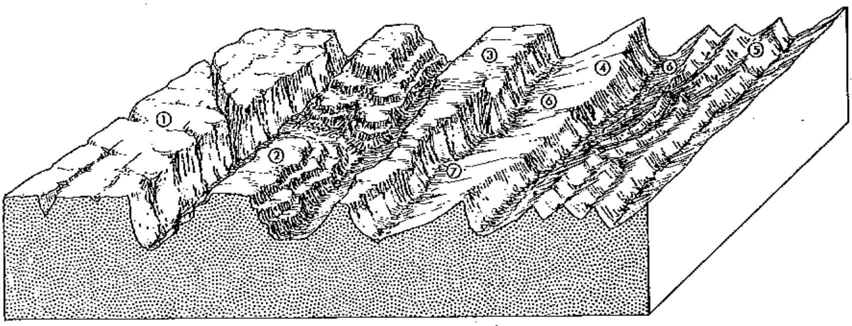
Rugged stony country on sedimentary rocks in the northern part of the area.

Climate.—Wettest locality: mean annual rainfall 50 in.; mean agricultural growing season 23 wk; mean pasture growing season 25 wk. Driest locality: mean annual rainfall 25 in.; mean agricultural growing season 13 wk; mean pasture growing season 17 wk.

Geology.—Sandstone, shale, and some dolomite; Adelaidean, Carpentarian, and Lower Proterozoic.

Geomorphology.—Ridges, hogbacks, cuestas, and structural plateaux.

Drainage.—Angular and rectangular patterns of moderate to high density. Gentle slopes adjacent to stream lines may be subject to flash floods.



Unit	Area	Land Forms	Soils	Vegetation
1	Medium	Structural plateaux of sandstone or quartzite with deep V-shaped gorges	Rock outcrop and skeletal soils	Stringybark–bloodwood woodland (*E. tetrodonta, E. dichromophloia, E. ferruginea, E. miniata, E. phoenicea*) with upland tall grass (*Sorghum stipoideum, Plectrachne pungens*)
2	Medium	Structural plateaux with benches, formed on interbedded limestone, shale, and sandstone		
3	Small	Mesas capped by hard sandstone overlying shales		
4	Medium	Cuestas formed on interbedded hard sandstones and shales		
5	Medium	Hogbacks and ridges		
6	Very small	Gentle lower slopes	Tippera, Elliott—loamy surface soils merging into subsoils of red and yellow clay respectively	Northern box–bloodwood woodland (*E. tectifica, E. foelscheana, E. latifolia, E. confertiflora, E. argillacea* form C) with Tippera tall grass (*Themeda australis, Sehima nervosum, Chrysopogon fallax*) or upland tall grass (*Sorghum stipoideum*)
7	Very small	Gentle slopes adjacent to stream lines	Elliott and miscellaneous alluvial soils	
8	Very small	Stream channels		Fringing communities

Unmappable inclusions: Cockburn, Dinnabung, and Tanmurra.

Comparable with Buldiva land system of the Katherine–Darwin and North Kimberley areas.

(2) Wickham Land System (7100 sq miles)

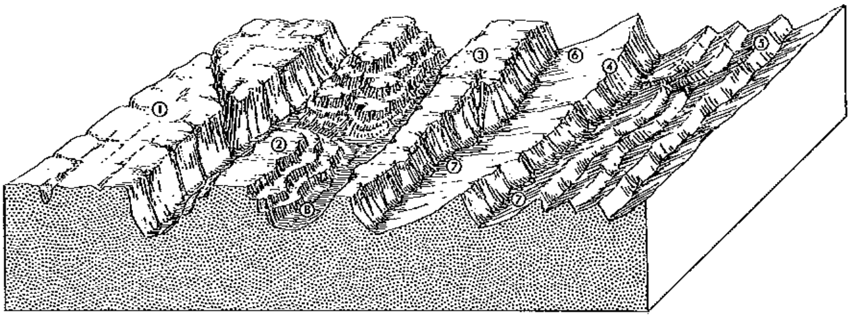
Rugged stony country formed on sedimentary rocks widespread in the southern half of the area.

Climate.—Wettest locality: mean annual rainfall 27 in.; mean agricultural growing season 13 wk; mean pasture growing season 17 wk. Driest locality: mean annual rainfall 15 in.; mean agricultural growing season <5 wk; mean pasture growing season <10 wk.

Geology.—Sandstone, shale, and some dolomite; Adelaidean and Carpentarian.

Geomorphology.—Ridges, hogbacks, cuestas, and structural plateaux.

Drainage.—Angular and rectangular patterns of moderate to high intensity.



Unit	Area	Land Forms	Soils	Vegetation
1	Medium	Structural plateaux of sandstone or quartzite with deep V-shaped gorges	Rock outcrop and shallow sandy skeletal soil	Snappy gum sparse low woodland (*E. brevifolia*) with soft spinifex (*Triodia pungens*, *Plectrachne pungens*)
2	Medium	Structural plateaux with benches, formed on interbedded limestone, shale, and sandstone		
3	Small	Mesas, capped by hard sandstone overlying soft shales		
4	Medium	Cuestas formed on interbedded hard sandstone over shales		
5	Medium	Hogbacks and ridges		
6	Very small	Lower gentle slopes	Elliott—grey loam merging into yellow clay; some Tobermorey—shallow calcareous loamy soils	Bloodwood–southern box sparse low woodland (*E. terminalis*, *E. argillacea* form B, *E. argillacea* form A, *E. confertiflora*) or silver-leaved box sparse low woodland, both with three-awn mid-height grass (*Aristida pruinosa*, *A. browniana*, *Chrysopogon fallax*) or arid short grass (*Enneapogon* spp., *Aristida* spp.)
7	Very small	Gentle slopes adjacent to stream lines	Elliott and miscellaneous alluvial soils	

Unmappable inclusions: Humbert.

(3) Weaber Land System (400 sq miles)

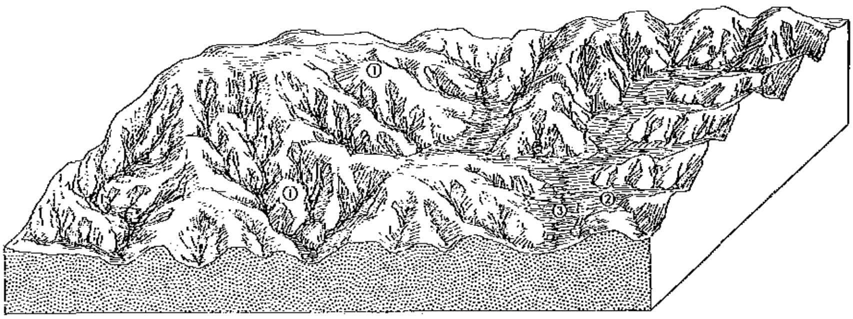
Scattered small areas of rugged sandstone hills with some gentle lower slopes in the north-western part of the area.

Climate.—Wettest locality: mean annual rainfall 34 in.; mean agricultural growing season 17 wk; mean pasture growing season 21 wk. Driest locality: mean annual rainfall 26 in.; mean agricultural growing season 11 wk; mean pasture growing season 15 wk.

Geology.—Sandstone, calcareous sandstone, conglomerate, and minor limestone; Permian, Devonian–Carboniferous, and Cambrian–Ordovician.

Geomorphology.—Ridges, hogbacks, cuestas, and structural plateaux.

Drainage.—Angular and rectangular patterns of moderate to high intensity.



Unit	Area	Land Forms	Soils	Vegetation
1	Large	Very rugged hills	Sandstone outcrops with patches of skeletal soils and shallow red and yellow soils	Stringybark–bloodwood woodland (*E. tetrodonta*, *E. dichromophloia*, *E. miniata*, *E. ferruginea*, *E. aspera*) or deciduous sparse low woodland (*Xanthostemon paradoxus*, *Owenia vernicosa*, *Terminalia* spp.), both with upland tall grass (*Sorghum stipoideum*, *Plectrachne pungens*, *Triodia stenostachya*)
2	Small	Gentle lower slopes	Cockatoo—deep red sand; Pago—deep yellow sands	Stringybark–bloodwood woodland (*E. tetrodonta*, *E. miniata*, *E. dichromophloia*) or frontage woodlands (*E. polycarpa*, *E. papuana*, *E. apodophylla*), both with upland tall grass (*Sorghum stipoideum*, *Plectrachne pungens*, *Aristida* spp.)
3	Very small	Small stream channels		Fringing communities

(4) Elder Land System (450 sq miles)

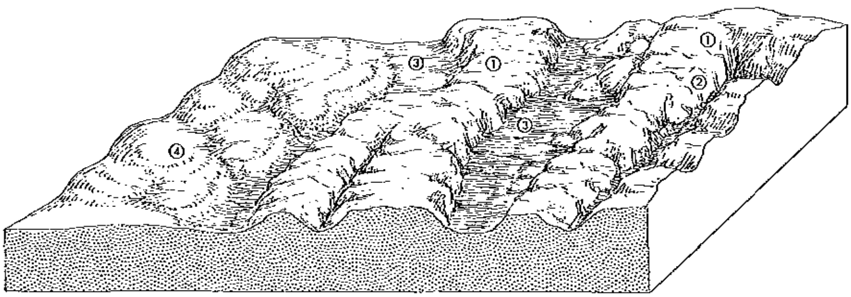
Rugged sandstone hills in the central-western part of the area.

Climate.—Mean annual rainfall 22 in.; mean agricultural growing season 8 wk; mean pasture growing season 13 wk.

Geology.—Sandstone. Upper Devonian (Elder Sandstone).

Geomorphology.—Sandstone structural plateaux (asymmetric basin) and sandstone–shale cuestas (asymmetric basin).

Drainage.—Angular and rectangular patterns of moderate to high intensity.



Unit	Area	Land Forms	Soils	Vegetation
1	Large	Very rugged hills	Sandstone outcrops	Snappy gum (*E. brevifolia*) or silver-leaved box (*E. pruinosa*) sparse low woodlands with soft or hard spinifex
2	Very small	Moderate to steep slopes within unit 1	Outcrops with patches of skeletal soils and shallow red and yellow soils	
3	Small	Gently sloping sand plains and valley floors	Cockatoo—deep red sand	Silver-leaved box sparse low woodland (*E. pruinosa–E. grandifolia*) with three-awn mid-height grass (*Aristida* spp., *Chrysopogon fallax*)
4	Medium	Undulating to low hilly country	Alternating outcrop and sandy soils, Cockatoo—deep red sand; minor Tippera	Snappy gum (*E. brevifolia*) or silver-leaved box (*E. pruinosa*) sparse low woodlands with soft or hard spinifex on outcrop areas and three-awn mid-height grass on areas with soil

(5) Brocks Creek Land System (200 sq miles)

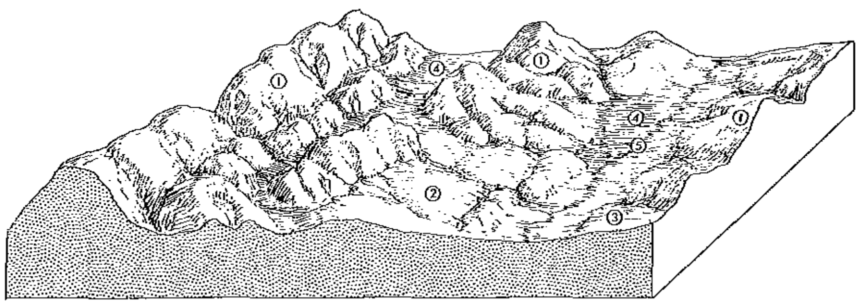
Three small areas of rugged parallel ridges with small patches of undulating country in the north-eastern corner of the area.

Climate.—Wettest locality: mean annual rainfall 50 in.; mean agricultural growing season 23 wk; mean pasture growing season 25 wk. Driest locality: mean annual rainfall 40 in.; mean agricultural growing season 20 wk; mean pasture growing season 23 wk.

Geology.—Sandstone, conglomerate, siltstone; Lower Proterozoic–Archaean sediments and metamorphic rocks.

Geomorphology.—Ridges, hogbacks, cuestas, and structural plateaux.

Drainage.—Trellis drainage of high intensity in the ridges and hills; the alluvial flats are liable to flooding in the wet season.



Unit	Area	Land Forms	Soils	Vegetation
1	Large	Steep slopes of the parallel ridges	Rock outcrop or shallow skeletal soils	Stringybark–bloodwood woodland (*E. tetrodonta*, *E. miniata*, *E. phoenicea*, *E. dichromophloia*), northern box–bloodwood woodland (*E. tectifica*, *E. foelscheana*, *E. confertiflora*), and on very rocky areas deciduous sparse low woodland (*Cochlospermum fraseri*, *Erythrophleum chlorostachys*), all with upland tall grass (*Sorghum* spp., *Heteropogon triticeus*)
2	Small	Moderate slopes of low ridges and hills	Shallow gravelly yellow sandy loam soils	
3	Small	Gentle slopes	Elliott—grey sandy loam merging into mottled yellow clay	Northern box–bloodwood woodland (*E. foelscheana*, *E. grandifolia*, *E. confertiflora*) with Tippera tall grass (*Themeda australis*, *Chrysopogon latifolius*, *Alloteropsis semialata*, and *Sorghum plumosum*)
4	Small	Alluvial flats	Marrakai—light grey powdery loam merging into mottled light grey clay	Marrakai mid-height grass (*Eriachne* spp., *Themeda australis*) with widely spaced large trees of *E. papuana* and *E. grandifolia*
5	Very small	Stream channels		Fringing communities

Comparable with the Brocks Creek land system of the Katherine–Darwin area; this description has been adapted from the report on that area.

(6) DOCKRELL LAND SYSTEM (1900 SQ MILES)

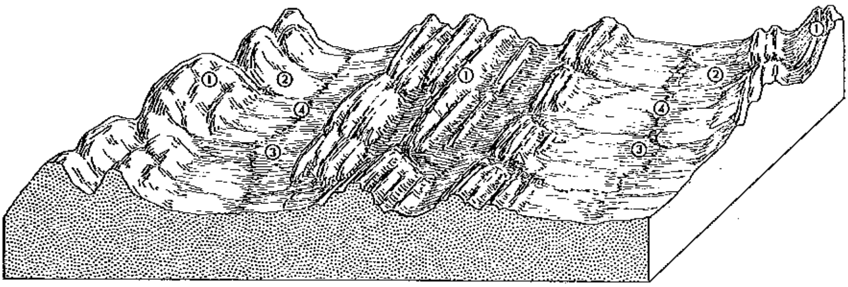
A series of NNW.-trending ridges and valleys in one large or several small areas in the western half of the area.

Climate.—Wettest locality: mean annual rainfall 30 in.; mean agricultural growing season 15 wk; mean pasture growing season 19 wk. Driest locality: mean annual rainfall 17 in.; mean agricultural growing season 5 wk; mean pasture growing season 10 wk.

Geology.—Siltstone, shale, sandstone, basic volcanics, and greywacke; Lower Proterozoic–Archaean sediments and metamorphics.

Geomorphology.—Complex fold mountains (ridge metamorphic belt).

Drainage.—Intense youthful trellis drainage; the major rivers, Ord, Panton, Elvire, and Black Elvire, flow transverse to the trend of the ridges through a series of water gaps.



Unit	Area	Land Forms	Soils	Vegetation
1	Large	Steep to moderately sloping parallel ridges and low hills	Rock outcrop with pockets of shallow gravelly soils	Acid rocks: snappy gum sparse low woodland (*E. brevifolia*) with hard spinifex (*Triodia inutilis*) or upland tall grass (*Sorghum australiense, Plectrachne pungens*). More basic rocks, higher rainfall: northern box–bloodwood woodland (*E. tectifica, E. grandifolia*) with upland tall grass (*Sorghum australiense, Plectrachne pungens*); lower rainfall: bloodwood–southern box sparse low woodland (*E. terminalis*) with hard spinifex (*Triodia inutilis, T. wiseana*) or arid short grass (*Enneapogon* spp.)
2	Medium	Gentle lower slopes	Elliott in northern higher-rainfall parts; Moonah in southern drier parts; commonly gravelly and shallow	Paperbark sparse low woodland with upland tall grass (*Plectrachne pungens*) in north; bloodwood–southern box sparse low woodland or snappy gum sparse low woodland, both over hard spinifex (*T. inutilis, T. intermedia*), in south
3	Very small	Alluvial flats fringing stream lines	Elliott in north, Hooper in south	Northern box–bloodwood woodland (*E. grandifolia*) with upland tall grass

(7) Pompey Land System (800 sq miles)

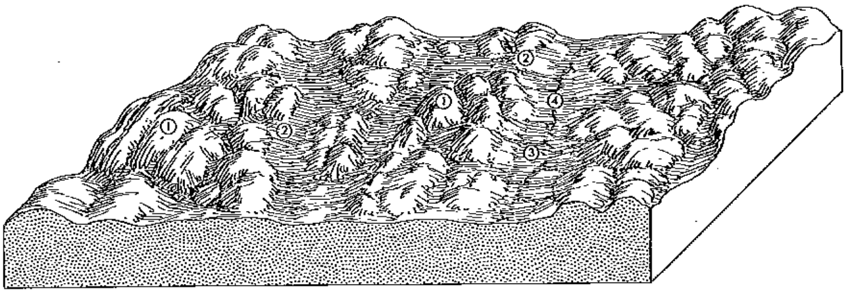
Rugged granite country with some sandy soils occurring as a number of small areas in the north-western part of the area.

Climate.—Wettest locality: mean annual rainfall 27 in.; mean agricultural growing season 14 wk; mean pasture growing season 18 wk. Driest locality: mean annual rainfall 25 in.; mean agricultural growing season 10 wk; mean pasture growing season 14 wk.

Geology.—Granitic rocks, high-grade metamorphics, gabbro, acid volcanics; Lower Proterozoic.

Geomorphology.—Ancient igneous masses.

Drainage.—Angular and rectangular pattern of moderate intensity in the steeply sloping parts, becoming dendritic in the broader valleys.



Unit	Area	Land Forms	Soils	Vegetation
1	Large	Rugged bouldery hills	Mostly boulders of granite	Trees absent or deciduous sparse low woodland with upland tall grass (*Triodia cunninghamii*, *Plectrachne pungens*, *Sorghum australiense*), or snappy gum sparse low woodland (*E. brevifolia*) over hard spinifex (*Triodia inutilis*) or upland tall grass (*Sorghum australiense*, *Plectrachne pungens*, *Eriachne obtusa*)
2	Small	Moderate slopes	Pago—very gritty yellow sands, with boulders of granite	Snappy gum sparse low woodland (*E. brevifolia*) with hard spinifex (*Triodia inutilis*)
3	Very small	Narrow depressions or flats adjacent to stream lines	Hooper—shallow sand or sandy loam over tough clay	Trees absent with Marrakai mid-height grass (*Eriachne* spp., *Themeda australis*)
4	Very small	Stream channels		Fringing communities

Comparable with Amy land system of the West Kimberley area.

(8) Mullaman Land System (1300 sq miles)

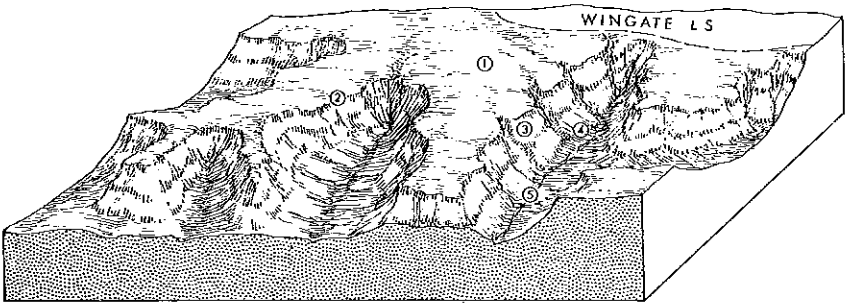
Many small mesas and scarp lines along the edge of tablelands in the north-eastern part of the area.

Climate.—Wettest locality: mean annual rainfall 50 in.; mean agricultural growing season 24 wk; mean pasture growing season 25 wk. Driest locality: mean annual rainfall 26 in.; mean agricultural growing season 14 wk; mean pasture growing season 18 wk.

Geology.—Lateritized sediments and volcanics; Cretaceous sediments, Lower Cambrian volcanics, and Adelaidean sediments.

Geomorphology.—Dissected elevated lateritic plain.

Drainage.—Drained by headwater tributaries of coastal rivers.



Unit	Area	Land Forms	Soils	Vegetation
1	Large	Gently sloping mesa crests	Laterite outcrop with pockets of sandy soil; some Koolpinyah—yellowish grey or sandy loam over laterite	Stringybark–bloodwood woodland (*E. tetrodonta, E. miniata, E. ferruginea*) with upland tall grass (*Sorghum australiense, Plectrachne pungens*)
2	Small	Edge of tableland. Steep scarps and edges of mesas	Outcrop of ferruginous zone and mottled zone	Mesa gum sparse low woodland (*E. umbrawarrensis*) with sparse upland tall grass (*Plectrachne pungens*) or lancewood forest with bare ground
3	Small	Upper steep slopes	Shallow stony soils overlying deeply weathered rocks	Stringybark–bloodwood woodland (*E. tetrodonta, E. miniata, E. ferruginea*) with upland tall grass (*Sorghum australiense, Plectrachne pungens*)
4	Medium	Lower steep to moderate slopes, sometimes benched	Shallow stony soils on underlying unweathered rocks	Stringybark–bloodwood woodland (*E. tetrodonta, E. miniata, E. dichromophloia*) or northern box–bloodwood woodland (*E. tectifica, E. foelscheana*) with upland tall grass (*Sorghum australiense, Plectrachne pungens*)
5	Very small	Narrow incised stream channels		Fringing communities

Comparable with Mullaman land system of the Katherine–Darwin and Tipperary areas.

(9) Napier Land System (1100 sq miles)

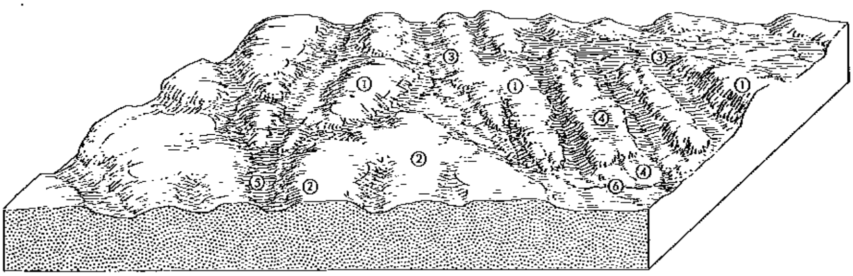
Hilly basaltic country in the northern half of the area.

Climate.—Wettest locality: mean annual rainfall 42 in.; mean agricultural growing season 21 wk; mean pasture growing season 24 wk. Driest locality: mean annual rainfall 27 in.; mean agricultural growing season 12 wk; mean pasture growing season 16 wk.

Geology.—Basalt, agglomerate, and tuff. Lower Cambrian (Antrim Plateau Volcanics), some Carpentarian dolerite.

Geomorphology.—Volcanic mesas and buttes.

Drainage.—Fairly intense angular or rectangular pattern.



Unit	Area	Land Forms	Soils	Vegetation
1	Medium	Mesas and buttes with steeply sloping margins	Mostly rock outcrops with basalt boulders and pockets of red clayey soil	Northern box–bloodwood woodland (*E. tectifica*) or deciduous sparse low woodland (*Terminalia* spp., *Cochlospermum fraseri*), both with upland tall grass (*Sorghum australiense, Triodia stenostachya*)
2	Medium	Crests and slopes of rounded hills		
3	Small	Moderate to gentle slopes	Frayne—stony brown loam merging into dark red clay	Silver-leaved box sparse low woodland (*E. pruinosa*) with Tippera tall grass (*Sehima nervosum, Themeda australis*)
4	Very small	Gentle lower slopes and flat areas	Cununurra, Argyle, Barkly—grey and brown cracking clays	Blue grass tall grass (*Dichanthium* spp., *Eulalia fulva, Ophiuros exaltatus*)
5	Very small	Flats bordering stream lines	Variable light- and medium-textured alluvial soils	Frontage woodland (*E. papuana, E. tectifica, E. foelscheana*) with frontage tall grass
6	Very small	Stream channels		Fringing communities

Comparable with Napier land system of the North Kimberley area and Looingnin land system of the West Kimberley area.

(10) Antrim Land System (6700 sq miles)

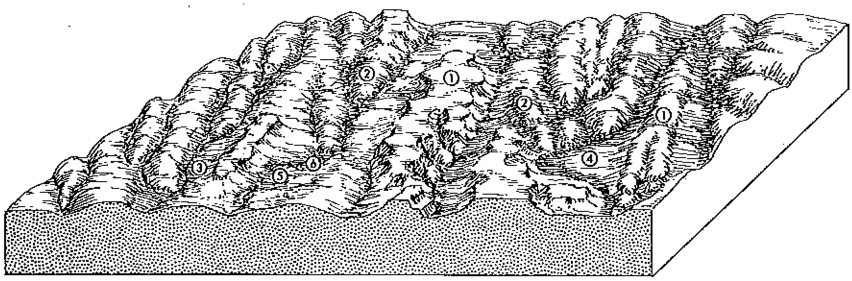
Hilly country associated with intermediate and basic igneous rocks, spread widely throughout the southern half of the area.

Climate.—Wettest locality: mean annual rainfall 27 in.; mean agricultural growing season 12 wk; mean pasture growing season 16 wk. Driest locality: mean annual rainfall 16 in.; mean agricultural growing season 5 wk; mean pasture growing season 10 wk.

Geology.—Basalt, agglomerate, and tuff; Lower Cambrian (Antrim Plateau Volcanics). Some Carpentarian dolerite.

Geomorphology.—Volcanic mesas and buttes, and volcanic structural benches; minor ancient igneous masses.

Drainage.—Fairly intense angular or rectangular drainage patterns.



Unit	Area	Land Forms	Soils	Vegetation
1	Medium	Mesas and buttes with steeply sloping margins	Mostly rock outcrops with basalt boulders and pockets of red clayey soils	Bloodwood–southern box sparse low woodland (*E. terminalis*) with arid short grass (*Enneapogon* spp.) or upland tall grass (*Sorghum stipoideum*); snappy gum sparse low woodland (*E. brevifolia*) with hard spinifex (*Triodia wiseana, T. inutilis, T. intermedia*) or arid short grass (*Enneapogon* spp.)
2	Medium	Crests and slopes of rounded hills		
3	Small	Moderate to gentle slopes	Frayne—brown loam merging into dark red clay, generally stony on surface	Bloodwood–southern box sparse low woodland (*E. terminalis, E. argillacea* form B, *E. argillacea* form A), silver-leaved box sparse low woodland (*E. pruinosa*), or snappy gum sparse low woodland (*E. brevifolia*), all with arid short grass (*Enneapogon* spp.)
4	Very small	Gentle lower slopes and flat areas	Cununurra, Argyle, Barkly—grey and brown cracking heavy clays	Mitchell and other mid-height grasses (*Astrebla pectinata, Aristida latifolia*)
5	Very small	Flats bordering drainage lines	Variable light- to medium-textured alluvial soils	Frontage woodland (*E. terminalis, E. papuana*) with arid short grass (*Enneapogon* spp.) or frontage tall grasses
6	Very small	Stream channels		Fringing communities

Unmappable inclusions: Franklin.

(11) Tanmurra Land System (900 sq miles)

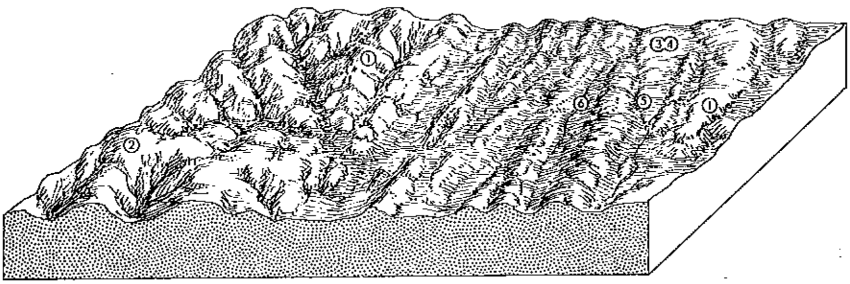
Hilly dolomite and limestone country in the northern half of the area.

Climate.—Wettest locality: mean annual rainfall 35 in.; mean agricultural growing season 18 wk; mean pasture growing season 22 wk. Driest locality: mean annual rainfall 27 in.; mean agricultural growing season 13 wk; mean pasture growing season 17 wk.

Geology.—Adelaidean dolomitic rocks, some sandstone; Lower Carboniferous and Upper Devonian limestones.

Geomorphology.—Limestone ridges, hogbacks, cuestas, and structural plateaux.

Drainage.—Dendritic, angular, and radial patterns of moderate intensity.



Unit	Area	Land Forms	Soils	Vegetation
1	Large	Very bouldery limestone hills	Limestone outcrops or boulders	Deciduous sparse low woodland (*Terminalia* spp., *Bauhinia cunninghamii*, *Cochlospermum fraseri*) with upland tall grass (*Sorghum stipoideum*)
2	Small	Gently sloping limestone boulder areas or short steep strike scarps	Shallow soils with limestone outcrops or boulders	
3	Small	Gentle slopes	Tippera—brown loam merging into red clay; some areas of Elliott—grey sandy loam merging into mottled yellow clay; minor Tobermorey—shallow grey to yellow-brown calcareous loamy soil on limestone	Northern box–bloodwood woodland (*E. tectifica*, *E. foelscheana*, *E. latifolia*) with Tippera tall grass (*Themeda australis*, *Sehima nervosum*, *Chrysopogon fallax*)
4	Very small	Lower gentle slopes	Cununurra—grey cracking heavy clays	Blue grass tall grass (*Dichanthium* spp., *Sorghum* spp., *Ophiuros exaltatus*)
5	Very small	Gentle slopes near stream lines	Variable light- to medium-textured alluvial soils	Northern box–bloodwood woodland (*E. tectifica*, *E. foelscheana*, *E. grandifolia*) with frontage tall grass (*Chrysopogon latifolius*, *Panicum* spp., *Sorghum* spp.)
6	Very small	Stream channels		Fringing communities

(12) Humbert Land System (1700 sq miles)

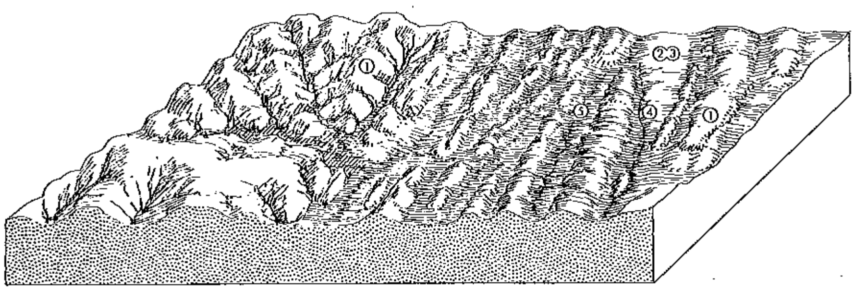
Hilly limestone country in the southern half of the area.

Climate.—Wettest locality: mean annual rainfall 27 in.; mean agricultural growing season 13 wk; mean pasture growing season 17 wk. Driest locality: mean annual rainfall 17 in.; mean agricultural growing season 5 wk; mean pasture growing season 10 wk.

Geology.—Dolomitic sediments, chert, sandstone; Adelaidean dolomitic rocks.

Geomorphology.—Limestone ridges, hogbacks, cuestas, and structural plateaux.

Drainage.—Dendritic, angular, and radial patterns of moderate intensity.



Unit	Area	Land Forms	Soils	Vegetation
1	Large	Very bouldery limestone hills	Limestone outcrops and boulders with pockets of shallow soils	Bloodwood–southern box sparse low woodland (*E. terminalis*) with arid short grass (*Enneapogon* spp.)
2	Small	Gentle slopes	Tobermorey—shallow grey to yellow-brown calcareous loamy soils on limestone; minor Tippera—brownish loam merging into dark red clay; some small areas Elliott—greyish sandy loam merging into mottled yellow clay	Silver-leaved box sparse low woodland (*E. pruinosa*) with three-awn mid-height grass (*Aristida* spp., *Chrysopogon fallax*)
3	Very small	Lower gentle slopes	Cununurra—grey cracking clay	Mitchell and other mid-height grasses (*Astrebla pectinata, Panicum* spp., *Dichanthium fecundum*)
4	Very small	Gentle slopes near stream lines	Variable light- to medium-textured alluvial soils	Bloodwood–southern box sparse low woodland (*E. terminalis*) with frontage grasses (*Aristida* spp.)
5	Very small	Stream channels		Fringing communities

Comparable with Windjana land system of the West Kimberley area and Thorntonia land system of the Barkly region.

(13) Headley Land System (550 sq miles)

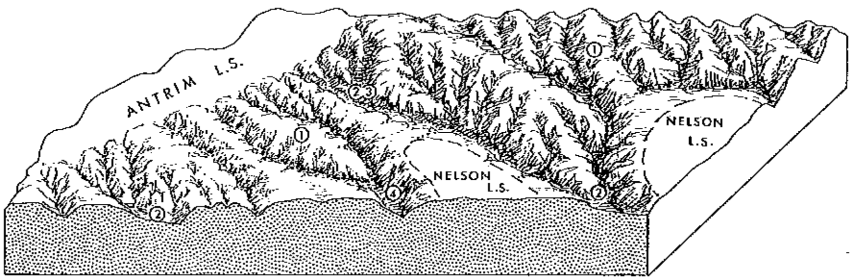
Dissected limestone hills in the south-western part of the area.

Climate.—Wettest locality: mean annual rainfall 25 in.; mean agricultural growing season 11 wk; mean pasture growing season 15 wk. Driest locality: mean annual rainfall 19 in.; mean agricultural growing season 6 wk; mean pasture growing season 11 wk.

Geology.—Limestone, minor shale. Middle Cambrian (Negri Group).

Geomorphology.—Limestone cuestas (asymmetric basin).

Drainage.—Intense pattern of insequent stream channels in unit 1, widely spaced insequent channels in unit 2.



Unit	Area	Land Forms	Soils	Vegetation
1	Large	Steep low hills separated by many deeply incised stream channels	Limestone outcrops with pockets of shallow skeletal soils	Deciduous sparse low woodland with hard spinifex
2	Small	Gentle lower slopes at foot of hills	Tobermorey—shallow grey to yellow-brown calcareous loamy soils or limestone; many limestone boulders and outcrops	Bloodwood–southern box sparse low woodland (*E. terminalis*) with arid short grass (*Enneapogon* spp.) or hard spinifex (*Triodia wiseana*)
3	Very small	Gentle slopes associated with unit 2	Negri—brown calcareous loamy soil or shales	Bare ground or sparse arid short grasses and low trees
4	Very small	Stream channels		Fringing communities

(14) RICHENDA LAND SYSTEM (2300 SQ MILES)

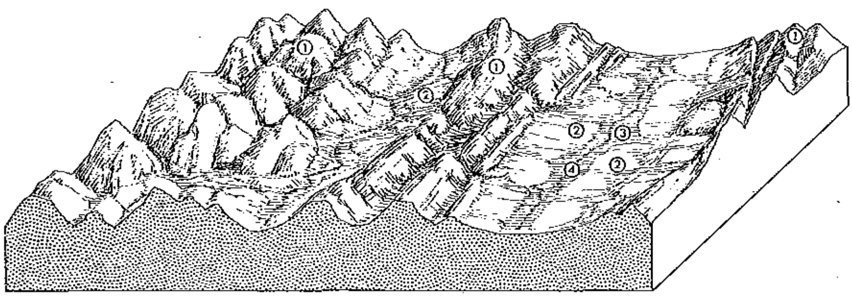
Granite hills in the west of the area.

Climate.—Wettest locality: mean annual rainfall 26 in.; mean agricultural growing season 11 wk; mean pasture growing season 15 wk. Driest locality: mean annual rainfall 20 in.; mean agricultural growing season 7 wk; mean pasture growing season 11 wk.

Geology.—Lower Proterozoic granite, gabbro, rhyolite, metamorphic rocks (Lamboo Complex).

Geomorphology.—Ancient igneous masses.

Drainage.—Intense angular or rectangular pattern of incised drainage.



Unit	Area	Land Forms	Soils	Vegetation
1	Large	Rocky hill slopes	Mainly outcrop	Snappy gum sparse low woodland (*E. brevifolia*) with soft spinifex (*Plectrachne pungens*)
2	Medium	Lower slopes, colluvial in lower sectors	Mainly outcrop with shallow skeletal soils. Minor Moonah	
3	Very small	Drainage floors	Medium-textured alluvial soils	
4	Very small	Channels		Fringing communities

Comparable with Richenda land system of the West Kimberley area.

(15) Cockburn Land System (1500 sq miles)

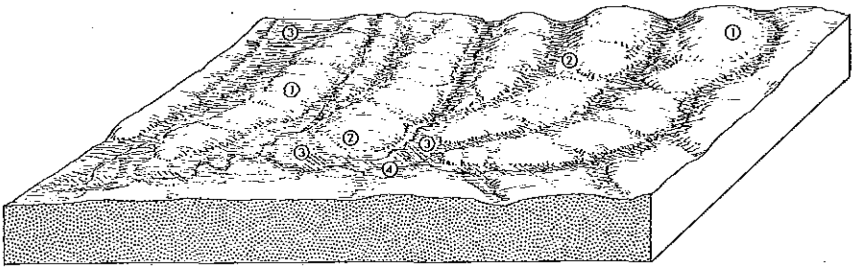
Several small patches of undulating to low shaly country with sparse shrub vegetation scattered throughout the northern part of the area.

Climate.—Wettest locality: mean annual rainfall 40 in.; mean agricultural growing season 20 wk; mean pasture growing season 23 wk. Driest locality: mean annual rainfall 25 in.; mean agricultural growing season 10 wk; mean pasture growing season 14 wk.

Geology.—Mainly shales and siltstones; Adelaidean and Carpentarian sediments.

Geomorphology.—Coastal erosional plains.

Drainage.—Rectangular and angular stream pattern of moderate intensity; unit 3 may be flooded for short periods after heavy rains.



Unit	Area	Land Forms	Soils	Vegetation
1	Large	Moderate to gentle slopes	Rock outcrops and shallow, very gravelly, skeletal soils	Trees absent, or paperbark sparse low woodland (*Melaleuca* spp.) with soft spinifex (*Plectrachne pungens*)
2	Small	Gentle lower slopes on shale	Elliott—shallow grey sandy loam merging into mottled yellow clay	Paperbark sparse low woodland (*Melaleuca* spp.) with upland tall grass (*Sorghum stipoideum*, *Plectrachne pungens*)
3	Small	Alluvial depressions or flats fringing stream lines	Elliott—deep grey sandy loam merging into mottled yellow clay	
4	Very small	Small stream channels		Fringing communities

Comparable with Glenroy land system of the West Kimberley area, Kurunjie land system of the North Kimberley area.

(16) Franklin Land System (1600 sq miles)

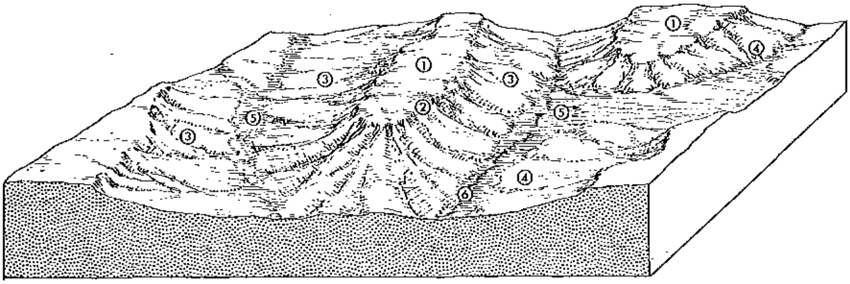
Many small areas of mesas and dissection scarps capped with lateritic material, scattered throughout the southern half of the area.

Climate.—Wettest locality: mean annual rainfall 24 in.; mean agricultural growing season 12 wk; mean pasture growing season 16 wk. Driest locality: mean annual rainfall 15 in.; mean agricultural growing season <5 wk; mean pasture growing season <10 wk.

Geology.—Lateritized sediments and volcanics; Lower Cambrian volcanics and Adelaidean sediments.

Geomorphology.—Dissected elevated lateritic plain.

Drainage.—Moderately intense dendritic pattern of both coastal and inland draining streams.



Unit	Area	Land Forms	Soils	Vegetation
1	Small	Gentle slopes above scarps	Wonorah shallow phase—red-brown clay loam with many ferruginous concretions	Snappy gum sparse low woodland (*E. brevifolia*) or stringybark–bloodwood woodland (*E. dichromophloia*), both with soft spinifex (*Triodia pungens*)
2	Very small	Steep scarps and upper slopes	Outcrops of ferruginous, mottled, and pallid zones with pockets of skeletal soils	Snappy gum sparse low woodland (*E. brevifolia*) with soft spinifex (*Triodia pungens*) or lancewood forest with bare ground
3	Large	Moderate colluvial slopes with many small gullies	Shallow reddish soils with much ferruginous gravel	Snappy gum sparse low woodland (*E. brevifolia*) with soft spinifex (*Triodia pungens*) or upland tall grass (*Sorghum australiense*)
4	Medium	Moderate to gentle lower slopes	Frayne—brown loam merging into dark red clay; some Argyle—brown cracking clay	Bloodwood–southern box woodland (*E. terminalis*) with Tippera tall grass (*Themeda australis*)
5	Small	Valley floors	Cununurra—grey cracking clay	Mitchell and other mid-height grasses (*Astrebla pectinata, Aristida latifolia*)
6	Very small	Stream channel		Fringing communities

(17) Ruby Land System (100 sq miles)

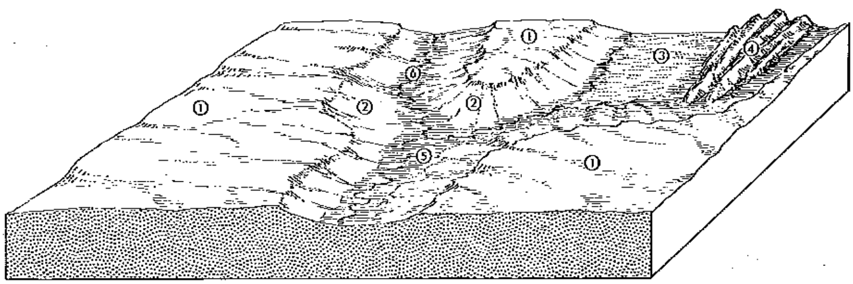
Shallowly dissected lateritic country in the south-west corner of the area.

Climate.—Mean annual rainfall 18 in.; mean agricultural growing season <5 wk; mean pasture growing season <10 wk.

Geology.—Lateritized sedimentary and metamorphic rocks; Lower Proterozoic–Archaean sediments and metamorphic rocks.

Geomorphology.—Elevated lateritic plain (lateritic red earth and lateritic podzolic surface horizon).

Drainage.—Moderately dense dendritic drainage pattern.



Unit	Area	Land Forms	Soils	Vegetation
1	Large	Remnants of lateritic plains	Wonorah—brown loam merging into dark red clay, over laterite	Snappy gum sparse low woodland (*E. brevifolia*) with patches of desert shrubland and with hard spinifex (*Triodia intermedia*)
2	Medium	Breakaways and slopes below	Reddish loamy and clayey skeletal soils with lateritic gravel and some outcrop; locally Moonah	Snappy gum sparse low woodland (*E. brevifolia*) with arid short grass
3	Small	Sand plain	Cockatoo—deep red sand	Snappy gum sparse low woodland (*E. brevifolia*); in parts with desert shrubland, with soft spinifex (*Triodia pungens*)
4	Very small	Ridges, <200 ft high, with basal scree slopes	Mainly outcrop	Snappy gum sparse low woodland (*E. brevifolia*) with hard spinifex (*Triodia intermedia*)
5	Very small	Alluvial drainage floors	Hooper—greyish sand surface over hard mottled clay	Snappy gum sparse low woodland (*E. brevifolia*), silver-leaved box sparse low woodland (*E. pruinosa*)
6	Very small	Channels up to 5 ft deep		Fringing communities

Comparable with Ruby land system of the West Kimberley area.

(18) Koongie Land System (200 sq miles)

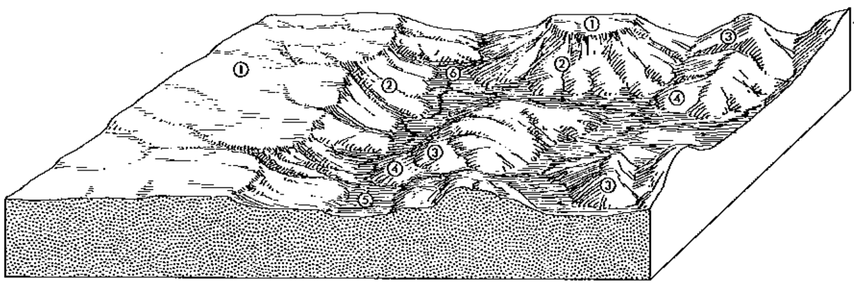
Shallowly dissected lateritic plains in the south and south-west.

Climate.—Mean annual rainfall 20 in.; mean agricultural growing season 6 wk; mean pasture growing season 11 wk.

Geology.—Lateritized igneous and metamorphic rocks; Lower Proterozoic granite, gabbro, rhyolite, metamorphic rocks.

Geomorphology.—Dissected elevated lateritic plain and elevated lateritic plain (lateritic red earth and lateritic podzolic surface horizons).

Drainage.—Moderately dense pattern of incised valleys.



Unit	Area	Land Forms	Soils	Vegetation
1	Medium	Remnants of lateritic plains, partly stripped	Exposed lateritic surface with pockets of Wonorah—brown loam merging into red clay, over laterite	Snappy gum sparse low woodland (*E. brevifolia*), in parts with desert shrubland, over hard spinifex (*Triodia intermedia*)
2	Small	Slopes below breakaways, dissected up to 20 ft into rounded spurs	Mainly reddish shallow gravelly soils	Arid short grass or snappy gum sparse low woodland (*E. brevifolia*) over hard spinifex (*Triodia intermedia*)
3	Medium	Rocky hill slopes on granite, gneiss, and schist	Mainly outcrop with some areas of sandy skeletal soils	Hard spinifex (*Triodia intermedia, T. inutilis*), in part with snappy gum sparse low woodland (*E. brevifolia*)
4	Small	Colluvial hill foot slopes	Mainly reddish shallow gravelly soils	
5	Very small	Alluvial drainage floors	Moonah—brown sandy loam over red-brown clay	Snappy gum sparse low woodland (*E. brevifolia*) with arid short grass or three-awn mid-height grass
6	Very small	Channels		Fringing communities

Comparable with Koongie land system of the West Kimberley area.

(19) Winnecke Land System (1200 sq miles)

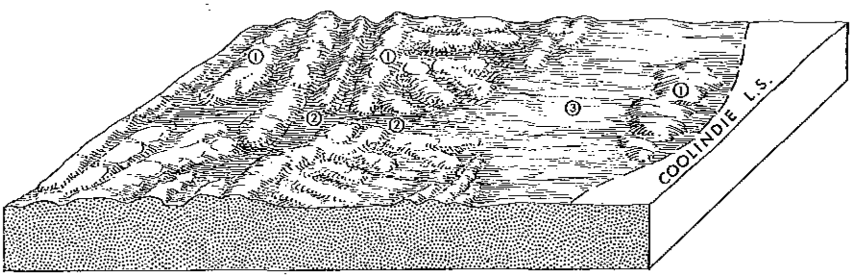
A number of irregular areas or linear bands of stony hills associated with the red sandy "deserts" in the southern part of the area.

Climate.—Wettest locality: mean annual rainfall 20 in.; mean agricultural growing season 8 wk; mean pasture growing season 12 wk. Driest locality: mean annual rainfall <15 in.; mean agricultural growing season <5 wk; mean pasture growing season <10 wk.

Geology.—Mainly sandstone, some conglomerate and dolomite; Gardiner Beds of Carpentarian age.

Geomorphology.—Ancient monadnocks.

Drainage.—Intensive parallel drainage on the first unit, widely spaced angular drainage on the other units, generally terminating in deep sands at the base of hills.



Unit	Area	Land Forms	Soils	Vegetation
1	Large	Low linear or rounded hills	Outcrops of sandstone	Trees absent or snappy gum sparse low woodland (*E. brevifolia*, *E. aspera*) with soft spinifex (*Triodia pungens*, *T. spicata*)
2	Small	Gently sloping valley floors, mainly unchannelled	Cockatoo—deep red sandy soil, minor Elliott	Desert shrubland (*Acacia* spp., *Eucalyptus* spp.) with soft spinifex (*Triodia pungens*)
3	Medium	Gently sloping sand plain	Cockatoo—deep red sandy soil	

Comparable with Hann land system of the Alice Springs area.

(20) Wingate Land System* (1000 sq miles)

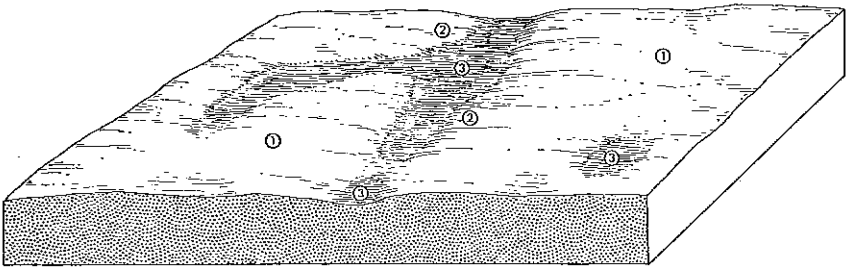
A number of areas of timbered gently undulating lateritic country in the northern part of the area on plateau surfaces isolated from the main Sturt Plateau.

Climate.—Wettest locality: mean annual rainfall 45 in.; mean agricultural growing season 22 wk; mean pasture growing season 24 wk. Driest locality: mean annual rainfall 30 in.; mean agricultural growing season 16 wk; mean pasture growing season 20 wk.

Geology.—Lateritized sediments, Cretaceous and Adelaidean.

Geomorphology.—Elevated lateritic plain (lateritic red earth and lateritic podzolic surface horizons).

Drainage.—Widely spaced insequent headwater tributaries of coastal rivers; unit 3 is probably flooded for periods during the wet season.



Unit	Area	Land Forms	Soils	Vegetation
1	Very large	Gentle upper slopes	Probably Koolpinyah—yellow-grey sand or sandy loam over laterite and/or Cockatoo—deep red sand	Stringybark–bloodwood woodland (*E. tetrodonta, E. miniata, E. dichromophloia*) with upland tall grass (*Plectrachne pungens, Sorghum stipoideum*)
2	Very small	Lower slopes fringing unit 3	Probably Koolpinyah and/or Florina—yellowish sand over ferruginous concretions over mottled clay	*Tristania–Grevillea–Banksia* low woodland
3	Small	Broad shallow drainage floors or shallow rounded enclosed depressions	Probably Marrakai—light grey powdery loam merging into light grey mottled clay; some Card near creeks	Marrakai mid-height grass (*Eriachne* spp., *Themeda australis*)

* No field observations have been made on this land system and the description is based on recorded geological data, air-photo nterpretation, and correlation with similar air-photo patterns in surveyed areas in north-western Australia.

(21) MOYLE LAND SYSTEM (1700 SQ MILES)

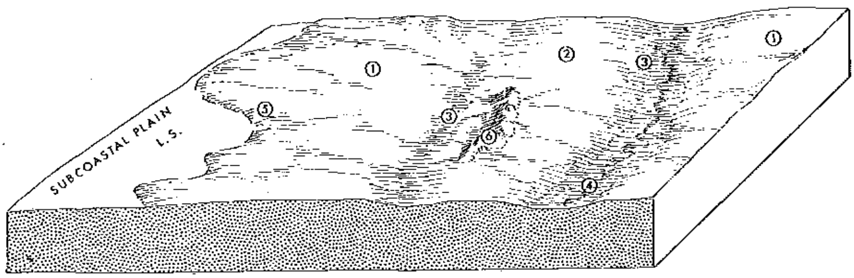
A number of areas of timbered undulating plains adjacent to the eastern edge of Bonaparte Gulf.

Climate.—Wettest locality: mean annual rainfall 55 in.; mean agricultural growing season 26 wk; mean pasture growing season 27 wk. Driest locality: mean annual rainfall 45 in.; mean agricultural growing season 21 wk; mean pasture growing season 23 wk.

Geology.—Sandstone, shale, and limestone; Permian (Port Keats Group).

Geomorphology.—Coastal erosional plains.

Drainage.—Unit 1 has widely spaced shallow unchannelled depressions, remainder has widely spaced dendritic pattern of stream lines; some small streams are spring-fed and flow perennially; the flats along stream lines are waterlogged throughout the year and may be flooded during the wet season.



Unit	Area	Land Forms	Soils	Vegetation
1	Large	Broad, gently undulating plains, 1–10 miles wide	Blain—brown sandy surface merging into dark red clay; minor Florina	Stringybark–bloodwood woodland (*E. tetrodonta, E. miniata, E. dichromophloia*) with upland tall grass (*Sorghum intrans, S. stipoideum*)
2	Medium	Gently undulating interfluves up to 1 mile wide	Florina—yellowish sand over ferruginous concretions over mottled clay; and Cullen—deep yellow sand with mottled subsoil	
3	Small	Lower slopes between unit 2 and stream lines, also broad shallow depressions in unit 1	Card—deep sandy light grey soil with rusty mottling	*Tristania–Grevillea–Banksia* low woodland with upland tall grass (*Sclerandrium grandiflorum, Eriachne triseta, Coelorachis rottboellioides*)
4	Very small	Stream lines and associated flats	Peaty surface overlying saturated sands	*Sclerandrium–Leptocarpus* swamp community and fringing forest with fringing tall grass
5	Very small	Slopes adjacent to Subcoastal Plain land system	Florina—yellowish sand over ferruginous concretions over mottled clay	Stringybark–bloodwood woodland (*E. grandifolia, Pandanus integer*) with upland tall grass (*Coelorachis rottboellioides, Capillipedium parviflorum*)
6	Very small	Steep low hills	Shallow gravelly soils and outcrop	Stringybark–bloodwood woodland with upland tall grass

Comparable with Moyle land system of the Katherine–Darwin area; this description has been adapted from the report on that area.

(22) Cockatoo Land System (1600 sq miles)

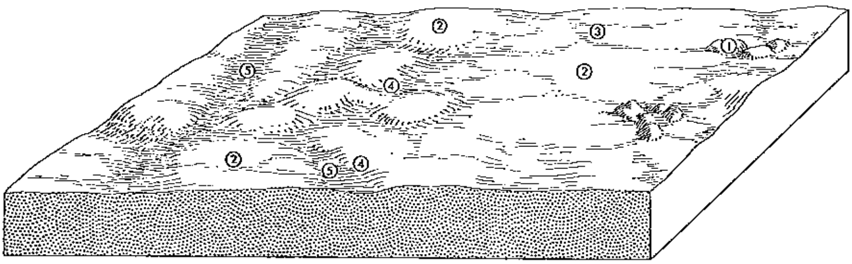
Gently undulating timbered sandy country in the north-western part of the area.

Climate.—Wettest locality: mean annual rainfall 35 in.; mean agricultural growing season 18 wk; mean pasture growing season 22 wk. Driest locality: mean annual rainfall 27 in.; mean agricultural growing season 12 wk; mean pasture growing season 16 wk.

Geology.—Sandstone, calcareous sandstone, calcareous conglomerate, and minor limestone; Permian, Lower Carboniferous, Upper Devonian, and Ordovician–Cambrian (Carlton Group).

Geomorphology.—Coastal erosional plains.

Drainage.—Widely spaced insequent stream pattern, shallow depressions may be waterlogged or flooded for short periods.



Unit	Area	Land Forms	Soils	Vegetation
1	Very small	Very bouldery low hills	Sandstone boulders with pockets of sandy soils	Stringybark–bloodwood woodland (*E. tetrodonta, E. dichromophloia, E. miniata, E. ferruginea, E. aspera*) or deciduous sparse low woodland (*Xanthostemon paradoxus, Owenia vernicosa, Terminalia* spp.), both with upland tall grass (*Sorghum stipoideum, Plectrachne pungens, Triodia stenostachya*)
2	Large	Gentle slopes and crests of gently undulating landscape	Cockatoo—deep red sand; and Pago—deep yellow sand; small areas of Cullen—greyish sand merging into mottled yellow sand	Stringybark–bloodwood woodland (*E. tetrodonta, E. miniata, E. dichromophloia*) with upland tall grass (*Sorghum stipoideum, Plectrachne pungens*)
3	Very small	Small isolated areas in gently undulating landscape	Tippera—brown sandy loam merging into dark red clay	Northern box–bloodwood woodland (*E. tectifica, E. foelscheana, E. confertiflora*) with upland tall grass (*Sorghum stipoideum*)
4	Very small	Lower slopes and shallow drainage floors	Pago—deep yellow sand; and Cullen—greyish sand merging into mottled yellow sand	Stringybark–bloodwood woodland (*E. tetrodonta, E. miniata, E. dichromophloia*) with upland tall grass (*Sorghum stipoideum, Plectrachne pungens*)
5	Very small	Shallow linear depression lines	Hooper—greyish surface over mottled hard clay	Marrakai mid-height grass (*Eriachne* spp., *Themeda australis*)

(23) LITCHFIELD LAND SYSTEM (800 SQ MILES)

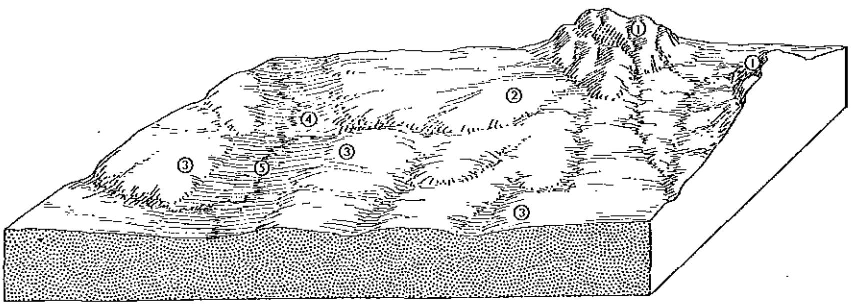
Gently undulating granite country in the northern part of the area.

Climate.—Wettest locality: mean annual rainfall 55 in.; mean agricultural growing season 24 wk; mean pasture growing season 26 wk. Driest locality: mean annual rainfall 43 in.; mean agricultural growing season 21 wk; mean pasture growing season 24 wk.

Geology.—Lower Proterozoic granite, gabbro, rhyolite, metamorphic rocks.

Geomorphology.—Coastal erosional plain.

Drainage.—Well-defined dendritic or rectangular pattern of moderate intensity; unit 4 may be flooded for periods each wet season.



Unit	Area	Land Forms	Soils	Vegetation
1	Small	Tor-studded hills	Granite boulders and gritty skeletal soils	Deciduous sparse low woodland with upland tall grass
2	Medium	Moderate to gentle slopes	Cullen—grey sand merging into mottled yellow sand	Stringybark–bloodwood woodland (*E. tetrodonta, E. miniata, E. phoenicea*) with upland tall grass (*Sorghum intrans*)
3	Large	Lower gentle slopes	Florina—yellowish sand over ferruginous concretions over mottled clay; or Koolpinyah—yellowish grey sand or sandy loam over laterite	Northern box–bloodwood woodland (*E. grandifolia, Pandanus* sp.) with upland tall grass (*Sorghum intrans, Plectrachne pungens, Eriachne obtusa*)
4	Small	Alluvial drainage floors	Marrakai—light grey powdery loam merging into light grey mottled clay	Marrakai mid-height grass (*Eriachne* spp., *Themeda australis*)
5	Very small	Stream channels		Fringing communities

Comparable with Litchfield land system of the Katherine–Darwin area; this description has been adapted from the report on that area.

(24) Macphee Land System (350 sq miles)

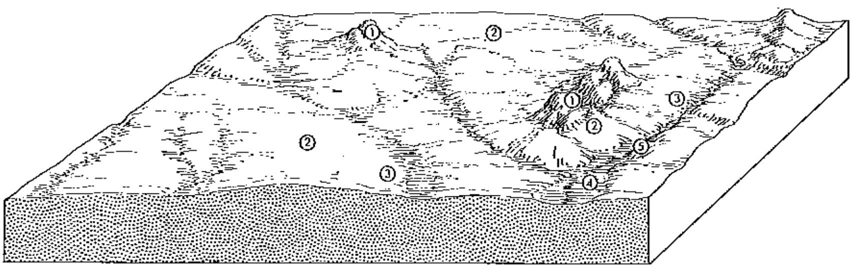
Several small patches of undulating sandy granite country in the north-western portion of the area.

Climate.—Wettest locality: mean annual rainfall 30 in.; mean agricultural growing season 14 wk; mean pasture growing season 18 wk. Driest locality: mean annual rainfall 25 in.; mean agricultural growing season 10 wk; mean pasture growing season 14 wk.

Geology.—Lower Proterozoic granite (Lamboo Complex).

Geomorphology.—Coastal and inland erosional plains.

Drainage.—Dendritic and subangular drainage of moderate intensity.



Unit	Area	Land Forms	Soils	Vegetation
1	Small	Steep bouldery hills	Mostly boulders of granite	Snappy gum sparse low woodland (*E. brevifolia*) with hard spinifex (*Triodia inutilis*)
2	Large	Moderate slopes	Pago—very gritty yellow sands, with scattered outcrops of granite	Northern box–bloodwood woodland (*E. grandifolia, E. foelscheana, E. latifolia*) with upland tall grass (*Sorghum australiense, Eriachne obtusa, Plectrachne pungens*). Southern parts stringybark woodland (*E. dichromophloia*) with upland tall grass
3	Small	Lower gentle slopes	Cullen—grey sand merging into mottled yellow sand	
4	Very small	Narrow depressions or flats adjacent to stream lines	Hooper—greyish sandy surfaces over mottled hard clay	Trees absent with Marrakai mid-height grass. Small areas paperbark low woodland (*Melaleuca minutifolia*) with upland tall grass (*Sorghum australiense, Eriachne obtusa*)
5	Very small	Stream channels		Fringing communities

(25) Birrimbah Land System (1000 sq miles)

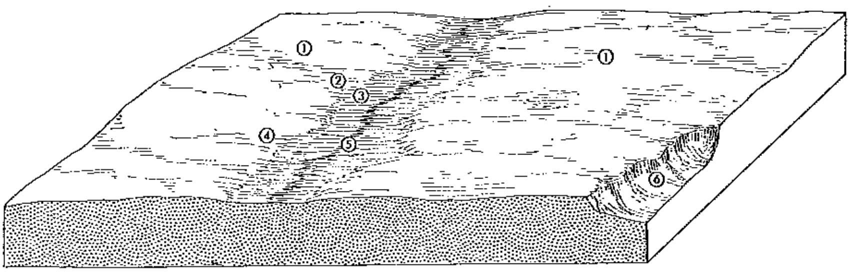
Timbered gently undulating plains with shallow lateritic soils in the north-eastern part of the area.

Climate.—Wettest locality: mean annual rainfall 30 in.; mean agricultural growing season 16 wk; mean pasture growing season 20 wk. Driest locality: mean annual rainfall 20 in.; mean agricultural growing season 8 wk; mean pasture growing season 13 wk.

Geology.—Lateritized Lower Cretaceous sediments; lacustrine sandstone and conglomerate, marine sandstone, shale, and mudstone.

Geomorphology.—Elevated lateritic plain (lateritic red earth and lateritic podzolic surface horizon).

Drainage.—Shallow widely spaced insequent stream lines draining to coastal rivers.



Unit	Area	Land Forms	Soils	Vegetation
1	Large	Gentle slopes	Koolpinyah—yellow-grey sand or sandy loam over laterite; patches of Chunuma, shallow phase—brown sands with ferruginous gravel	Stringybark–bloodwood woodland (*E. tetrodonta, E. dichromophloia, E. miniata, E. ferruginea, E. bleeseri, E. umbrawarrensis*) with upland tall grass (*Sorghum stipoideum, Plectrachne pungens*) or three-awn mid-height grass (*Aristida* spp.); small patches bulwaddy scrub (*Macropteranthes kekwickii*) with mostly bare ground
2	Small	Very gentle slopes	Berrimah—brown loam merging into red clay, over laterite	Desert sparse low woodland (*E. polycarpa, E. argillacea* form B) with three-awn mid-height grass (*Aristida* spp., *Chrysopogon fallax*)
3	Very small	Broad shallow drainage floors	Cununurra—grey or yellowish grey cracking clay	Blue grass tall grass (*Eulalia fulva, Dichanthium* spp., *Sorghum* sp.), in some areas with downs sparse low woodland (*E. microtheca*)
4	Very small	Very gentle slopes fringing unit 3	Elliott—grey sandy loam merging into mottled yellow clay	Paperbark low woodland (*Melaleuca* spp.) with Marrakai mid-height grass (*Eriachne* spp.)
5	Very small	Shallow sinuous stream channels		Fringing communities (*E. microtheca*)
6	Very small	Steep to moderate dissection scarps, similar to those in Mullaman land system	Shallow stony soils, overlying deeply weathered rock on upper parts, unweathered rocks on lower parts	Stringybark–bloodwood woodland (*E. tetrodonta, E. miniata*) or northern box–bloodwood woodland (*E. tectifica, E. foelscheana*) with upland tall grass (*Sorghum australiense, Plectrachne pungens*)

Comparable with Pollyarra land system of the Barkly region.

(26) BUCHANAN LAND SYSTEM (500 SQ MILES)

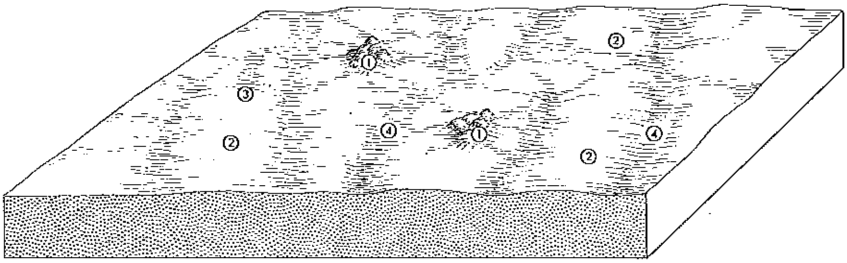
Gently undulating sandy country in the central-western part of the area.

Climate.—Mean annual rainfall 22 in.; mean agricultural growing season 8 wk; mean pasture growing season 13 wk.

Geology.—Sandstone. Middle Cambrian (Elder Sandstone).

Geomorphology.—Sandstone structural bench (asymmetric basin) and sandstone–shale cuestas (asymmetric basin).

Drainage.—Sparse.



Unit	Area	Land Forms	Soils	Vegetation
1	Small	Very bouldery low hills	Sandstone boulders with pockets of sandy soil	Snappy gum sparse low woodland (*E. brevifolia*) with soft spinifex (*Triodia pungens*), or silver-leaved box sparse low woodland (*E. pruinosa*) with three-awn mid-height grass (*Aristida* spp., *Chrysopogon fallax*)
2	Large	Gentle slopes and crests of gently undulating landscape	Cockatoo—deep red sand; minor Pago—deep yellow sand	Silver-leaved box sparse low woodland (*E. pruinosa*, *E. grandifolia*) with three-awn mid-height grass (*Aristida* spp., *Chrysopogon fallax*)
3	Small	Small isolated areas in gently undulating landscape	Tippera—brown sandy loam merging into dark clay	Bloodwood–southern box sparse low woodland (*E. terminalis*) with three-awn mid-height grass (*Aristida* spp., *Chrysopogon fallax*)
4	Small	Shallow linear drainage floors, in some cases with shallow sandy stream channels	Pago—deep yellow sand; some Cullen—greyish sand merging into mottled yellow sand	Silver-leaved box sparse low woodland (*E. pruinosa*, *E. grandifolia*) with three-awn mid-height grass (*Aristida* spp., *Chrysopogon fallax*)

(27) Coolindie Land System (3800 sq miles)

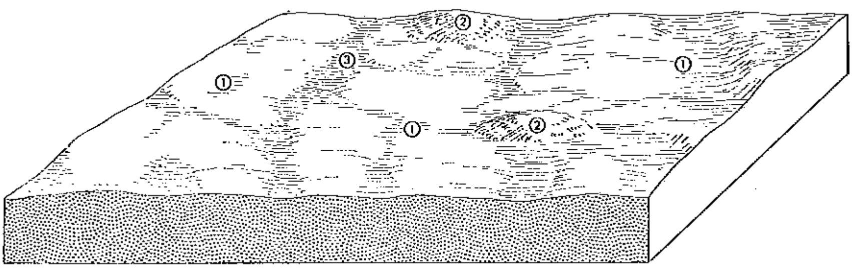
One large area of gently undulating red sandy "desert" with shrub vegetation along the southern edge of the area.

Climate.—Mean annual rainfall <17 in.; mean agricultural growing season <5 wk; mean pasture growing season <10 wk.

Geology.—Lateritized arenaceous sediments; Carpentarian sandstones (Gardiner Beds).

Geomorphology.—Elevated lateritic plain (sandy red earth surface horizon).

Drainage.—Very widely spaced shallow insequent drainage lines.



Unit	Area	Land Forms	Soils	Vegetation
1	Large	Gently sloping plains	Cockatoo—deep red sand; and some Pago—deep yellow sands	Trees absent or desert shrubland (*Acacia* spp., *Eucalyptus* spp.) with soft spinifex (*Triodia pungens*)
2	Small	Low gravelly rises	Chunuma, shallow phase—shallow sands with laterite gravel	Snappy gum sparse low woodland (*E. brevifolia*) with soft spinifex (*Triodia pungens*)
3	Very small	Broad shallow linear drainage floors	Argada—greyish loam merging into hard mottled yellow clay	Desert sparse low woodland (*E. microtheca*) with soft spinifex (*Triodia pungens*)

Unmappable inclusion: Winnecke land system.

(28) Redsan Land System (1200 sq miles)

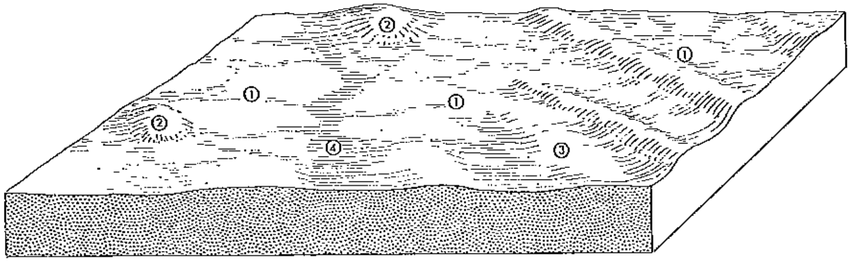
One area of gently undulating plain with deep sandy soil, eucalypt woodland, lancewood, or bulwaddy vegetation along the south-eastern margin of the area.

Climate.—Wettest locality: mean annual rainfall 21 in.; mean agricultural growing season 9 wk; mean pasture growing season 13 wk. Driest locality: mean annual rainfall 16 in.; mean agricultural growing season 6 wk; mean pasture growing season 10 wk.

Geology.—Lateritized Lower Cretaceous sediments; lacustrine sandstones.

Geomorphology.—Elevated lateritic plain (sandy red earth surface horizon).

Drainage.—No surface drainage.



Unit	Area	Land Forms	Soils	Vegetation
1	Large	Very gentle slopes with some low WNW.-ESE. dunes	Cockatoo—deep red sand; some Pago—deep yellow sand	Desert sparse low woodland (*E. polycarpa*, *E. argillacea* form B, *E. setosa*, *E. pruinosa*, *E. microtheca*, *E. ferruginea*) with soft spinifex (*Triodia pungens*) or three-awn mid-height grass (*Aristida pruinosa*)
2	Very small	Low crests	Chunuma, shallow phase—brown sand with much ferruginous gravel	
3	Very small	Very gentle slopes	Koolpinyah—yellow-grey sand or sandy loam over laterite	
4	Very small	Shallow linear depressions	Elliott—grey sandy loam merging into mottled yellow clay	

Comparable with Elliott land system of the Barkly region.

(29) Barry Land System (2100 sq miles)

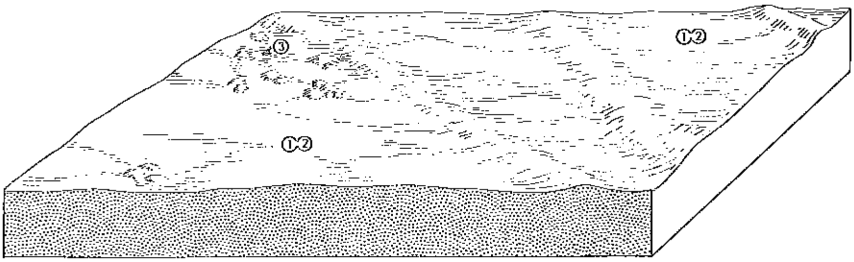
Two medium-sized areas, in the south-east and south-west corners of the area, of gently undulating red soil "desert" with shrub vegetation.

Climate.—Wettest locality: mean annual rainfall 20 in.; mean agricultural growing season 8 wk; mean pasture growing season 12 wk. Driest locality: mean annual rainfall 15 in.; mean agricultural growing season <5 wk; mean pasture growing season <10 wk.

Geology.—Tertiary laterite and associated soils, over Adelaidean dolomitic rocks.

Geomorphology.—Elevated non-lateritic plain (red earth and yellow earth soils).

Drainage.—No surface drainage.



Unit	Area	Land Forms	Soils	Vegetation
1	Large	Very gentle slopes with some poorly defined low WNW.–ESE. dunes	Camil—brown sandy loam merging into dark red clay, sandier on low dunes	Desert shrubland with soft spinifex (*Triodia pungens*)
2	Medium	Very gentle slopes	Argada—grey sandy loam merging into hard mottled yellow clay	Desert sparse low woodland (*E. microtheca*) with soft spinifex (*Triodia pungens*)
3	Small	Outcrops on gentle slopes	Limestone outcrops and shallow soils	Bloodwood–southern box sparse low woodland (*E. terminalis*) with arid short grass (*Enneapogon* spp.)

Comparable with Camil land system of the Barkly region.

(30) Geebee Land System (5100 sq miles)

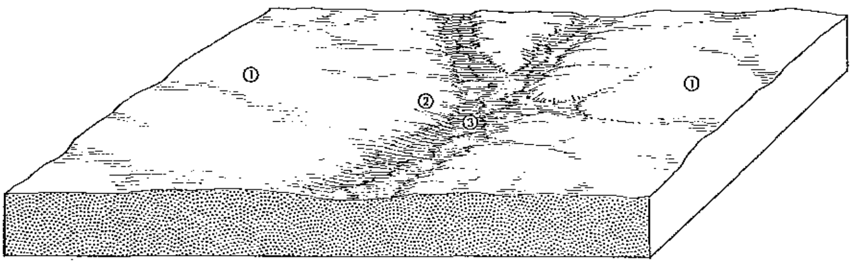
Many small and large areas of gently undulating gravelly red "deserts" with shrub or woodland vegetation scattered throughout the southern half of the area.

Climate.—Wettest locality: mean annual rainfall 25 in.; mean agricultural growing season 13 wk; mean pasture growing season 17 wk. Driest locality: mean annual rainfall 15 in.; mean agricultural growing season <5 wk; mean pasture growing season <10 wk.

Geology.—Tertiary laterite and associated soils overlie Lower Cambrian volcanics, Adelaidean sediments, and Lower Proterozoic granite, gabbro, and metamorphic rocks.

Geomorphology.—Elevated lateritic plain (lateritic red earth and lateritic podzolic surface horizon).

Drainage.—Widely spaced insequent headwater tributaries of both coastal rivers and the inland-draining Hookers and Sturts Creeks.



Unit	Area	Land Forms	Soils	Vegetation
1	Large	Upper slopes and crests	Wonorah, shallow phase—red-brown clay loam with much ferruginous gravel	Snappy gum sparse low woodland (*E. brevifolia*) or stringybark–bloodwood woodland (*E. dichromophloia*) with soft spinifex (*Triodia pungens*)
2	Small	Gentle lower slopes	Wonorah—brown sandy loam merging into dark red clay over laterite	Silver-leaved box sparse low woodland (*E. pruinosa*), or bloodwood–southern box sparse low woodland (*E. argillacea* form B) with three-awn mid-height grass (*Aristida pruinosa*)
3	Small	Shallow linear depressions with narrow shallow stream lines	Elliott—grey sandy loam merging into mottled yellow clay	

Comparable with Wonorah land system of the Barkly region.

(31) Matheson Land System (350 sq miles)

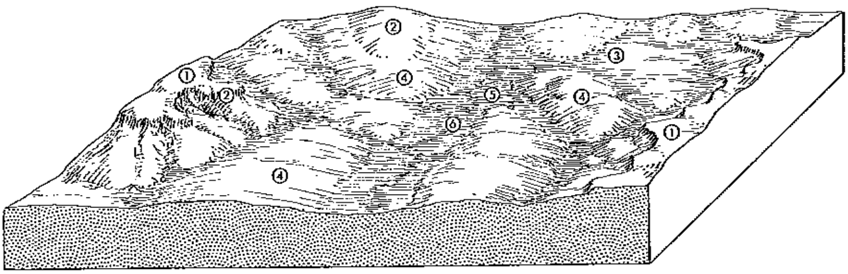
Three small areas of timbered country with variable relief and soils along the north-eastern margin of the area.

Climate.—Wettest locality: mean annual rainfall 30 in.; mean agricultural growing season 16 wk; mean pasture growing season 20 wk. Driest locality: mean annual rainfall 25 in.; mean agricultural growing season 13 wk; mean pasture growing season 17 wk.

Geology.—Lateritized sediments and volcanics; Lower Cretaceous sediments, Middle Cambrian sediments (Daly River Group), and Lower Cambrian volcanics.

Geomorphology.—Truncated lateritic plain.

Drainage.—Drained by moderately sparse headwater tributaries of the Daly River system.



Unit	Area	Land Forms	Soils	Vegetation
1	Small	Gently sloping plateau surface	Koolpinyah—yellow-grey sand or sandy loam over laterite	Stringybark–bloodwood woodland (*E. tetrodonta, E. dichromophloia, E. miniata, E. bleeseri, E. ferruginea*) with upland tall grass (*Sorghum stipoideum, Plectrachne pungens*)
2	Small	Low hills and short steep scarps	Outcrop of lateritic material, skeletal soils	Lancewood forest with bare ground; mesa gum sparse low woodland with sparse upland tall grass (*Plectrachne pungens*); stringybark–bloodwood woodland (*E. tetrodonta, E. miniata, E. dichromophloia*) with upland tall grass (*Sorghum stipoideum, Plectrachne pungens*)
3	Small	Gentle slopes	Florina—yellowish sand over ferruginous concretions over mottled clay	Stringybark–bloodwood woodland (*E. tetrodonta, E. miniata, E. dichromophloia, E. bleeseri, E. ferruginea*) with upland tall grass (*Sorghum stipoideum, Plectrachne pungens*)
4	Medium	Gentle slopes	Tippera—brown loam merging into dark red clay; and Elliott	Northern box–bloodwood woodland (*E. tectifica, E. foelscheana, E. confertiflora*), smaller areas silver-leaved box sparse low woodland (*E. pruinosa*), both with Tippera tall grass (*Themeda australis, Sehima nervosum, Sorghum plumosum, Chrysopogon fallax*)
5	Small	Flats fringing stream lines	Elliott—grey sandy loam merging into mottled yellow clay	Paperbark low woodland (*Melaleuca* spp.) with Tippera tall grass (*Themeda australis, Sehima nervosum, Chrysopogon fallax*)
6	Very small	Shallow ill-defined stream channels		Fringing communities

(32) Jindara Land System (90 sq miles)

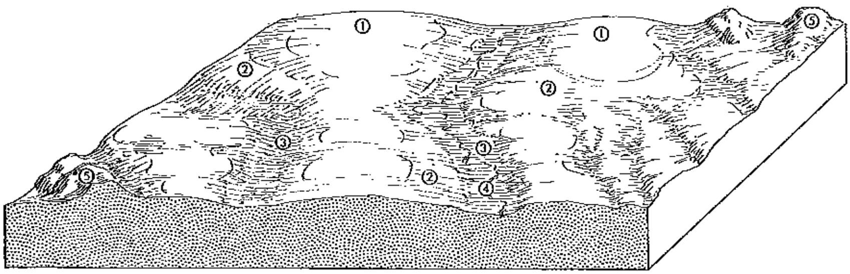
Timbered red earth plains in the north-eastern corner of the area.

Climate.—Mean annual rainfall 30 in.; mean agricultural growing season 17 wk; mean pasture growing season 21 wk.

Geology.—Limestone, some shale and sandstones. Middle Cambrian (Daly River Group).

Geomorphology.—Coastal erosional plains.

Drainage.—Sparse to dense, branching or rectangular pattern of drainage floors.



Unit	Area	Land Forms	Soils	Vegetation
1	Medium	Crest surfaces	Florina—yellowish sand over ferruginous concretions over mottled clay	Stringybark–bloodwood woodland (*E. miniata, E. tetrodonta, E. confertiflora, E. tectifica, E. bleeseri*) with upland tall grass (*Sorghum stipoideum, Plectrachne pungens*)
2	Large	Gentle slopes	Tippera—brown loam merging into dark red clay; locally Elliott	Northern box–bloodwood woodland (*E. tectifica, E. foelscheana, E. confertiflora*) with Tippera tall grass (*Themeda australis, Sehima nervosum, Sorghum plumosum, Chrysopogon fallax*)
3	Small	Drainage floors	Florina—yellowish sand over ferruginous concretions over mottled clay subsoil; locally Marrakai, Tippera, Cununurra	Northern box–bloodwood woodland (*E. tectifica, E. latifolia, E. papuana, E. confertiflora*) with Tippera tall grass or frontage tall grass
4	Very small	Channels up to 100 ft wide and 20 ft deep		Fringing forests with fringing tall grass
5	Very small	Low rocky hilly	Outcrops of limestone and sandstone with pockets of shallow skeletal soil	Northern box–bloodwood woodland (*E. tectifica, E. foelscheana*) with upland tall grass (*Sorghum stipoideum*)

Comparable with Jindara land system of the Tipperary area; this description has been adapted from the report on that area.

(33) Wriggley Land System (150 sq miles)

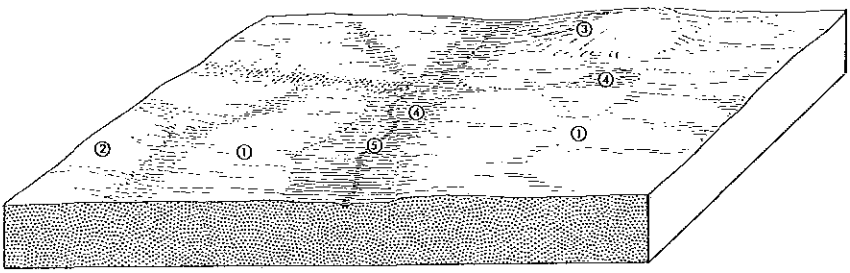
Timbered red earth plains in the north-eastern corner of the area.

Climate.—Mean annual rainfall 30 in.; mean agricultural growing season 17 wk; mean pasture growing season 21 wk.

Geology.—Limestone, some shale and sandstone; Middle Cambrian (Daly River Group).

Geomorphology.—Coastal erosional plains.

Drainage.—Sparse to moderately dense pattern of through-going floors with ill-defined, unchannelled tributary floors; drainage locally entrenched up to 40 ft.



Unit	Area	Land Forms	Soils	Vegetation
1	Very large	Plains	Tippera—brown loam merging into dark clay; some Elliott—greyish sandy loam merging into mottled yellow clay	Northern box–bloodwood woodland (*E. foelscheana, E. tectifica, E. confertiflora, E. tetrodonta*) over Tippera tall grass (*Themeda australis, Sorghum plumosum, Sehima nervosum, Chrysopogon fallax*)
2	Small	Gentle colluvial slopes	Tippera—brown loam merging into dark red clay	Stringybark–bloodwood woodland (*E. tetrodonta, E. foelscheana, E. miniata*) with Tippera tall grass (*Themeda australis, Sehima nervosum, Sorghum plumosum, S. stipoideum*)
3	Small	Stony slopes	Mainly skeletal soils	Northern box–bloodwood woodland (*E. tectifica, E. foelscheana*) with Tippera tall grass
4	Small	Drainage floors	Marrakai—light grey powdery loam merging into mottled light grey clay; minor Elliott and Cununurra	Frontage woodland (*E. papuana, E. polycarpa, E. latifolia*) with frontage tall grass
5	Very small	Channels up to 100 ft wide and 20 ft deep		Fringing forest with fringing tall grass

Comparable with Wriggley land system of the Tipperary area; this description has been adapted from the report on that area.

(34) Dinnabung Land System (2700 sq miles)

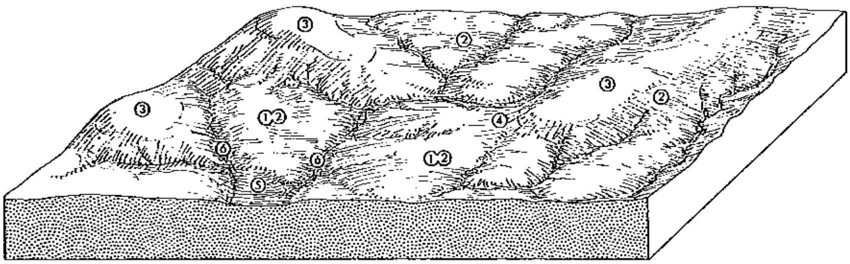
Many small areas of timbered gently undulating limestone country scattered throughout the northern part of the area.

Climate.—Wettest locality: mean annual rainfall 50 in.; mean agricultural growing season 23 wk; mean pasture growing season 25 wk. Driest locality: mean annual rainfall 24 in.; mean agricultural growing season 12 wk; mean pasture growing season 16 wk.

Geology.—Limestone and shale. Calcareous and dolomitic sediments of Permian, Upper Devonian, Middle Cambrian, and Adelaidean age.

Geomorphology.—Coastal erosional plains and limestone structural benches.

Drainage.—Moderately spaced angular, rectangular, and dendritic drainage patterns; the shallow depressions may be flooded for very short periods.



Unit	Area	Land Forms	Soils	Vegetation
1	Medium	Gentle slopes	Tippera—brown sandy loam over permeable red clay, with scattered limestone outcrops	Northern box–bloodwood woodland (*E. tectifica, E. confertiflora, E. foelscheana, E. argillacea* form C) with Tippera tall grass (*Themeda australis, Sorghum plumosum, Sehima nervosum, Chrysopogon fallax*)
2	Large	Gentle slopes	Elliott—grey sandy loam over mottled yellow clay, with scattered limestone outcrops	As unit 1. Smaller areas silver-leaved box sparse low woodland (*E. pruinosa*) with Tippera tall grass
3	Medium	Crests and low rises	Limestone outcrops with pocket of Tippera in north and of Tobermorey in south	As unit 1. Very stony areas deciduous sparse low woodland with upland tall grass
4	Very small	Gentle slopes or slight depressions	Springvale—shallow dark grey clay loam over soft limestone	Bloodwood–southern box low woodland (*E. terminalis, E. confertiflora*) with Tippera tall grass
5	Small	Lower gentle slopes of depressions	Cununurra—grey cracking clay	Trees absent on downs sparse low woodland (*Bauhinia cunninghamii*) with blue grass tall grass (*Dichanthium* spp., *Sorghum plumosum*)
6	Very small	Stream channels		Fringing communities

(35) Frayne Land System (1400 sq miles)

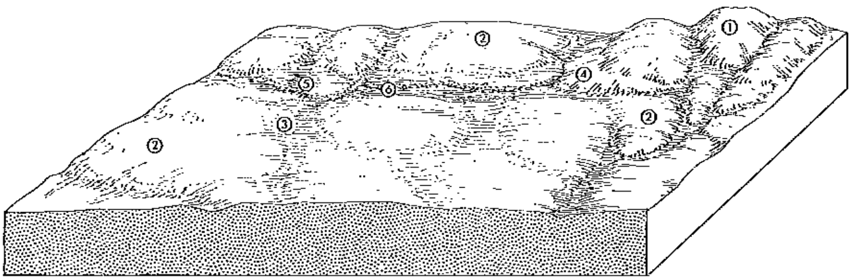
Many small patches scattered throughout the area of undulating to low hilly basalt country with predominantly red soils.

Climate.—Wettest locality: mean annual rainfall 50 in.; mean agricultural growing season 23 wk; mean pasture growing season 25 wk. Driest locality: mean annual rainfall 17 in.; mean agricultural growing season 5 wk; mean pasture growing season 10 wk.

Geology.—Basalt, agglomerate, and tuff, Lower Cambrian (Antrim Plateau Volcanics); small areas of Carpentarian dolerite.

Geomorphology.—Volcanic structural benches, and coastal and inland erosional plains.

Drainage.—Moderately intense angular or rectangular drainage on the benches and mostly moderately intense dendritic on the inland and coastal plains.



Unit	Area	Land Forms	Soils	Vegetation
1	Small	Rounded hills or structural benches in the east; bouldery rugged hills in the west	Mostly rock outcrops and basalt boulders, with pockets of skeletal soil	Deciduous sparse low woodland with upland tall grass. Snappy gum sparse low woodland (*E. brevifolia*) or trees absent with soft spinifex (*Triodia pungens*)
2	Large	Moderate to gentle slopes	Mostly Frayne—brown loam merging into dark red clay; some brown clay skeletal soils and small areas of Elliott	Bloodwood–southern box sparse low woodland (*E. terminalis, E. argillacea* form A), or silver-leaved box sparse low woodland (*E. pruinosa*) with Tippera tall grass (*Themeda australis, Sehima nervosum, Chrysopogon fallax*)
3	Small	Gentle slopes	Cununurra and Barkly—grey and brown cracking heavy clays	Downs sparse low woodland (*Terminalia arostrata, T. volucris*), or trees absent with blue grass tall grass (*Dichanthium* spp., *Astrebla squarrosa*) or Mitchell and other mid-height grasses (*A. pectinata, Dichanthium fecundum, Panicum* spp., *Aristida latifolia*)
4	Small	Moderate to gentle slopes adjacent to alluvial floors	Tobermorey—shallow grey to yellow-brown calcareous loamy soils	Bloodwood–southern box sparse low woodland (*E. terminalis*) with arid short grass (*Enneapogon* spp., *Tragus australianus*)
5	Very small	Alluvial floors along stream lines	Variable light- to medium-textured alluvial soils	Frontage woodland (*E. papuana*) with frontage grass (*Themeda australis*)
6	Very small	Stream channels		Fringing communities

Comparable with Barton land system of the North Kimberley area.

(36) Angallari Land System (1300 sq miles)

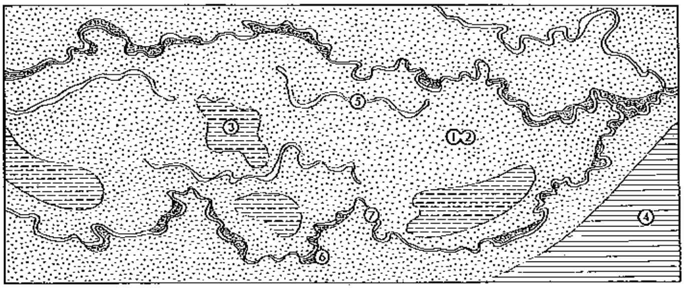
Many small areas of timbered gently sloping alluvial plains scattered with benched yellowish loamy or sandy soils through the northern part of the area.

Climate.—Wettest locality: mean annual rainfall 40 in.; mean agricultural growing season 19 wk; mean pasture growing season 23 wk. Driest locality: mean annual rainfall 23 in.; mean agricultural growing season 11 wk; mean pasture growing season 15 wk.

Geology.—Quaternary alluvia.

Geomorphology.—Coarse-textured fluvial plains.

Drainage.—Generally insequent channels of moderate intensity, some areas have intensive patterns of braided stream channels; the slight depressions are probably flooded for short periods each wet season.



Unit	Area	Land Forms	Soils	Vegetation
1	Large	Very gentle slopes	Elliott and Batten—grey sandy loam over mottled yellow clay	Northern box–bloodwood woodland (*E. tectifica, E. foelscheana*) and silver-leaved box sparse low woodland (*E. pruinosa*) with Tippera tall grass (*Themeda australis, Sehima nervosum, Chrysopogon fallax*); paperbark low woodland (*Melaleuca* spp.) with upland tall grass (*Sorghum stipoideum, Plectrachne pungens*)
2	Medium	Gentle slope	Cullen—deep sands with mottled yellow subsoil	Northern box–bloodwood woodland (*E. grandifolia*) with upland tall grass (*Sorghum stipoideum*)
3	Small	Shallow depressions of the back plains	Marrakai—grey loam over mottled clay; Card—deep sandy light grey soil with rusty mottling	Marrakai mid-height grass (*Eriachne* spp., *Themeda australis*)
4	Small	Gentle slopes, generally at base of sandstone hills	Pago—deep yellow sands; and Chunuma—deep brown sands	Frontage woodland (*E. polycarpa, E. papuana, E. apodophylla*) with upland tall grass (*Sorghum stipoideum, Aristida browniana*)
5	Very small	Nearly flat or slight depressions, commonly associated with abandoned stream channels	Hooper—sand surface over tough clay subsoil	Saline soil short grass (*Xerochloa imberbis*)
6	Very small	Levees associated with active streams	Manbulloo and Katherine—brown sand or sandy loam over permeable reddish brown subsoil	Frontage woodland (*E. papuana, E. tectifica*) with Tippera tall grass (*Themeda australis, Sehima nervosum, Heteropogon contortus, Aristida hygrometrica*)
7	Small	Stream channels, 5–20 yd wide, sinuous with steep banks		Fringing communities

Unmappable inclusion: Cockburn.

Comparable with Keighran land system of the Barkly region.

(37) Nelson Land System (1200 sq miles)

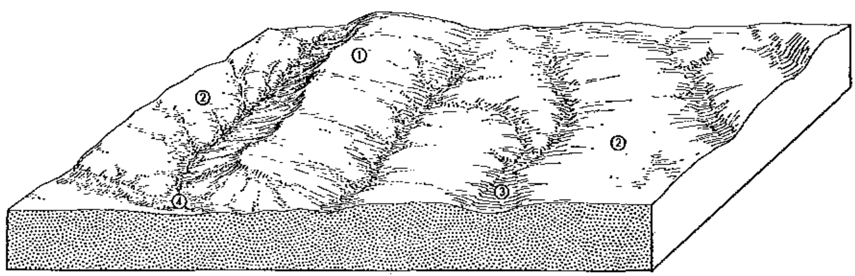
One area of undulating sparsely timbered country with powdery calcareous soil in the southern-central part of the area; many parts have suffered severe wind and gully erosion.

Climate.—Wettest locality: mean annual rainfall 22 in.; mean agricultural growing season 10 wk; mean pasture growing season 14 wk. Driest locality: mean annual rainfall 20 in.; mean agricultural growing season 7 wk; mean pasture growing season 12 wk.

Geology.—Shale and limestone. Middle Cambrian (Negri Group).

Geomorphology.—Inland erosional plains.

Drainage.—Subparallel to dendritic patterns of moderate intensity; gully erosion active in small headwater tributaries; also considerable sheet erosion on drainage divides of unit 2.



Unit	Area	Land Forms	Soils	Vegetation
1	Small	Crests or low scarps	Limestone outcrops and Tobermorey—shallow calcareous loams	Bloodwood–southern box sparse low woodland (*E. terminalis*) with hard spinifex (*Triodia wiseana*) or arid short grass (*Enneapogon* spp.)
2	Large	Moderate slopes, many areas severely gullied	Negri—brown powdery calcareous loams over deep clay loams	Arid short grass (*Enneapogon* spp.)
3	Very small	Gentle lower slopes or shallow depressions	Argyle—brown cracking clays	Mitchell and other mid-height grasses (*Astrebla pectinata, Aristida latifolia*)
4	Very small	Stream channels		Fringing communities

(38) Gordon Land System (800 sq miles)

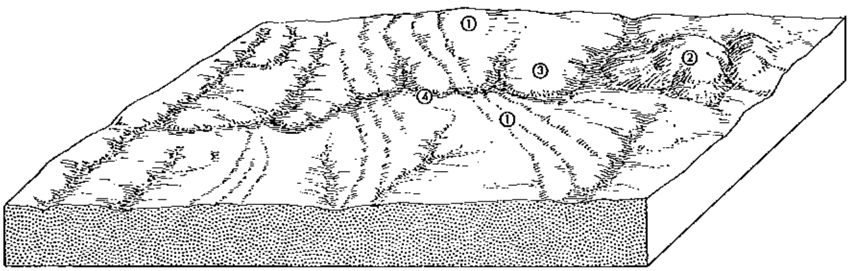
Low hilly to undulating limestone country scattered throughout the southern half of the area.

Climate.—Wettest locality: mean annual rainfall 24 in.; mean agricultural growing season 12 wk; mean pasture growing season 16 wk. Driest locality: mean annual rainfall 17 in.; mean agricultural growing season 5 wk; mean pasture growing season 10 wk.

Geology.—Calcareous and dolomitic sediments of Adelaidean age.

Geomorphology.—Inland and coastal erosional plains.

Drainage.—Moderately intense dendritic pattern.



Unit	Area	Land Forms	Soils	Vegetation
1	Large	Gently undulating uplands	Tobermorey—shallow grey to yellow-brown calcareous loamy soils; scattered outcrops and boulders of limestone	Bloodwood–southern box sparse low woodland (*E. terminalis*) with arid short grass (*Enneapogon* spp.)
2	Very small	Low hills	Limestone outcrops with pockets of loamy skeletal soil	Deciduous sparse low woodland with arid short grass
3	Small	Gentle lower slopes	Cununurra, Barkly, and Argyle—grey and brown cracking clays	Barley Mitchell mid-height grass (*Astrebla pectinata*)
4	Very small	Stream lines		Fringing communities

(39) Montejinni Land System (600 sq miles)

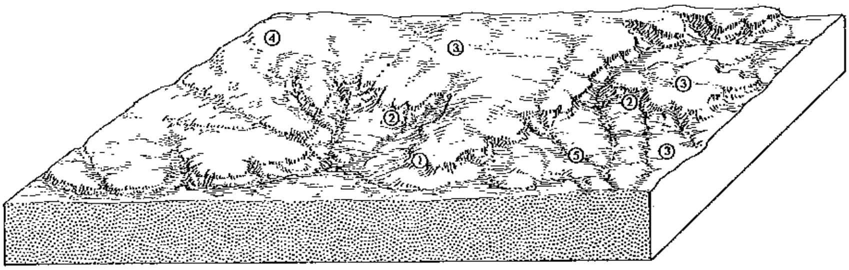
Limestone plains in the south-east of the area.

Climate.—Wettest locality: mean annual rainfall 22 in.; mean agricultural growing season 10 wk; mean pasture growing season 14 wk. Driest locality: mean annual rainfall 17 in.; mean agricultural growing season 6 wk; mean pasture growing season 10 wk.

Geology.—Limestone. Middle Cambrian (Montejinni Limestone).

Geomorphology.—Limestone structural benches.

Drainage.—Widely spaced rectangular.



Unit	Area	Land Forms	Soils	Vegetation
1	Very small	Short irregular steep slopes at edge of benches	Outcrops of limestone with pockets of shallow soil	Deciduous sparse low woodland with arid short grass
2	Small	Moderate slopes below edge of benches	Negri—brown calcareous loamy soils on calcareous shale	Sparse arid short grass
3	Large	Gently sloping bench surfaces	Tobermorey with many boulders and outcrops of flaggy limestone; minor areas of Tippera in northern parts	Bloodwood–southern box sparse low woodland (*E. terminalis*) with arid short grass
4	Small	Gently sloping areas within unit 3	Cununurra and Argyle—grey and brown cracking clays, scattered limestone outcrops	Barley Mitchell mid-height grass (*Astrebla pectinata*)
5	Very small	Stream channels		Fringing communities

(40) O'Donnell Land System (900 sq miles)

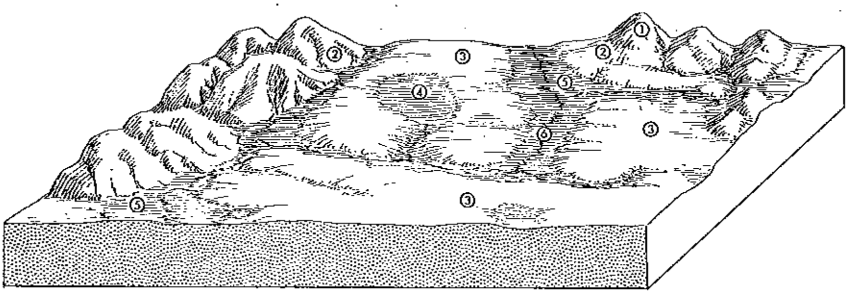
Stony undulating granite country with scattered hills, in the west of the area.

Climate.—Wettest locality: mean annual rainfall 25 in.; mean agricultural growing season 12 wk; mean pasture growing season 16 wk. Driest locality: mean annual rainfall 20 in.; mean agricultural growing season 7 wk; mean pasture growing season 11 wk.

Geology.—Lower Proterozoic granite, gabbro, rhyolite, and metamorphic rocks.

Geomorphology.—Coastal and inland erosional plains.

Drainage.—Moderately intense dendritic pattern.



Unit	Area	Land Forms	Soils	Vegetation
1	Small	Hills and ridges less than 200 ft high, with basal scree slopes	Outcrop with limited areas of reddish shallow gravelly skeletal soil	Snappy gum sparse low woodland (*E. brevifolia*)
2	Small	Hill foot slopes	Outcrop with reddish skeletal soil	Arid short grass (*Enneapogon* spp.)
3	Large	Low rounded uplands	Outcrop with reddish sandy and loamy skeletal soils; minor Moonah	Snappy gum sparse low woodland (*E. brevifolia*) with arid short grass (*Enneapogon* spp.)
4	Very small	Gentle low slopes	Argyle—brown cracking clay	Mitchell and other mid-height grasses (*Astrebla pectinata, Dichanthium fecundum, Aristida latifolia*) with volcanics sparse low woodland
5	Very small	Alluvial drainage floors	Medium-textured alluvial soils	Arid short grass
6	Very small	Channels		Fringing communities

Comparable with O'Donnell and Pigeon land systems of the West Kimberley area.

(41) Inverway Land System (2800 sq miles)

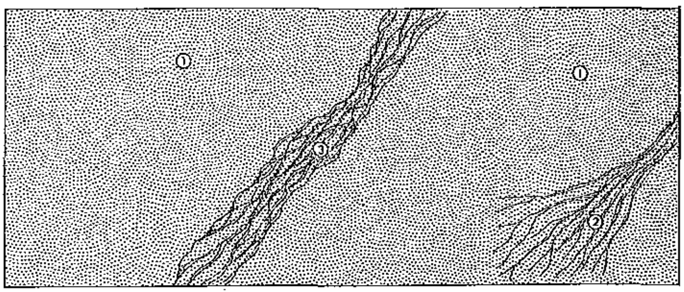
Nearly treeless high-level "black soil" plains scattered throughout the southern part of the area.

Climate.—Wettest locality: mean annual rainfall 20 in.; mean agricultural growing season 8 wk; mean pasture growing season 12 wk. Driest locality: mean annual rainfall 15 in.; mean agricultural growing season <5 wk; mean pasture growing season <10 wk.

Geology.—Tertiary swamp, lake, and river deposits.

Geomorphology.—Elevated non-lateritic plain (grey soils of heavy texture), interior fluvial plains, and interior swamp plains.

Drainage.—Largely drained by insequent stream lines of the internally draining streams; the distributary systems are flooded for prolonged periods after heavy rain, the braided streams for short periods, and the nearly flat plains may be waterlogged, but not flooded, for short periods.



Unit	Area	Land Forms	Soils	Vegetation
1	Very large	Nearly flat broad plains	Cununurra—grey cracking clays; and Argyle—brown cracking clays	Barley Mitchell mid-height grass (*Astrebla pectinata*)
2	Very small	Low-lying distributary areas with low linear rises and depressions	Cununurra—grey cracking clays	Bluebush shrubland (*Chenopodium auricomum, Muehlenbeckia cunninghamii*)
3	Very small	Linear tracts up to ½ mile wide with intense braided pattern of small stream channels		Fringing low woodland (*E. microtheca, Acacia stenophylla*) with blue grass tall grass (*Themeda avenacea, Eulalia fulva*)

Unmappable inclusion: Geebee.

Comparable with Barkly land system of the Barkly region.

(42) WAVE HILL LAND SYSTEM (4800 SQ MILES)

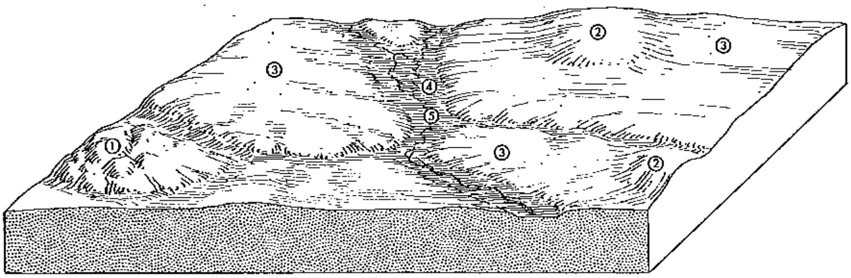
Gently undulating basalt "black soil" country, occurring in one large area near Wave Hill and many small areas scattered throughout the southern half of the area.

Climate.—Wettest locality: mean annual rainfall 25 in.; mean agricultural growing season 12 wk; mean pasture growing season 16 wk. Driest locality: mean annual rainfall 16 in.; mean agricultural growing season 5 wk; mean pasture growing season 10 wk.

Geology.—Basalt, minor agglomerate, tuff of Lower Cambrian volcanics, some Lower Proterozoic gabbro.

Geomorphology.—Volcanic structural benches, inland and coastal erosional plains.

Drainage.—Rectangular, angular, and dendritic drainage patterns of moderate intensity; the Camfield River has a braided system of channels; the braided river systems and flats adjacent to stream lines may be flooded for short periods.



Unit	Area	Land Forms	Soils	Vegetation
1	Very small	Low stony rises	Mostly basalt boulders and rock outcrops with pockets of red clayey soils	Deciduous sparse low woodland (*Terminalia* spp., *Bauhinia cunninghamii*, *Cochlospermum fraseri*) with upland tall grass (*Sorghum stipoideum*); snappy gum sparse low woodland (*E. brevifolia*) with soft spinifex (*Triodia pungens*)
2	Small	Steep to gentle slopes	Shallow stony red clay soils, some Frayne—brown loam merging into dark red clay	Bloodwood–southern box sparse low woodland (*E. terminalis*, *E. argillacea* form B, *E. argillacea* form A) with arid short grass (*Enneapogon* spp.) or three-awn mid-height grass (*Aristida pruinosa*, *Chrysopogon fallax*)
3	Large	Moderate to gentle slopes, may be stony	Cununurra, Barkly, and Argyle—grey and brown cracking clays	Mitchell and other mid-height grasses (*Astrebla pectinata*, *Dichanthium fecundum*, *Panicum* spp.)
4	Very small	Lower slopes near drainage lines	Tobermorey—shallow grey to yellow-brown calcareous loamy soils	Bloodwood–southern box sparse low woodland (*E. terminalis*) with arid short grass (*Enneapogon* spp.)
5	Very small	Flats adjacent to drain lines	Cununurra—grey cracking clay	Blue grass tall grass (*Dichanthium* spp., *Aristida latifolia*, *Eulalia fulva*)
6	Very small	Stream channels		Fringing communities

(43) Argyle Land System (450 sq miles)

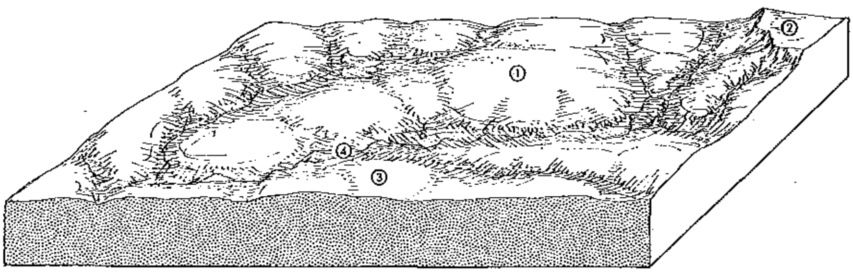
Several medium and small areas of gently undulating "black soil" plain in the north-central part of the area.

Climate.—Wettest locality: mean annual rainfall 25 in.; mean agricultural growing season 13 wk; mean pasture growing season 17 wk. Driest locality: mean annual rainfall 24 in.; mean agricultural growing season 11 wk; mean pasture growing season 15 wk.

Geology.—Calcareous, dolomitic, and shale sediments of Middle Cambrian and Adelaidean age.

Geomorphology.—Coastal erosional plains.

Drainage.—Widely spaced dendritic stream pattern; the lower slopes near drain lines may be waterlogged or flooded for short periods after heavy rain.



Unit	Area	Land Forms	Soils	Vegetation
1	Very large	Very gentle slopes	Argyle, Cununurra—brown and grey cracking clays	Mitchell and other mid-height grasses (*Astrebla pectinata*, *Aristida latifolia*)
2	Small	Low limestone rises	Limestone outcrops, with pockets of shallow loamy soil	Deciduous sparse low woodland (*Terminalia* spp., *Bauhinia cunninghamii*, *Cochlospermum fraseri*) with upland tall grass (*Sorghum stipoideum*), hard spinifex (*Triodia* sp.), or arid short grass (*Enneapogon* spp.)
3	Small	Gentle slopes	Negri—brown calcareous loamy soils on soft shales	Bloodwood–southern box sparse low woodland (*E. terminalis*) with arid short grass (*Enneapogon* spp.)
4	Very small	Stream lines		Fringing communities

Comparable with Wonardo land system of the Barkly and Leichhardt–Gilbert areas and Fossil land system of the West Kimberley area.

(44) Hawk Land System (200 sq miles)

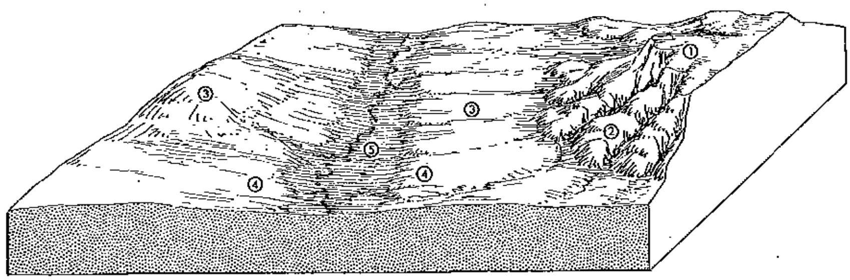
Two small patches of dissected laterite country near the eastern margin of the area.

Climate.—Wettest locality: mean annual rainfall 24 in.; mean agricultural growing season 12 wk; mean pasture growing season 16 wk. Driest locality: mean annual rainfall 21 in.; mean agricultural growing season 9 wk; mean pasture growing season 13 wk.

Geology.—Lower Cretaceous sandstone, shale, and mudstone.

Geomorphology.—Truncated lateritic plain and dissected elevated lateritic plain.

Drainage.—Drained by moderate pattern of insequent headwater tributaries of the Victoria River.



Unit	Area	Land Forms	Soils	Vegetation
1	Very small	Gently sloping plateau surface	Koolpinyah—yellow-grey sand or sandy loam over laterite	Stringybark–bloodwood woodland (*E. tetrodonta*, *E. dichromophloia*) with upland tall grass (*Plectrachne pungens*) or soft spinifex (*Triodia pungens*)
2	Small	Low hills and short steep scarps	Outcrop of lateritic material, skeletal soils	Lancewood forest with bare ground; stringybark–bloodwood woodland (*E. dichromophloia*) with soft spinifex (*Triodia pungens*)
3	Medium	Gentle slopes	Elliott—grey sandy loam merging into mottled yellow clay; some Tippera	Bloodwood–southern box sparse low woodland (*E. terminalis*) or silver-leaved box sparse low woodland (*E. pruinosa*) with Tippera tall grass (*Themeda australis*, *Sehima nervosum*, *Chrysopogon fallax*, *Aristida pruinosa*)
4	Medium	Gentle lower slopes	Cununurra—grey cracking clays; and Argyle—brown cracking clays	Mitchell and other mid-height grasses (*Astrebla pectinata*, *Aristida latifolia*) with fringing communities along streams
5	Small	Valley floors with narrow sinuous stream channels up to 5 ft deep	Cununurra—grey cracking clays; and Argyle—brown cracking clays	Mitchell and other mid-height grasses (*Astrebla pectinata*, *Aristida latifolia*) with fringing communities along streams

Comparable with Kilgour land system of the Barkly region.

(45) Willeroo Land System (900 sq miles)

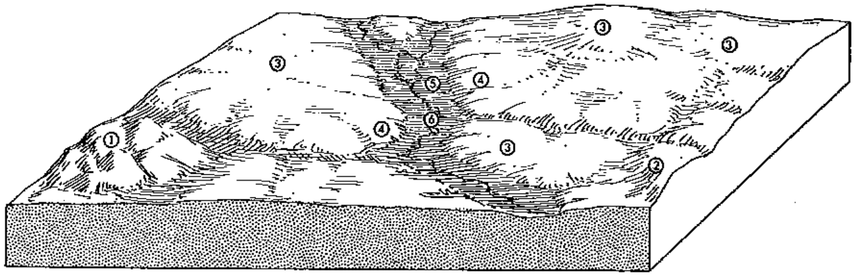
Numerous small areas of basalt "black soil" plains with tall pastures, mostly in the north-eastern part of the area.

Climate.—Wettest locality: mean annual rainfall 45 in.; mean agricultural growing season 22 wk; mean pasture growing season 24 wk. Driest locality: mean annual rainfall 24 in.; mean agricultural growing season 12 wk; mean pasture growing season 16 wk.

Geology.—Basalt, agglomerate, and tuff; Lower Cambrian (Antrim Plateau Volcanics), some Carpentarian dolerite.

Geomorphology.—Volcanic structural benches and coastal erosional plains.

Drainage.—Generally rectangular, angular, and dendritic drainage patterns of moderate intensity but some large streams are braided; the braided river systems and flats adjacent to stream lines may be flooded for short periods.



Unit	Area	Land Forms	Soils	Vegetation
1	Very small	Low stony rises	Mostly rock outcrops with basalt boulders and pockets of red clayey soil	Northern box–bloodwood woodland (*E. tectifica, E. foelscheana*) or deciduous sparse low woodland (*Terminalia* spp., *Bauhinia cunninghamii, Cochlospermum fraseri*), both with upland tall grass (*Sorghum stipoideum*)
2	Small	Steep to gentle slopes	Shallow stony red clay soils and Frayne—brown loam merging into dark red clay; minor Elliott	Northern box–bloodwood woodland (*E. tectifica*), or silver-leaved box sparse low woodland (*E. pruinosa*), both with Tippera tall grass (*Themeda australis, Sehima nervosum, Chrysopogon fallax*)
3	Large	Moderate to gentle slopes	Cununurra and Argyle—grey and brown cracking clays	Blue grass tall grass (*Dichanthium* spp., *Sorghum* spp., *Eulalia fulva, Ophiuros exaltatus*)
4	Small	Flats adjacent to drain lines	Cununurra—grey cracking clays	Fringing communities
5	Very small	Stream channels		

Comparable with Isdell land system of the North Kimberley area.

(46) Dillinya Land System (150 sq miles)

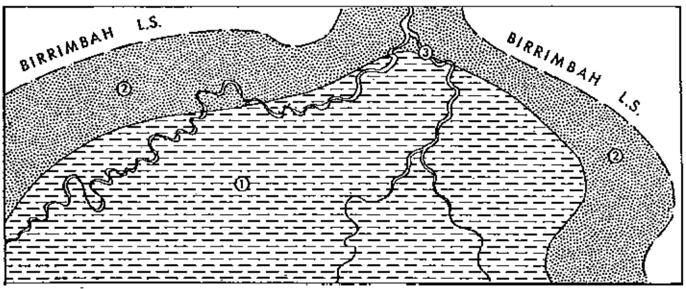
Broad shallow drainage floors of mainly cracking clays with blue grass downs, in the north-eastern part of the area.

Climate.—Mean annual rainfall 25 in.; mean agricultural growing season 13 wk; mean pasture growing season 17 wk.

Geology.—Tertiary swamp, lake, river deposits.

Geomorphology.—Elevated non-lateritic plain (grey soils of heavy texture).

Drainage.—Widely spaced insequent drainage.



Unit	Area	Land Forms	Soils	Vegetation
1	Large	Broad shallow drainage floors	Cununurra—grey or yellowish grey cracking clay	Blue grass tall grass (*Eulalia fulva*, *Dichanthium* spp., *Sorghum* sp.), in some areas with downs sparse low woodland (*E. microtheca*)
2	Medium	Very gentle slopes fringing unit 1	Elliott—grey sandy loam merging into mottled yellow clay	Paperbark sparse low woodland (*Melaleuca* spp.) with Marrakai mid-height grass (*Eriachne* spp.); small areas bullwaddy scrub (*Macropteranthes kekwickii*) with mostly bare ground
3	Very small	Shallow sinuous stream channels		Fringing communities (*E. microtheca*)

Comparable with Creswell and Joanundah land systems of the Barkly region.

(47) Ivanhoe Land System (2200 sq miles)

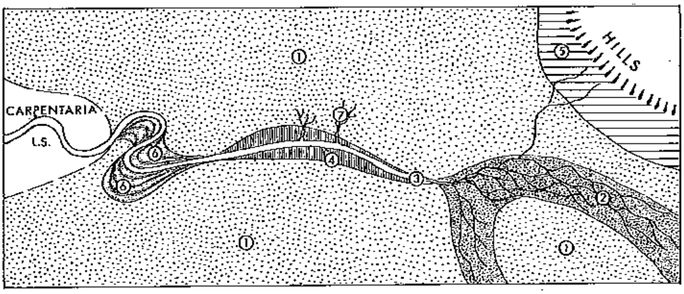
Many small to medium areas of gently sloping alluvial "black soil" plains with some timbered "red" soil in the central and northern parts of the area.

Climate.—Wettest locality: mean annual rainfall 35 in.; mean agricultural growing season 18 wk; mean pasture growing season 22 wk. Driest locality: mean annual rainfall 22 in.; mean agricultural growing season 10 wk; mean pasture growing season 14 wk.

Geology.—Quaternary alluvia.

Geomorphology.—Fine-textured fluvial plain.

Drainage.—The flood-plains of the Ord and Victoria Rivers are characterized by deep broadly meandering channels, and the flood-plains of the upper Baines and Armstrong Rivers have an intense pattern of braided stream channels.



Unit	Area	Land Forms	Soils	Vegetation
1	Large	Nearly flat plains	Cununurra—grey cracking clays with small areas of Argyle—brown cracking clays	Blue grass tall grass (*Dichanthium* spp., *Astrebla squarrosa*, *Sorghum stipoideum*, *Ophiuros exaltatus*, *Aristida latifolia*) with fringing forest and fringing tall grasses near stream lines
2	Small	Valley floors up to 2 miles with intense braided pattern of small channels		
3	Very small	Major stream channel, ¼–¾ mile wide and up to 60 ft deep		Fringing communities
4	Very small	Levees associated with major stream channels	Mostly Manbulloo and Katherine—brown sand or sandy loam over permeable reddish brown subsoil; Ord along Ord River and its major tributaries	Frontage woodland (*E. papuana*, *E. tectifica*, *E. terminalis*) with frontage tall grass (*Sorghum stipoideum*, *Chrysopogon latifolius*, *Panicum* sp., *Aristida* spp.)
5	Very small	Plains adjacent to sandstone hills, in upper part of West Baines River valley	Manbulloo and Katherine	Northern box–bloodwood woodland (*E. grandifolia*, *E. latifolia*) or silver-leaved box sparse low woodland (*E. pruinosa*) with three-awn mid-height grass (*Aristida* spp., *Chrysopogon fallax*)
6	Very small	Scroll plains with alternating low levee ridges and swales; adjacent to and inland from Carpentaria land system	Brown alluvial soils with stratified sediments at shallow depth	Frontage woodland (*E. papuana*, *E. tectifica*, *E. terminalis*) with frontage tall grass (*Sorghum stipoideum*, *Chrysopogon latifolius*, *Panicum* sp., *Aristida* spp.)
7	Very small	Moderately to steeply sloping gully systems up to 60 ft deep	Various undefined loamy and clayey soils, commonly with carbonate concretions at the surface	Scattered trees and sparse grass

(48) Legune Land System (300 sq miles)

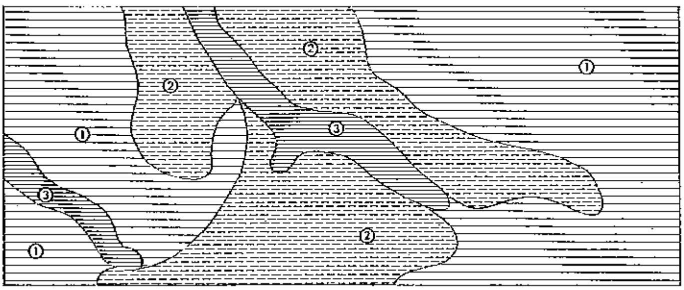
Nearly flat grasslands behind the littoral fringe at the mouth of the Keep and Victoria Rivers.

Climate.—Mean annual rainfall 35 in.; mean agricultural growing season 18 wk; mean pasture growing season 22 wk.

Geology.—Quaternary alluvia.

Geomorphology.—Estuarine–deltaic plain.

Drainage.—Widely spaced shallow meandering stream lines; liable to freshwater flooding in wet years.



Unit	Area	Land Forms	Soils	Vegetation
1	Large	Nearly flat plain with gilgai	Complex of Flapper—grey sandy loam over mottled heavy clay—and Legune, shallow phase—grey cracking clay over stratified alluvium; minor Carpentaria	Mostly saline soil short grass (*Xerochloa imberbis*), patches of blue grass tall grass (*Dichanthium* spp., *Eulalia fulva*, *Ophiuros exaltatus*)
2	Medium	Nearly flat plain	Mainly Legune—grey cracking clay; minor Flapper	Mainly blue grass tall grass (*Ophiuros exaltatus*, *Dichanthium* spp.) and lowland tall grassland (*Imperata cylindrica*)
3	Small	Shallow linear depressions	Mainly Carpentaria—highly saline clay	Bare mud of sparse samphire

(49) Subcoastal Plain Land System (950 sq miles)

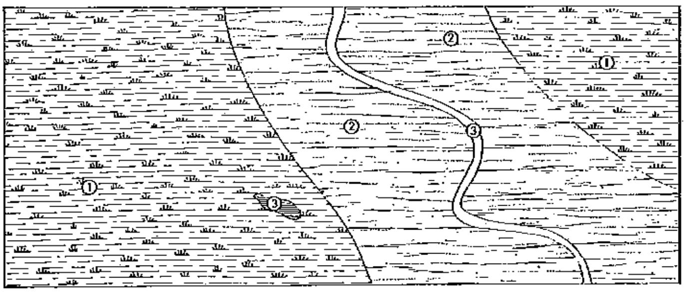
Nearly flat swamps and cracking clay plains in the northern part of the area.

Climate.—Wettest locality: mean annual rainfall 55 in.; mean agricultural growing season 25 wk; mean pasture growing season 27 wk. Driest locality: mean annual rainfall 40 in.; mean agricultural growing season 18 wk; mean pasture growing season 22 wk.

Geology.—Quaternary alluvia.

Geomorphology.—Fine-textured fluvial plains.

Drainage.—Widely spaced, poorly defined, insequent stream lines, sometimes terminating in swamps; all of this land system is flooded for prolonged periods each wet season, during the dry season the water-table is at surface level in unit 1 and 3 ft below surface level in unit 2.



Unit	Area	Land Forms	Soils	Vegetation
1	Large	Nearly flat swampy plains, water-table at or near surface throughout the dry season, flooded in the wet season	Dashwood—peaty clay over dark grey clay over mottled clay	Lowland tall grass (*Eleocharis* spp.) or paperbark forest
2	Medium	Nearly flat "black soil" plains, dry in the dry season but flooded for 2–6 months each wet season	Wildman—dark grey cracking clays over wet mottled clay	Lowland tall grass (*Imperata cylindrica, Oryza rufipogon*)
3	Very small	Stream lines and freshwater lagoons		Fringing forest (*E. camaldulensis, Terminalia platyphylla, Barringtonia* sp.) and lagoon vegetation (*Pseudoraphis spinescens, Nymphaea* sp., *Nymphoides* sp.). Mangroves near coast

Comparable with Subcoastal Plain land system of the Katherine–Darwin region, from which this description has been adapted.

(50) Carpentaria Land System (2100 sq miles)

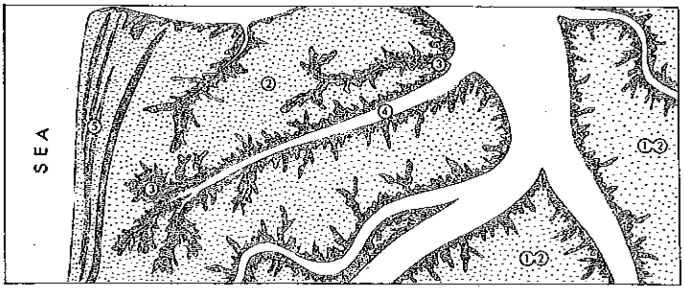
A discontinuous strip of saline country, with some sand dunes, along the coastline.

Climate.—Wettest locality: mean annual rainfall 55 in.; mean agricultural growing season 25 wk; mean pasture growing season 27 wk. Driest locality: mean annual rainfall 28 in.; mean agricultural growing season 14 wk; mean pasture growing season 18 wk.

Geology.—Quaternary alluvia.

Geomorphology.—Coastline plains and estuarine-deltaic plains.

Drainage.—Dendritic tidal channels and small stream lines of very variable intensity, some large meandering estuaries; unit 3 is regularly flooded by tidal waters, unit 2 only by highest tides, and unit 1 only by combinations of peak floods and high tides.



Unit	Area	Land Forms	Soils	Vegetation
1	Medium	Higher plains mainly along the inland margin of the land system	Mainly Flapper—grey sandy loam over mottled clay; some Legune—grey cracking clay	Saline soil short grass (*Xerochloa imberbis, Sporobolus virginicus*)
2	Large	Nearly flat plains	Carpentaria—highly saline clays	Bare mud or samphire
3	Small	Slopes and flats adjacent to channels and coast, submerged at high tide		Mangroves
4	Small	Salt-water channels		
5	Very small	Sand dunes, isolated small areas near the coast	Coastal sand dunes—deep yellow-grey sands	Sand-dune vegetation

Comparable with Carpentaria land system of the Leichhardt–Gilbert, North Kimberley, and West Kimberley areas and Littoral land system of the Katherine–Darwin and Barkly regions.

PART III. CLIMATE OF THE ORD–VICTORIA AREA

By R. O. Slatyer*

I. Introduction

This predominantly semi-arid region, lying between latitudes 14° and 19°S., has a warm dry monsoonal climate characterized by a rainy season of 4–5 months and a dry period of virtual drought for the remainder of the year.

Day temperatures seldom fall below 84°F, and even in winter night temperatures remain sufficiently high to preclude frost occurrence in all but the most inland areas and parts of the highlands where frosts have occasionally been recorded.

Definite and marked climatic trends are evident, due primarily to latitude and also to the proximity to the coast of the northern portions of the region. In these areas there are higher total rainfall, less extreme temperatures, and a climate more generally humid than in the inland sections to the south.

This report is concerned with the variations in climate throughout the region, based mainly on rainfall and temperature data. More detailed climatic data are available only for Kimberley Research Station, near Kununurra (Anon. 1965, 1968).

II. General Climatic Characteristics

(*a*) *Rainfall*

Over most of the area mean annual rainfall is less than 30 in., but it ranges from 50 in. in the northernmost coastal areas to 15 in. in the most inland areas. Annual isohyets run generally from slightly south of west to slightly north of east. This pattern is disturbed in the coastal regions by the influence of the Joseph Bonaparte Gulf (Fig. 3). Rainfall characteristics of representative localities in or close to the area are shown in Table 1. As well as a decrease in total rainfall with increasing distance to the south and inland, there is an accompanying decrease in the intensity and reliability of rainfall.

The greater part of the rainfall occurs in the four months from December to March. Nearly 85% of the total falls during these months and almost all of the annual amount falls between November and March. These features are well illustrated by the histograms of monthly rainfall given in Figure 3 as well as by the data of Table 1. Katherine and Daly River are included in this list because they are the only stations in or adjacent to the wetter portions of the region with sufficient years of records to provide comparative information. The rapid onset of rain in November and December is clearly seen, as is the equally rapid but rather more erratic decline at the end of March. Apart from small amounts of rainfall in April and October the remainder of the year is practically rainless, particularly the month of August.

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Most of what little rain there is between May and September occurs in the southern parts of the area. At Halls Creek, for instance, 1·35 in. falls in this period,

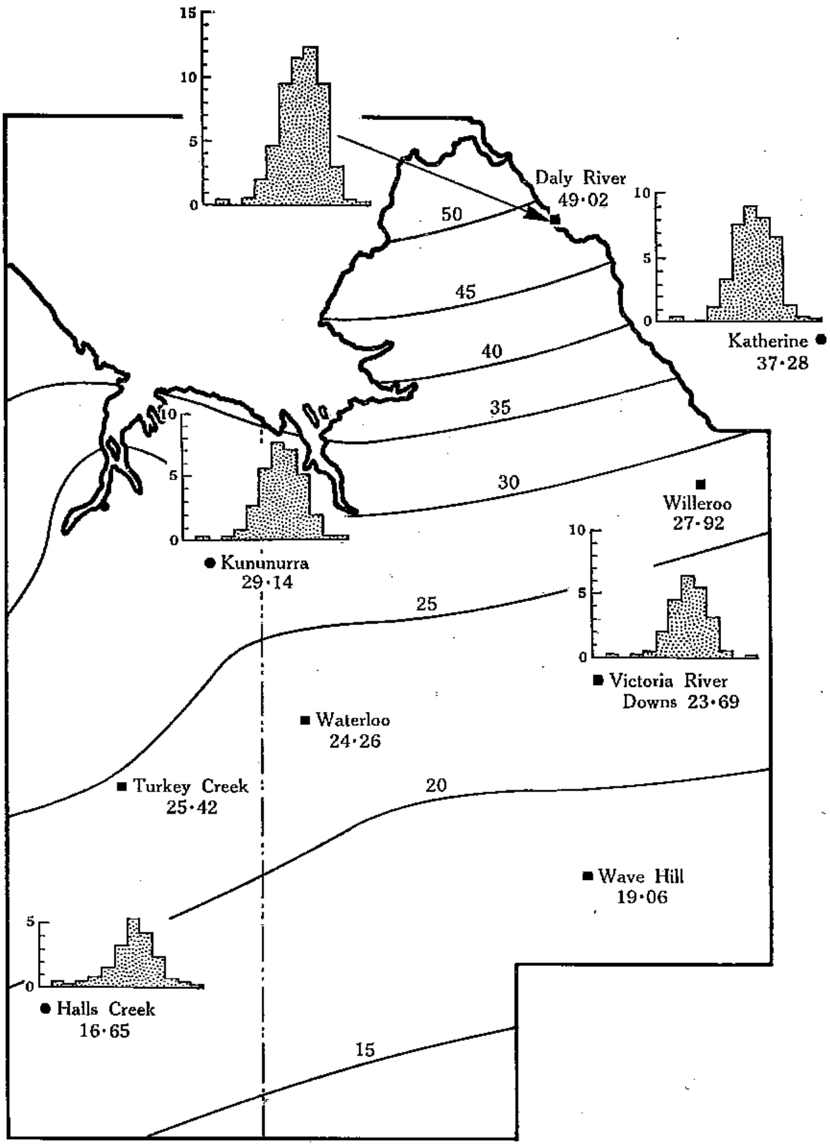

Fig. 3.—Isohyets of mean annual rainfall together with histograms of monthly rainfall (July–June) at specific localities. Values shown for the station names are the mean annual rainfall in inches for the station.

representing 8·1% of the total rainfall; at Wyndham 1·09 in., representing 3·9% of the total; and at Katherine the comparable figures are 0·67 in. and 2·4%. This feature is evident in Figure 3.

TABLE 1

RAINFALL CHARACTERISTICS FOR 10 STATIONS*

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Daly River (30 yr of records)													
Mean rainfall (in.)	10·50	12·01	9·06	2·57	0·55	0·09	0·04	0	0·22	1·97	4·09	7·84	49·02
Mean no. rain days	16	15	12	3	1	0	0	0	1	3	8	13	72
Halls Creek (30 yr of records)													
Mean rainfall (in.)	4·83	4·29	2·01	0·60	0·48	0·30	0·36	0·11	0·10	0·37	0·88	2·32	16·65
Mean no. rain days	11	10	6	2	2	1	1	1	0	2	5	8	49
Ivanhoe (Kununurra) (29 yr of records)													
Mean rainfall (in.)	7·81	6·22	4·54	1·69	0·27	0·31	0·18	0·03	0·07	0·75	2·38	4·89	29·14
Mean no. rain days	11	9	6	2	1	0	0	0	0	2	5	8	44
Katherine (30 yr of records)													
Mean rainfall (in.)	9·60	7·61	6·34	1·36	0·22	0·11	0·03	0·03	0·28	1·24	3·10	7·36	37·28
Mean no. rain days	15	12	10	3	1	1	0	0	1	3	7	12	65
Turkey Creek (30 yr of records)													
Mean rainfall (in.)	6·70	6·24	3·60	0·58	0·21	0·25	0·30	0·02	0·25	0·69	1·83	4·75	25·42
Victoria River Downs (30 yr of records)													
Mean rainfall (in.)	5·75	5·10	4·05	0·81	0·27	0·09	0·10	0·01	0·09	0·70	2·50	4·22	23·69
Mean no. rain days	11	9	7	2	1	1	0	0	1	2	7	9	50
Wave Hill (30 yr of records)													
Mean rainfall (in.)	4·38	4·47	3·54	0·36	0·19	0·17	0·26	0·05	0·13	0·71	1·99	2·81	19·06
Waterloo (30 yr of records)													
Mean rainfall (in.)	6·17	5·63	3·71	0·74	0·33	0·17	0·23	0·03	0·03	0·70	2·05	4·47	24·26
Mean no. rain days	10	9	6	1	1	0	0	0	0	2	4	7	40
Willeroo (30 yr of records)													
Mean rainfall (in.)	8·08	6·07	4·88	0·32	0·12	0·09	0·03	0·03	0·13	0·70	2·42	5·05	27·92
Wyndham (30 yr of records)													
Mean rainfall (in.)	7·96	6·41	4·82	1·34	0·38	0·38	0·20	0·02	0·06	0·35	1·65	4·09	27·66
Mean no. rain days	13	10	9	3	1	1	0	0	1	1	5	9	53

* Data from Bureau of Meteorology (1966) and other daily records for 1931–60.

Table 1 also shows that there is little change in number of wet days with increasing distance from the coast, and the distribution of wet days is concentrated in the November–March period, with peaks conforming to the rainfall peaks for each respective station. At Halls Creek, as distinct from the other stations, at least one wet day can be expected each month, whereas at Katherine and Wyndham there are periods of three and four months respectively where the expected number is virtually zero.

Because the number of wet days does not change to any great extent throughout the area, rainfall per wet day is highest in the regions of greatest rainfall and decreases with decreasing rainfall. In the December–March period the values are 0·63 in. per wet day at Katherine and 0·69 in. at Kununurra and decline to 0·38 in. at Halls Creek.

Although rainfall variability in any one month is high, annual rainfall variability in the area as a whole is low to moderate. In the wettest portions it is as reliable as in areas of similar rainfall elsewhere in Australia, the mean deviation of annual rainfall from the mean being less than 20%. As the rainfall decreases, however, there is a corresponding increase in variability and in the driest areas it exceeds 30%. Figures for Katherine, Kununurra, and Halls Creek are 19, 21, and 31% respectively.

(*b*) *Temperature*

Mean monthly temperatures for Katherine, Kununurra, and Halls Creek are shown in Figure 4. Several interesting features are at once obvious. The low altitude and latitude and the proximity to the sea of Kununurra are reflected in slightly lower maxima during the hottest periods of the year, in higher minima at all times than the other stations, and in lower and more steady diurnal variation in temperature. Conversely, the higher altitude and latitude and greater distance inland of Halls Creek produce more extreme conditions and greater diurnal variation. The influence of rainfall at Katherine, the wettest locality, in causing a wet-season depression of temperature is much more marked than at the other stations where the depression in maxima with the onset of the wet season is hardly noticeable.

Most of the important aspects of the temperature regime in this area are covered by these three stations. It can be seen that, in general, mean maximum temperatures remain high throughout the year and during October, November, and December reach exceptionally high levels. During and around November, periods of more than a week can be expected each year with daily maxima consecutively exceeding 100°F and occasionally approaching 110°F. Another, but much shorter, period of high temperatures occurs in March when the reduction of maximum temperature through greater cloudiness during the wet season is diminished. At this time maxima exceeding 100°F are again occasionally recorded on several successive days.

Mean minimum temperatures show much greater annual variation throughout the year than mean maximum temperatures. Although, as can be seen from Figure 4, these reach levels of more than 70°F during the hottest months, the decline in minima is rapid in autumn, particularly in elevated areas and as distance from the coast increases. At Halls Creek both these conditions hold and in July the mean minimum temperature falls below 50°F.

Foley (1945) reports that the lowest minima recorded at stations in or near this area are 30·0°F at Halls Creek, 30·2°F at Daly Waters, and 38·0°F at Wave Hill. The lowest minimum recorded at Kununurra is 41·5°F. Occasional light frosts may occur in June, July, and August at Halls Creek and at points closer to the coast during June and July. The earliest records of minima below 36°F and 32°F at Halls Creek have been June 1 and July 17 respectively, and the latest records of such temperatures August 24 and July 26 respectively. Foley considers the average frost-free period to be 359 days per year. In general, therefore, frost occurrence is rare, the northern parts being virtually frost-free and the southern parts having occasional light frosts in some years, particularly in topographically suited localities.

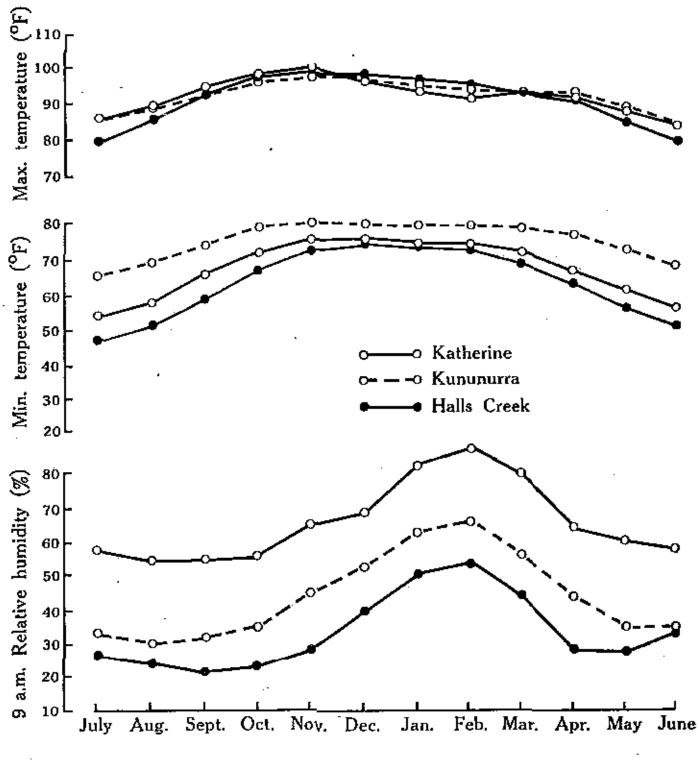

Fig. 4.—Mean monthly maximum and minimum temperature and 9 a.m. relative humidity at three stations.

(c) *Humidity*

The annual curves of 9 a.m. relative humidity for Katherine, Kununurra, and Halls Creek are also shown in Figure 4. Conditions at Katherine are seen to be more humid than at the other localities even though Kununurra is much closer to the coast. Both these centres, however, are significantly more humid than Halls Creek where both lower rainfall and geographical location combine to influence atmospheric aridity.

Although wet-season humidity levels reach moderate values at Katherine and Kununurra, it is important to note that these figures are much less than those characteristic of the humid tropics. Even during the wet season humidity levels can drop almost to dry-season values during periods of rainless weather, resulting in higher evaporation figures than would be expected from average monthly values alone.

(*d*) *Day Length*

Sunrise and sunset times have been computed from data provided by the Commonwealth Meteorological Bureau. The data do not include twilight but give a general picture of day length in this region. On the shortest day of the year day length ranges from approximately 11 hours in the southernmost portions of the area to 11¼ hours in the extreme north. On the longest day of the year the figures are approximately 13¼ hours in the south and 13 hours in the north. Thus no marked changes in length of day at various times of the year occur within the area. In the south the difference between longest and shortest days is most marked, but even so is only of the order of 2½ hours.

(*e*) *Evaporation*

Within the area evaporation data are available only for Kununurra (Kimberley Research Station). However, additional data are available for Katherine Research Station and monthly and annual estimates of evaporation from the standard Australian tank have been obtained for Halls Creek from mean maximum temperature and vapour pressure data (Fitzpatrick 1963).

At Kununurra and Katherine the mean annual evaporation totals (from standard Australian tank) are 105 and 88 in. respectively. At both stations the highest evaporation rates occur during the pre-wet-season period, September–November. During each of these months, the mean evaporation at Kimberley Research Station exceeds 10 in., and at Katherine the monthly means are between 9 and 9·5 in. during this period. For most of the remainder of the year the mean monthly evaporation at Kimberley ranges generally between 7 and 8 in. and at Katherine between 6 and 7·5 in.

During the wet season the estimated monthly levels of evaporation at Halls Creek are higher than at Kununurra, all the values from September to January inclusive exceeding 9 in. However, during the coolest part of the dry season the estimated evaporation at Halls Creek (6·54 in. in July) is lower than at Kununurra (7·33 in. in July), so that the annual totals do not differ greatly between the two stations. Although no data are available, it may be expected that the highest levels of annual evaporation occur in the extreme south-eastern part of the area.

III. Climate in Relation to Plant Growth

(*a*) *Introduction*

It is evident from Figure 3 and Table 1 that the distribution of rainfall places a severe limitation on the period during which sufficient soil moisture is available for plant growth in this area. Over much of the southern and eastern part, rainfall is too light and sporadic to support a stable agriculture and even in the wetter parts the intermittent nature of the rainfall during the rainy season makes soil moisture availability the most important factor limiting plant growth.

In early publications in this series (Christian and Stewart 1953; Slatyer and Christian 1954) the "adequate rainfall" method of assessing length of growing season was utilized primarily because only daily rainfall data were required, an important factor in areas with few climatic records other than rainfall. It also provided greater sensitivity than methods using monthly data and in most respects provided a valid, if somewhat empirical, analysis of growing season attributes. More recently, however, the accumulation of experimental agroclimatic data has enabled models of water use to be developed (Slatyer 1960) which, with improved methods of evaporation estimation from crude climatic data (Fitzpatrick 1963), can provide much more sensitive growing season estimates than those obtained previously. With the incorporation of these procedures into digital computer programmes it is now practicable to carry out rapidly the lengthy calculations involved for a large number of stations.

For the present study separate models have been developed for assessing the pastoral and agricultural growing periods and related characteristics (Slatyer 1960; Fitzpatrick and Arnold 1964). Briefly, the agricultural water use model represents the water-use pattern during land preparation, establishment, growth, and maturation of the crop, special emphasis being placed on periods of water stress which interfere with normal crop water use. The pastoral water use model is based on less detailed information but similarly represents the growth pattern of perennial pastures, from the critical stage of regrowth commencement through periods of active growth and induced dormancy to maturation. Full details are given in the papers cited above.

(b) *The Growing Period for Agricultural Plants*

Using these techniques, the start of the agricultural growing period is estimated to range from mid December in the areas of highest rainfall to mid January in the extreme south. The length of the growing season is likewise greatest in the wettest areas and decreases progressively as annual rainfall decreases. These trends are well illustrated in Figure 5, where the data for all stations have been mapped, and also in Table 2, where detailed information for representative stations is given.

If a growing period of 12 wk or more in at least 4 yr out of 5, equivalent to a mean annual rainfall of 30 in., is required for safe production of cash crops and Townsville stylo pastures, only 25% of the region in the north will be suitable for these forms of agriculture.

Also included in Table 2 is an estimate of the number of weeks occurring in the 12-wk period following sowing in which estimated soil water storage was more than 1 in. below the maximum value. Such deficits are considered to cause some decrease in plant growth, so that the total period involved can be expected to provide some indication of the degree to which growth and yield are reduced below potential levels. The figures indicate that these dry periods are a hazard in all but the wettest localities.

(c) *The Growing Period of Natural Pastures*

Using the technique already referred to, the start of the period of initial pasture growth is found to range from the end of November in the wettest areas to early

January in the driest. These dates are earlier than those for the agricultural growing period, and the range between dates for the wettest and driest localities is wider. This is because weekly falls of rain at the beginning of the season that are not adequate

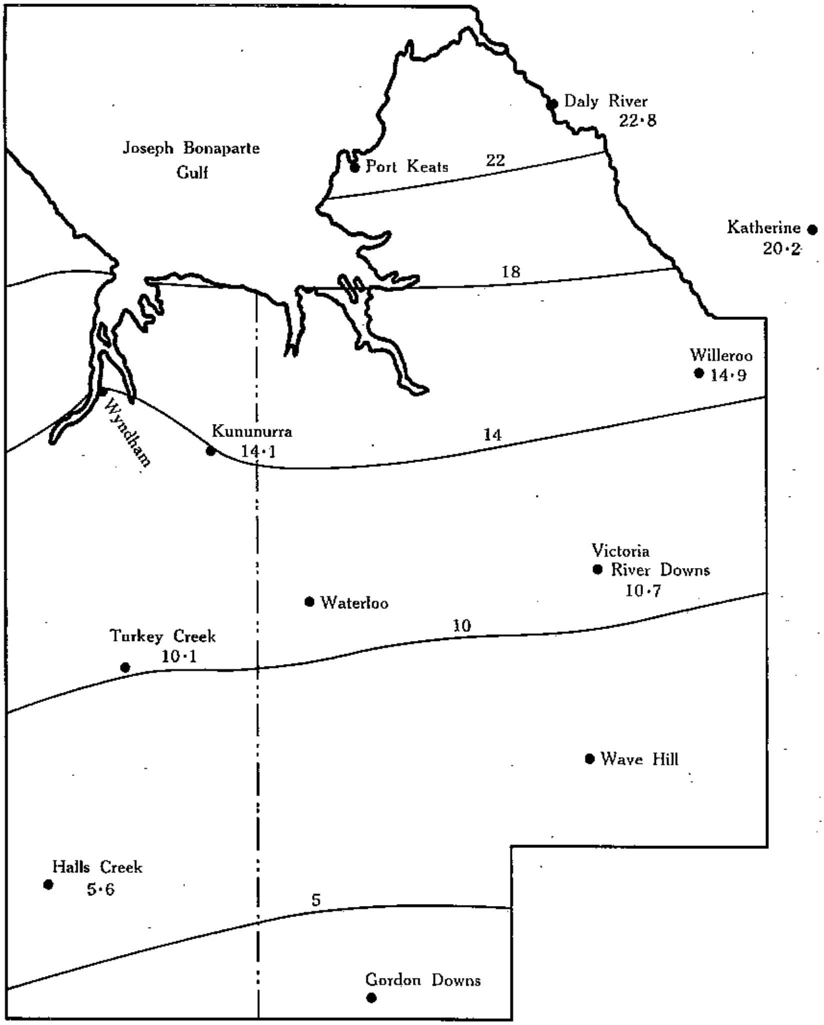

Fig. 5.—Estimated length (wk) of agricultural growing period.

for crop establishment may be sufficient to initiate pasture growth. There is usually a wider variation from year to year in the time of such falls, and in their distribution throughout the area, than in the occurrence of falls adequate to allow sowing of crops.

The length of the useful growing period for natural pastures is also appreciably longer than the agricultural growing period, the driest localities having an average

TABLE 2

PRIMARY CHARACTERISTICS OF ESTIMATED AGRICULTURAL GROWING PERIOD AT 7 STATIONS (1911–40)

	Daly River	Katherine	Kununurra*	Willeroo	Victoria Downs	Turkey Creek	Halls Creek
Date of pre-sowing rains							
Mean	Nov. 16	Nov. 30	Nov. 30	Dec. 14	Dec. 21	Dec. 11	Jan. 4.
Standard deviation (wk)	3·4	2·8	3·8	3·1	3·5	4·9	3·7
Years without pre-sowing rains	0	0	0	0	0	0	1
Date of sowing rains							
Mean	Dec. 30	Dec. 14	Dec. 28	Dec. 28	Jan. 11	Jan. 11	Jan. 18
Standard deviation (wk)	2·0	2·4	3·3	3·1	4·5	4·8	3·1
Years without sowing rains	0	0	0	0	0	1	1
Length of agricultural growing season (wk)							
Mean	22·8	20·2	14·1	14·9	10·7	10·1	5·6
Standard deviation	5·2	3·6	4·7	4·9	5·1	5·7	3·3
Mean no. of weeks with accumulated deficit >1·00 in. (<12 wk after sowing date)	0·5	2·1	4·4	4·4	5·2	6·0	7·0
% of years with agricultural growing period >8 wk	97	100	90	90	67	62	14
>12 wk	97	100	70	67	37	31	2
>16 wk	97	76	27	30	13	17	0
>20 wk	73	50	13	17	3	4	0
>24 wk	40	17	0	0	0	0	0

* Kimberley Research Station.

period of about 9 wk and the wettest of up to 5 months. These general trends are illustrated in Figure 6 and additional data for representative stations are given in Table 3.

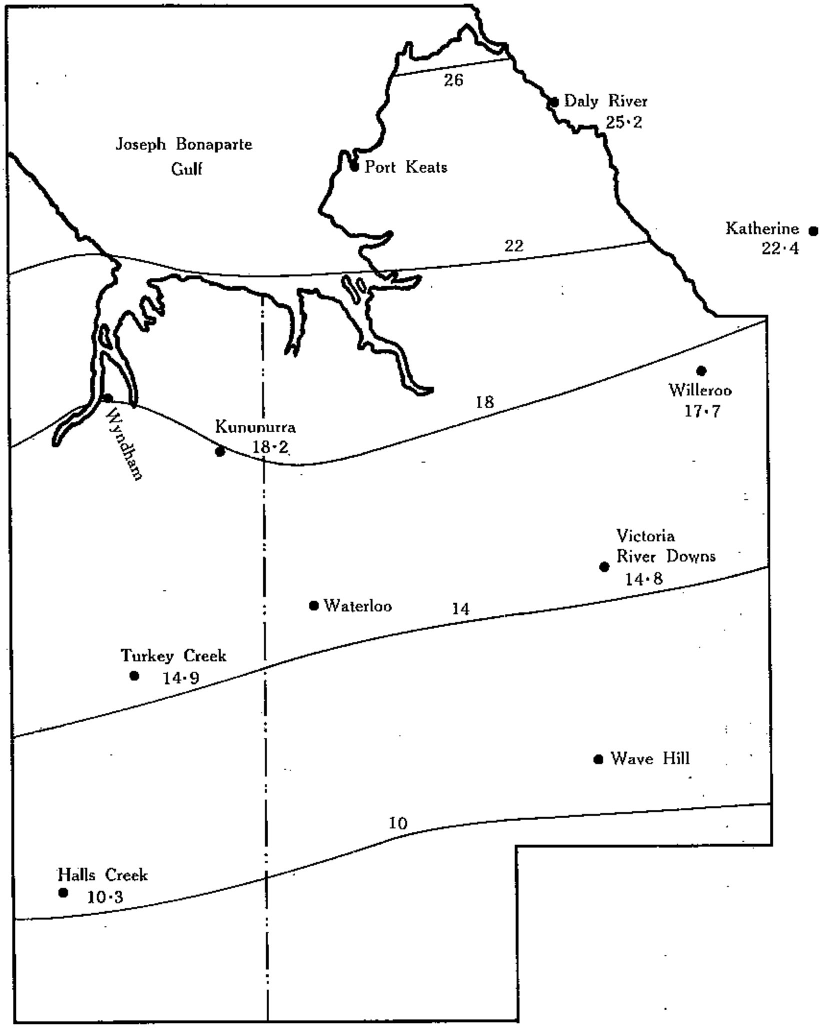

Fig. 6.—Estimated length (wk) of the period of useful pasture growth.

The period of useful pasture growth, as shown in Figure 6, not only represents the summation of several periods of growth but also includes varying periods of pasture activity. It is therefore essentially a total period during which a "green pick" is available for stock rather than one in which a high growth rate can be expected. For this reason additional data are included in Table 3 to give a more realistic estimate of the period during which a high rate of pasture production occurred.

TABLE 3

CHARACTERISTICS OF PERIOD OF USEFUL PASTURE GROWTH AT 7 STATIONS (1911–40)

	Daly River	Katherine	Kununurra	Willeroo	Victoria Downs	Turkey Creek	Halls Creek
Start of dominant pasture growth period							
Mean date	Nov. 23	Nov. 30	Dec. 14	Dec. 21	Jan. 4	Dec. 28	Jan. 11
Standard deviation (wk)	3·3	2·7	3·6	3·5	3·6	4·0	5·1
Total duration (wk) of useful pasture growth							
Mean	25·2	22·4	18·2	17·7	14·8	14·9	10·3
Standard deviation	2·8	2·8	3·4	3·7	3·6	4·2	3·2
Duration (wk) of pasture growth with available water >2·5 in.							
Mean	18·7	14·5	9·5	10·0	6·2	6·9	4·2
Standard deviation	3·0	3·0	2·5	3·8	3·2	3·5	2·2
% of years with total duration of							
pasture growth >8 wk	100	100	100	93	93	90	17
>12 wk	100	100	97	90	77	73	7
>16 wk	100	97	77	67	30	33	0
>20 wk	93	77	30	27	7	10	0
>24 wk	70	27	7	0	0	0	0

These data represent the period during which estimated soil water storage exceeded 2·5 in. The assumed maximum storage capacity is equivalent to a 4-in. depth of surface water stored in the soil, and experimental evidence (Slatyer 1956, 1960) suggests that substantial reductions in growth rate can be expected when storage falls below 2·5 in. The values calculated in this way suggest that, on the average, only 4 wk of rapid pasture growth can be expected in the driest areas even though a "green pick" may be available for 2–3 months. Likewise in the wetter areas the rapid growth phase seldom appears to last longer than 3 months even though some activity may continue for up to 5 months.

TABLE 4

WET-SEASON IRRIGATION CHARACTERISTICS AT KATHERINE, KUNUNURRA, AND FITZROY CROSSING*

	Katherine (30 yr)	Kununurra (30 yr)	Fitzroy Crossing (41 yr)
Mean seasonal irrigation need (in.)	3·5	8·6	12·6
Standard deviation (in.)	2·3	3·1	3·3
Highest in one season (in.)	7·2	15·7	19·3
Lowest in one season (in.)	0·6	3·8	5·3
Mean number of weeks having irrigation need	5·0	9·0	11·6
Fewest weeks in one season having irrigation need	1 (in 2 cases)	6 (in 3 cases)	7 (in 2 cases)
Most weeks in one season having irrigation need	10 (in 1 case)	13 (in 1 case)	15 (in 2 cases)

* Based on daily rainfall records over the seasons 1910–11 to 1939–40 except for Fitzroy Crossing where, owing to a broken record, the complete data over 41 years have been analysed.

(*d*) *Water Requirements for Irrigation*

Estimates of water requirements for irrigation have been obtained by Fitzpatrick and Arnold (1964) and Fitzpatrick (1965) for Katherine, Kununurra, and Fitzroy Crossing. Although Kununurra is the only one of these stations that is actually within the area, these estimates may be taken as representative because the three stations largely cover the range of climate experienced within the area. The methods used in obtaining these estimates are fully described in the references just cited. Basically the method is similar to that previously used for rain-dependent agriculture, but the water-usage models adopted are more appropriate to crops with a longer growth period that would be sown either before or after the normal wet season. The original estimates made by Fitzpatrick and Arnold (1964) for Fitzroy Crossing and Kimberley Research Station (Kununurra) included an estimate of water needs for pre-irrigation requirements upon specific physical soil properties. The estimates given in Table 4 represent only the water needs of the crop over a 16 wk period following the assumed sowing date.

Estimates relating to supplementary irrigation for a wet-season crop irrigated as required over the 16 wk from the last week in November are given in Table 4 for these three stations. The mean seasonal need at Fitzroy Crossing is seen to be over three times as high as at Katherine, and the estimate for Kununurra is intermediate. This range gives some indication of the extent to which irrigation needs increase from the wetter parts of the area in the north to the drier areas of the south. Even so, it is likely that in the extreme southern and eastern parts of the area supplementary water requirements would exceed even those of Fitzroy Crossing. Other features included in Table 4 show generally similar relationships to those for mean seasonal amount. It is notable that even in the wetter parts of the area some seasons are estimated to have an irrigation need as high as 7 in., and that this need would occur over 10 of the 16 wk following sowing.

Estimates of total water requirements for a dry-season crop sown during the last week in April and irrigated over 16 wk have also been obtained. Again the values given here are exclusive of possible pre-irrigation needs, and these are based upon the assumption that the contribution of water to the crop from rainfall is nil in all cases. The estimate for Katherine is 20 in., for Kununurra 23 in., and for Fitzroy Crossing 20 in. It is apparent that whereas water requirements for supplementary irrigation during the wet season differ considerably over the area, those of total irrigation for a dry-season crop are very uniform.

It should be noted that these estimates do not allow for losses in the delivery of water to the crop or other inefficiencies in the irrigation system.

IV. Acknowledgments

The valuable help of officers of the Commonwealth Meteorological Branch is acknowledged, in particular Mr. R. C. L. White, who prepared many of the rainfall data for this paper. Mr. E. A. Fitzpatrick, formerly of the Division of Land Research, CSIRO, developed the computer programme used in data processing as well as contributing substantially to data interpretation and discussion. The assistance of Mrs. A. Komarowski in data tabulation is also gratefully acknowledged.

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PART IV. OUTLINE OF THE GEOLOGY OF THE ORD–VICTORIA AREA*

By D. M. Traves,† P. R. Dunn,‡ and P. J. Jones‡

I. Introduction

Rocks of almost all periods are represented in the area. The various stratigraphic units together with their lithology are listed in Table 5, which also includes a list of the land systems associated with each stratigraphic unit. A small simplified geology map is shown as an inset on the geomorphology map sheet.

Traves (1955) produced the first account of the geology of the Ord–Victoria region as a whole and his report is accompanied by a map at a scale of 1 : 1,000,000. The brief summary given here is based on Traves's work and updated from accounts by Dow and Gemuts (1969) on the Kimberley area, Veevers and Roberts (1968) on the Bonaparte Gulf area, Walpole *et al.* (1968) on the north-eastern portion, and current (1968) work by the Bureau of Mineral Resources on the Victoria River region.

The Ord–Victoria region can be broadly subdivided into three structural units—the stable Kimberley Block in the west and the Sturt Block in the east separated by the Halls Creek Mobile Zone which extends north-eastwards to join the Pine Creek Geosyncline. These three units dictated the pattern of sedimentation throughout Precambrian time. In Palaeozoic times a number of shallow basins, the Hardman, Rosewood–Ivanhoe, and Daly River Basins, were developed on the Sturt Block and a deep basin, the Bonaparte Basin, was developed adjacent to the Halls Creek Mobile Zone.

The known economic geology of the region is mainly confined to the Kimberley and Bonaparte Gulf areas and is described by Dow and Gemuts (1969) and Veevers and Roberts (1968).

II. Archaean–Lower Proterozoic

The oldest rocks§ in the region mainly occur within the Halls Creek Mobile Zone and its extension to the north into the Pine Creek Geosyncline. They comprise volcanics, greywacke, sandstone, shale, siltstone, and minor conglomerate and dolomite which have been folded and subjected to low-grade metamorphism (Hermit Creek Metamorphics, Halls Creek Group, Finniss River Group, and Chilling Sandstone).

* Published with permission of the Director, Bureau of Mineral Resources, Geology, and Geophysics, Canberra.

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‡ Bureau of Mineral Resources, Geology, and Geophysics, Canberra. Provided up-to-date revision.

§ The subdivisions of the Precambrian used here are: oldest to youngest, Archaean, Lower Proterozoic, Carpentarian, and Adelaidean (Dunn, Plumb, and Roberts 1966).

TABLE 5

GEOLOGICAL GROUPS AND MAJOR STRATIGRAPHIC UNITS WITH LIST OF ASSOCIATED LAND SYSTEMS

Geological Group	Major Stratigraphic Units	Lithology	Land Systems
Quaternary alluvia		—	Subcoastal Plain, Carpentaria, Ivanhoe, Angallari, Legune
Tertiary swamp, lake, river deposits		—	Inverway, Dillinya
Tertiary laterite and associated soils		—	Mullaman, Geebee, Coolindie, Barry, Franklin, Ruby, Matheson
Lower Cretaceous sediments		Lacustrine fine sandstone and conglomerate, marine sandstone, shale, and mudstone	Wingate, Mullaman, Birrimbah, Matheson, Hawk, Redsan
Permian sandstone, shale, and conglomerate			
Lower Triassic–Lower Permian	Port Keats Group	Sandstone, shale, limestone	Moyle
Early Lower Permian	Keep Inlet Beds	Glacial boulders, sandstone, shale	Cockatoo
Devonian–Carboniferous sediments			
Late Upper Carboniferous	Border Creek Formation	Sandstone, conglomerate, siltstone	Weaber, Cockatoo
Early Upper Carboniferous–Late Lower Carboniferous	Point Spring Sandstone	Sandstone	Weaber, Cockatoo
Late Lower Carboniferous	Burvill Beds	Sandstone, shale, sandy limestone	Weaber, Cockatoo
	Waggon Creek Breccia	Pebbly sandstone, breccia	—
Middle Lower Carboniferous	Utting Calcarenite	Limestone	—
	Milligans Beds	Shale, siltstone	—
Early Lower Carboniferous	Zimmermann Sandstone	Sandstone	Weaber
	Septimus Limestone	Limestone	Weaber, Cockatoo
	Enga Sandstone	Sandstone	Weaber, Cockatoo

Late Upper Devonian	Burt Range Formation Ningbing Limestone Buttons Beds	Reef limestone, lagoonal deposits	Tanmurra, Dinnabung
Early Upper Devonian	Cockatoo Formation	Sandstone, conglomerate, limestone	Weaber, Cockatoo, Dinnabung
	Elder Sandstone	Sandstone, conglomerate, limestone	Elder, Buchanan
Cambrian–Ordovician limestone, sandstone, and shale			
Lower Ordovician–Early Middle Cambrian	Carlton Group	Sandstone, limestone	Weaber, Cockatoo
	Daly River Group	Limestone, some shale and sandstone	Matheson, Jindara, Wriggley
Early Middle Cambrian	Negri Group	Shale and limestone	Headley, Nelson, Argyle, Dinnabung
	Montejinni Limestone	Limestone	Barry, Montejinni, Dinnabung
	Tarrara Formation		—
Late Lower Cambrian	Blatchform Formation		—
Lower Cambrian volcanics	Antrim Plateau Volcanics	Basalt, agglomerate, tuff	Napier, Antrim, Frayne, Wave Hill, Willeroo
Adelaidean glacials and associated rocks			
	Albert Edward Group	Siltstone, shale, some sandstone and dolomite	Wickham, Gordon, Humbert
	Duerdin Group	Tillite, sandstone overlain by siltstone with minor dolomite	Pinkerton, Wickham, Argyle, Cockburn, Gordon
Adelaidean sandstone, shale, some dolomite			
	Auvergne Group Tolmer Group Helicopter Siltstone Wade Creek Sandstone	Sandstone, shale, siltstone, minor dolomite	Wickham, Pinkerton, Cockburn, Dinnabung
Adelaidean dolomitic rocks, some sandstone			
	Bullita Group Bungle Bungle Dolomite Mount Parker Sandstone	Dolomitic sediments, stromatolitic dolomite, chert, sandstone	Humbert, Tanmurra, Dinnabung, Gordon, Argyle

TABLE 5 (*Continued*)

Geological Group	Major Stratigraphic Units	Lithology	Land Systems
Adelaidean or Carpentarian sandstone, siltstone			
	Carr Boyd Group Fitzmaurice Group Legune Formation	Massive sandstone and siltstone	Pinkerton, Wickham, Cockburn
Carpentarian dolerite	Hart Dolerite	Dolerite, granophyre	Napier, Willeroo, Antrim, Wave Hill, Frayne
Carpentarian sandstone, siltstone, volcanics			
	Bastion Group	Sandstone, shale, minor dolomite	Pinkerton, Cockburn
	Kimberley Group	Sandstone, siltstone, basic volcanics	Wickham, Pinkerton, Cockburn
	Gardiner Beds	Sandstone, conglomerate, some dolomite	Wickham, Winnecke
	Speewah Group	Siltstone, sandstone, shale, minor volcanics	Wickham, Pinkerton
Proterozoic granite, gabbro, rhyolite, metamorphic rocks			
	Whitewater and Berinka Volcanics	Acid volcanics, ignimbrite	Pompey, Richenda
	Lamboo Complex	Granitic rocks, high-grade metamorphics, gabbro	Pompey, Macphee, Richenda, O'Donnell, Koongie, Wave Hill
	Mount Winnecke Granophyre	Granitic rocks	Koongie
	Litchfield Complex Allia Granite Soldiers Creek Granite	Granitic rocks	Litchfield
Lower Proterozoic–Archaean sediments and metamorphic rocks			
	Chilling Sandstone	Sandstone, conglomerate	Pinkerton
	Finniss River Group	Greywacke, siltstone, conglomerate	Brocks Creek
	Halls Creek Group	Siltstone, shale, sandstone, basic volcanics, greywacke; minor dolomite, conglomerate	Dockrell
	Hermit Creek Metamorphics	Mica schist, quartzite	Litchfield

In places the sediments and volcanics have been intensely metamorphosed and possibly mobilized to granitic rocks in the Lamboo and Litchfield Complexes. Later granitic and basic rocks were intruded into the complexes and into the low-grade metamorphics, the final period of granitic intrusion being accompanied by the extrusion of a large volume of acid volcanics (Whitewater and Berinka Volcanics) which overlies the metamorphics with a major unconformity. The Mount Winnecke Granophyre intruded acid volcanics during this period.

The metamorphics range in age from Archaean to Lower Proterozoic. The igneous intrusions are Lower Proterozoic and the final phase of granitic intrusion and acid volcanism marks the boundary between the Lower Proterozoic and Carpentarian.

III. Carpentarian

After a short period of erosion on the Kimberley Block the acid volcanics were followed by a period of sand deposition with interbedded silt and minor volcanics that have a total thickness of about 24,500 ft (Speewah, Kimberley, and Bastion Groups). There is no evidence of this sedimentation on the Sturt Block except in the extreme south of the Ord–Victoria region west from Mount Winnecke (Gardiner Beds). In the Mobile Zone itself Carpentarian sedimentation might have taken place and be represented by the Fitzmaurice and Carr Boyd Groups, but no direct correlations can be made with the Kimberley Block sediments. The Speewah and Kimberley Group rocks were intruded by a vast dolerite sill up to 6500 ft thick (Hart Dolerite) possibly about the same time as the volcanics were extruded in the Kimberley Group.

The Kimberley Block sediments are warped and faulted on the margin of the block but are gently dipping or flat-lying on the block itself. The sandstone at the base of the Kimberley Group (King Leopold Sandstone) characteristically forms steep cliffs along the eastern margin of the block. The Gardiner Beds are broadly folded and rocks of the Fitzmaurice and Carr Boyd Groups, which are within the Mobile Zone, are folded and extensively faulted.

The Speewah, Kimberley, and Bastion Groups were deposited in the early part of the Carpentarian, as probably were the Gardiner Beds. The Fitzmaurice and Carr Boyd Groups may be as young as Adelaidean.

IV. Adelaidean

Adelaidean sediments are confined to the Sturt Block in the Ord–Victoria area but probably lapped into the Mobile Zone. The sedimentation was thin and widespread; the total thickness is probably less than 5600 ft throughout most of the block, although it increases to about 16,500 ft on the edge of the Mobile Zone.

The oldest Adelaidean sediments are sandstone and dolomitic rocks which occur in the central part of the block (Bullita Group) and on the western margin. The dolomite contains stromatolites.

After a period of erosion these rocks were overlain by a sequence of sandstone and shale, and dolomite on the margin of the Daly River Basin was probably deposited about the same time (Tolmer Group).

Late in the Adelaidean, after a further period of erosion, glacial conditions prevailed and a series of tillites and glacigene sediments (Duerdin Group) were deposited on the west of the Sturt Block and extended westwards beyond the Ord–Victoria area. Glacial pavements occur below the tillites and striated boulders are common. The glacial deposits were followed by a short but significant period of dolomite deposition which in turn was followed by a predominantly shale–siltstone sequence with interbedded sandstone (upper Duerdin Group and Albert Edward Group).

The Adelaidean rocks have generally not been folded but are warped on the margins of the block and the Daly River Basin. The dolomitic rocks have been folded into elongate domes in some places.

V. Lower Cambrian Volcanism

Towards the end of the Precambrian the area was uplifted and in early Cambrian time very extensive outpouring of basalt of the Antrim Plateau Volcanics took place. The volcanics, which consist of a number of basalt flows interbedded with tuffs, sandstone, chert, and agglomerate, covered most of the Mobile Zone and Sturt Block but do not appear to have been very extensive on the Kimberley Block. Subaerial conditions prevailed throughout most of the period of extrusion of the basalt, but interbedded marine cherts near the top of the volcanics on the eastern side of the area suggest late-stage marine conditions.

VI. Lower Palaeozoic Transgression and Sedimentation

The period of volcanic activity was followed by the lower Palaeozoic marine transgressions which gave rise to deposition in a number of basins.

The Daly River Group, which consists of subhorizontal limestones with some sandstones and shales, crops out only in the north-eastern corner of the area.

The Montejinni Limestone crops out in a long narrow strip in the eastern part of the area. It consists of subhorizontal limestone with varying amounts of chert.

The Negri Group sediments were deposited in major basins in the western part of the area. They consist of alternating beds of crystalline limestone and shale, and are generally gently dipping except along the north-western margins of the basins.

The Carlton Group, consisting of sandstones and limestones of Middle Cambrian to Ordovician age, were deposited as the basal sediments in the south-western part of the Bonaparte Gulf Basin. They are gently dipping and little folded but are strongly strike-faulted.

VII. Upper Palaeozoic Sedimentation

The main area in which sediments of this era occur is in the Bonaparte Gulf Basin. However, numerous outliers of Devonian sediments also occur south of the present southern margin of this basin (Veevers and Roberts 1968). For example, in the Ragged Range a conglomeratic sandstone identified as a member of the Upper Devonian Cockatoo Formation unconformably overlies the later Lower Cambrian

Blatchford Formation. Also, the Elder Sandstone, a massive cross-bedded sandstone of possible Devonian age, unconformably overlies the Negri Group in the Hardman Basin. Recent more detailed geological information on the Bonaparte Gulf Basin (Veevers and Roberts 1968) has been used as a basis for the following summary.

Uplift in the Middle Ordovician initiated erosion that persisted through to Middle Devonian time. This was followed by marine deposition during the Upper Devonian in three main provinces: the platform conglomerate province along the south-eastern margin, the platform carbonate province along the south-western margin, and the basinal shale province in the axial part of the basin. The dominantly terrigenous deposition of the early Upper Devonian waned in the late Upper Devonian, and allowed the growth of a reef complex (limestone and lagoonal deposits) that persisted into the early Lower Carboniferous. During this time, uplift, faulting, and tilting resulted in deep erosion of the south-western margin, and deposition of sandstone and limestones (non-reef-forming) along the south-eastern margin. Along the western side of the basin, sedimentation was not re-established until the middle Lower Carboniferous, when shale and non-reef-forming limestones were deposited. This was followed by the deposition of pebbly sandstone, breccia, shale, and sandy limestone during the late Lower Carboniferous. In the axial part of the basin, however, subsidence continued throughout most of the Lower Carboniferous time with the deposition of shale and siltstone. In the early Upper Carboniferous, uplift resulted in re-initiation of erosion, which was succeeded by a depositional period that extended from the late Upper Carboniferous through the Permian. The late Upper Carboniferous sediments were mainly sandstones and conglomerates, and these were overlain by Permian glacial sediments and also Permian freshwater and marine sediments including sandstones and shales with some thin limestone beds. Where these last sediments occur between the mouths of the Fitzmaurice and Daly Rivers they have been termed the Port Keats Group. They probably range into the Lower Triassic in the Port Keats area.

VIII. Lower Cretaceous Sedimentation

Most, if not all, of the region was a mature land surface during the early part of the Mesozoic era. Recent more detailed geological information on the region (Skwarko 1967) has been used to revise the following paragraph.

In the Lower Cretaceous non-marine lakes were developed and lacustrine sandstone and fine conglomerate of the Mullaman Beds were deposited in them. These lakes were later inundated by the epeiric sea which covered most of northern Australia, and sandstone, shale, and mudstone were deposited.

The late Mesozoic uplift must have been very slight and even, as the easily erodable Mesozoic sediments are preserved as a veneer on the mature land surface with deeply weathered lateritic soils that developed in early to mid Tertiary time. In the Cainozoic, except possibly for a brief marine incursion in the Miocene, a trace of which is preserved as the White Mountain Formation (Lloyd 1968), the entire region was probably exposed and deeply weathered until the late Pleistocene. The development of the deeply weathered surface and its dissection, the deposition of Tertiary sediments, and the deposition of extensive alluvia are described in Part V.

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PART V. GEOMORPHOLOGY OF THE ORD–VICTORIA AREA

By S. J. PATERSON*

I. INTRODUCTION

This part of the report, produced by summarizing a much longer unpublished report by the author, includes the following:

(1) a brief description of the geomorphological regions and subregions;

(2) a summary of the geomorphological history;

(3) brief descriptions of the geomorphological sections and units.

The Ord–Victoria area is part of the West Australian shield. In common with most of the shield, it has a relatively small range of altitude. Most of the area is less than 1000 ft above sea level and only small areas of ridge crests in the western part are more than 2000 ft above sea level. However, approximately 50 % of the survey area consists of rugged country with much rock outcrop or relatively shallow stony soils. The remaining undulating to flat lands consist of three types:

(1) The gently undulating plateau surfaces with mainly lateritic soils in the eastern and southern parts of the area.

(2) The erosional plains on which moderate to deep soils have formed by weathering of the underlying rock. These are widely scattered throughout the area.

(3) Alluvial plains along the major stream valleys and along the coast.

The drainage systems of the area are shown on Figure 7. Approximately 60 % of the area is drained by the Ord and Victoria Rivers, a further 25 % by other streams flowing to the coast, and approximately 15 % is either drained by the internal drainage systems of Sturt Creek and Hooker Creek or has no surface drainage.

II. GEOMORPHOLOGICAL REGIONS

The area surveyed includes parts of three regions (Fig. 8), one of which has been divided into a number of subregions.

(a) *Kimberley Plateau Region*

A portion of the Kimberley plateau occupies the north-western section of the area examined. The plateau, which rises to over 2000 ft, consists of series of structural plateaux and benches, mesas and buttes, cuestas, hogbacks, and vales, and is formed

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of Carpentarian sandstone, siltstone, and volcanics. The rocks have been broadly folded and are strongly jointed. The plateau has been vigorously dissected by numerous streams, resulting in a generally rugged topography.

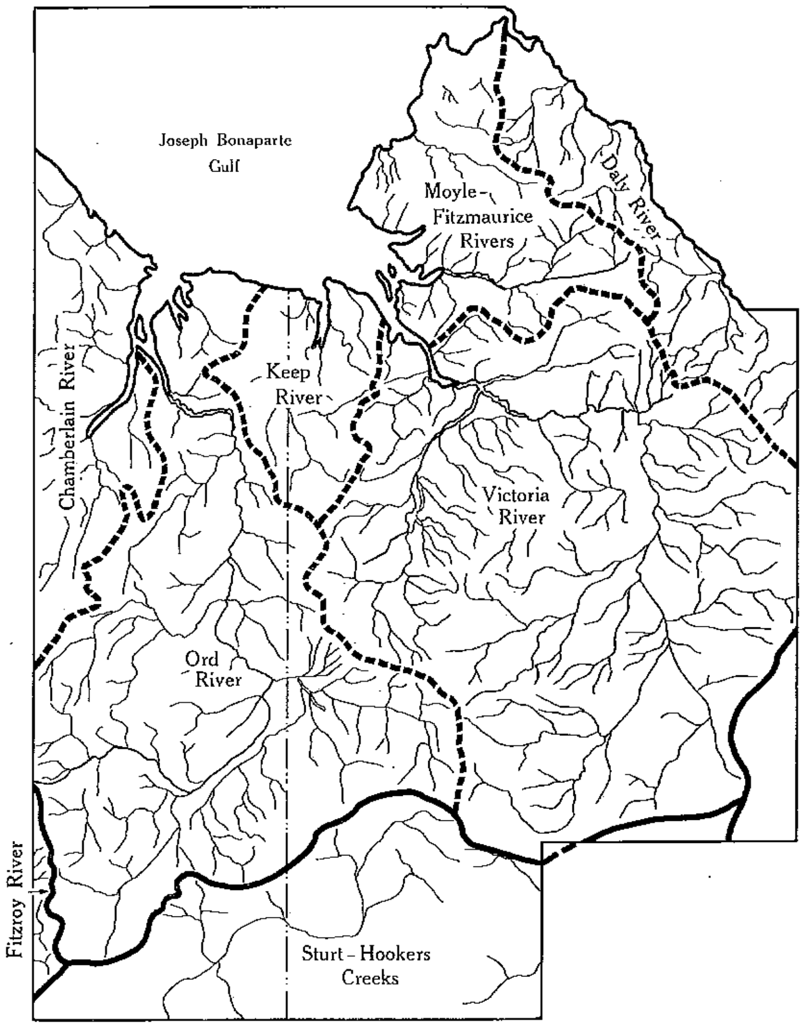

Fig. 7.—Drainage systems of the Ord–Victoria area.

(*b*) *Sturt Plateau Region*

This plateau occurs along the eastern and southern margins of the area. It is an old uplifted erosion surface and along its northern and western margins is generally separated from the dissected valleys of the Ord, Victoria, and Fitzmaurice Rivers by steep breakaways.

The plateau altitude ranges from 600 ft in the north-east to 1500 ft in the south, but the surface is only gently undulating and changes in height are gradual. Most of the surface is deeply weathered and covered by thick laterite and associated soils. It appears to be little altered from its original state except for minor aeolian erosion. Monadnocks, which occur only in the southern part, rise 100–200 ft above the general surface and consist of resistant Carpentarian sandstone.

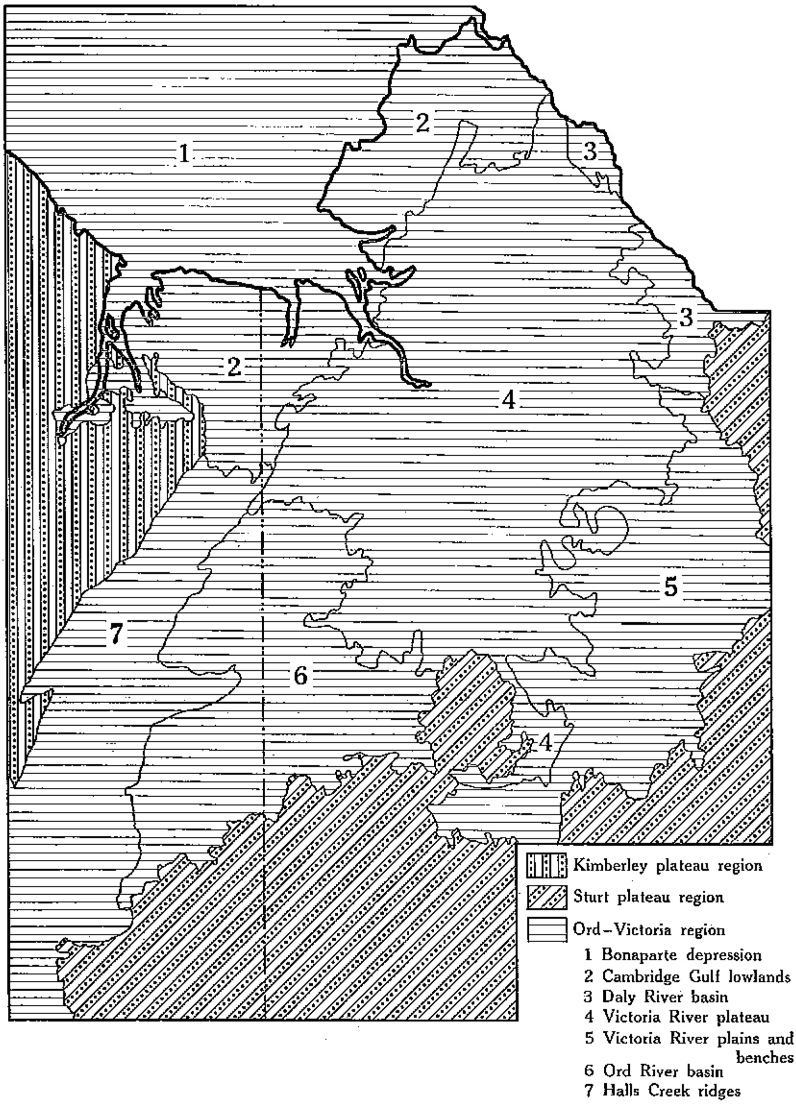

Fig. 8.—Geomorphic regions.

(c) *Ord–Victoria Region*

This region includes all of the dissected country between the Kimberley and Sturt plateaux. It has been divided into a number of subregions.

(i) *Joseph Bonaparte Gulf Depression.*—This is occupied by the shallow sea to the north of the area surveyed. Its floor is gently sloping and reaches 50 fathoms depth at approximately 100 miles from the coast.

(ii) *Cambridge Gulf Lowlands.*—These include the coastal erosional and alluvial plains adjacent to the Joseph Bonaparte Gulf which do not exceed 300 ft in altitude. Interspersed through the plains are a number of residuals rising to over 1000 ft, e.g. House Roof Hill and the Weaber Range.

(iii) *Victoria River Plateau.*—This plateau is formed on a broad little-disturbed area of Adelaidean sediments. It is a large dissected plateau, rarely exceeding 1000 ft in altitude, and consists of a collection of structural plateaux and benches, mesas and buttes with a few cuestas, hogbacks, vales, and karst areas. Some of the major watercourses have broad flat-bottomed alluvial valleys.

(iv) *Victoria River Plains and Benches.*—These are associated with Lower Cambrian volcanics and Middle Cambrian limestones of the upper Victoria River catchment. The southern section is mainly an undulating plain with scattered mesas and buttes, but plains are less extensive in the northern part. Towards the Sturt plateau in the east is a series of volcanic structural benches topped by a limestone bench. In the south the plains rise gradually almost to the plateau level. The altitude of the plains ranges from 350 ft in the north to 1200 ft in the south-west, while the mesas, buttes, and benches range from 500 to 1300 ft.

(v) *Ord River Basin.*—This basin occurs along the middle tract of the Ord River where it flows through a sequence of Lower Cambrian volcanics, Middle Cambrian limestones and shales, and Devonian sandstones in broad basin structures. The volcanics have mostly been dissected to form mesas and buttes, but in the northern part there are also appreciable areas of plains. Limestones and shales form low cuestas, while sandstones and shales form cuestas, a structural bench, and a structural plateau. Altitude ranges from 250 ft in the north to 1600 ft on ridge crests in the south.

(vi) *Halls Creek Ridges.*—This includes three distinct but related types of country. Steeply folded Lower Proterozoic–Archaean metamorphics have been dissected into a succession of parallel ridges. The Lamboo Complex of Lower Proterozoic igneous rocks forms ridges, plateau-like masses surmounted by ridges, exfoliation domes, and undulating plains with tor residuals. In the northern part of the subregion, a variety of Proterozoic and Palaeozoic rocks form cuestas, hogbacks, residual ridges, and structural plateaux. Altitude ranges from 200 ft along the north-eastern margin to over 2000 ft on ridge crests throughout the subregion.

III. Geomorphological History

In this section the evolution of the landscape from the end of the period of Mesozoic deposition until the present day is summarized.

Uplift at the end of the period of Mesozoic deposition must have been slight and gentle as veneers of the easily erodable Cretaceous sediments are retained on parts of the gently undulating erosional land surface that subsequently developed. Over large parts of this land surface deeply weathered lateritic soils were formed during the early to mid Tertiary period.

Various remaining parts of this old surface have distinctive complexes of soils that appear to be related to the nature of the parent materials. These relationships are briefly described in the description of geomorphological units of the interior plateau in the next section. In the far south, mature lateritic profiles occur where the present rainfall is approximately 15 in. per annum. On younger land surfaces, strongly leached and weathered soils are extensive only when the present rainfall is more than 30 in. per annum. This suggests that the climate must have been appreciably wetter during at least parts of the Tertiary.

The White Mountain Formation of siltstone, chert, and marl is known only from some isolated ridges near Mt. Elder. Although Tertiary in age, its relationship to the old erosional land surface is not clear. It may have been formed during the period of deep weathering or, as seems more likely from its altitude 500 ft lower than the nearest parts of the old land surface, its deposition may post-date the period of deep weathering.

In the far south some areas of resistant rock apparently resisted weathering and erosion and protrude as monadnocks above the weathered land surface. One of these, Mt. Winnecke, is capped by laterite. This capping may be the remnant of an earlier erosional surface possibly contemporaneous with the period of Mesozoic deposition.

Dissection of this old land surface appears to have been initiated by uplift in the late Tertiary, possibly in a number of stages. Apparently the major drainage systems of the old land surface were similar to the present-day drainage pattern. The rejuvenated streams have very actively dissected the major part of the area, the only extensive remnants of the old land surface being the Sturt plateau in the east and south of the area. Scattered mesas capped with laterite also occur in a roughly north–south line across the Victoria River plateau.

In the dissected areas, the exposed harder rocks gave rise to the simple fold mountains and structural plateaux, the complex fold mountains, and the ancient igneous masses described in the following section. The softer rocks were more extensively eroded to form the coastal and inland erosional plains. In the near coastal areas the major streams appear to have cut deep valleys during periods of low sea level in the Pleistocene, and these valleys and the gently sloping margins of the Bonaparte Depression were subjected to extensive depositions during a subsequent period or periods of high sea level. Due to a mid-Recent emergence, large areas of the flood-plain alluvia are now above deposition level. Only small areas of flood-plains occur in the upstream parts of coast-draining streams. On the old weathered land surface post-Tertiary deposition is confined to some shallow swamps and salinas and braided river channel areas.

In the far south of the area the masking of drainage patterns and the occurrence of low, widely spaced dunes indicate aeolian erosion. However, these areas now carry a stable vegetative cover. The aeolian erosion apparently took place during a period of greater aridity in early Recent time.

IV. Geomorphological Units

The area has been divided into a number of geomorphological units and some of these have been further divided into geomorphological sections to describe important land form types more adequately. The units and sections are shown on the accompanying geomorphological map at a scale of 1 : 1,000,000. Their relationship with land systems may be obtained by comparing the geomorphology and the land system maps or by referring to the geomorphology section in the land system descriptions.

(a) *Ancient Monadnocks*

These steep-sloped sandstone monadnocks rise above the general level of the Sturt plateau in the south. Some monadnocks are capped by deeply weathered lateritic material which may be remnants of an early Tertiary or late Cretaceous land surface.

(b) *The Interior Plateau*

This plateau corresponds to the Sturt plateau region in the southern and eastern parts of the area. The southern part is internally drained by the Sturt, Hookers, and Winnecke Creek systems, the north-eastern part by tributaries of the Daly River, but the south-easterly section forms part of a vast riverless region. This unit has been divided into six sections described below.

(i) *Elevated Lateritic Plains* (*Sandy Red Earth Surface Horizon*).—These gently undulating plains have deep sandy soils overlying ferruginous, mottled, and pallid zones. They have little or no surface drainage and some parts show evidence of weak dune formation. In the south they have formed from arenaceous Carpentarian sediments, whereas the area east of Wave Hill is believed to be formed of sandy Cretaceous sediments.

(ii) *Elevated Lateritic Plains* (*Lateritic Red Earth and Lateritic Podzolic Surface Horizon*).—These gently undulating plains have mainly red clay soils with some grey sandy soils in the north-eastern parts. In the north-east they appear to be formed largely on Cretaceous mudstones and sandstones, whereas in the south they are formed on Lower Cambrian volcanics and Adelaidean sediments. They generally have a clearly defined drainage pattern.

(iii) *Elevated Non-lateritic Plains* (*Red Earth and Yellow Earth Soils*).—These nearly flat plains have red and yellow soils overlying limestone and lateritic horizons are absent. Surface drainage is absent and it appears that good subsurface drainage through the limestone has been responsible for the prevention of lateritization.

(iv) *Elevated Non-lateritic Plains* (*Grey Soils of Heavy Texture*).—These nearly flat plains occur as lower plains associated with (ii) and appear to represent broad swamps and drainage lines within that landscape. They were apparently protected from lateritization by their low topographic situation and the low permeability of the grey clay soils.

(v) *Dissected Elevated Lateritic Plains*.—This section includes the breakaways at the margins of the Sturt plateau and the isolated laterite-capped mesas and buttes in the northern part of the region. The resistant layers at the edge of the breakaways and mesas may be the ferruginous zone or hard mottled or pallid zones.

(vi) *Truncated Elevated Lateritic Plains*.—These plains occur along the eastern margin of the area. They have been formed where headwater erosion of coast-flowing streams has partially stripped the deeply weathered horizons to form gently undulating plains. Apparently in these areas the deeply weathered profile does not have any layers that are hard and resistant to erosion.

(*c*) *Complex Fold Mountains* (*Ridge Metamorphic Belt*)

These mountains are associated with the strongly folded and faulted Lower Proterozoic metamorphics. They have been dissected into a series of parallel strike ridges with narrow intervening valleys, and drainage patterns are strongly structure-controlled.

(*d*) *Ancient Igneous Masses*

These masses include the steep terrain formed on the Lamboo Complex of igneous rocks. They consist of ridges, plateau-like masses surmounted by ridges, exfoliation domes, and tor-studded nubbins with minor areas of plains. The steeper parts clearly show the influence of jointing and faulting, but the valleys are normally irregular. This is the highest part of the area where valley altitudes range from 600 to 1600 ft and ridge crests frequently rise to more than 2000 ft.

(*e*) *Simple Fold Mountains and Structural Plateaux*

This unit includes the greater part of the country dissected by the Ord and Victoria Rivers. The wide variety of land form complexes has been divided into 11 geomorphological sections.

(i) *Ridges, Hogbacks, Cuestas, and Structural Plateaux*.—These range in altitude between 200 and 2000 ft and local relief ranges from 100 to 600 ft. They are formed on a wide range of Adelaidean and Carpentarian sediments. Structural plateaux occur where the rocks are subhorizontal, but with increasing dips they give way to cuestas, hogbacks, and ridges which are formed on Upper Proterozoic sediments. The structural plateaux are usually capped by resistant sandstone below which the denudation slope is remarkably consistent at 28·5°. It is possible that the upper levels of some structural plateaux coincide with the mid-Tertiary land surface but have not developed laterite horizons because of the unsuitability of the hard sandstone parent material. In general, sandstones are strongly jointed and this has exercised a very marked control over drainage.

(ii) *Sandstone Structural Plateau* (*Asymmetric Basin*).—This section occurs in the shallow dipping part of the Hardman Basin between the Ord River and the Osmond Range. The Elder Sandstone is particularly resistant to erosion but has been weakened by intense jointing, and dissection has produced a number of rugged joint blocks.

(iii) *Sandstone Structural Bench* (*Asymmetric Basin*).—It borders the previous section and consists of hard sandstone overlain by soft sandstone which has weathered to deep sandy soils.

(iv) *Sandstone Cuestas (Asymmetric Basin).*—Sandstone cuestas border the previous section. The crests of bare sandstone outcrop are separated by narrow vales eroded in shales.

(v) *Limestone Cuestas (Asymmetric Basin).*—These occur on the southern and eastern margins of the Hardman Basin. They are formed on the base limestone of the Cambrian Negri Group and are separated from the sandstone cuestas by a sector of inland erosional plains formed on shales.

(vi) *Limestone Structural Benches.*—These benches occur along the eastern margin of the catchment of the Victoria River. They were formed on the Cambrian Montejinni Limestone and range in altitude from 550 to 650 ft. Although a number of solution features are evident along the margins of the benches they have normal surface drainage, probably because of the limited thickness of the limestone.

(vii) *Limestone Ridges, Hogbacks, Cuestas, and Structural Plateaux.*—These are formed on broadly folded and jointed Upper Proterozoic and Palaeozoic limestone. The topographic form of the limestone is mainly structurally controlled and solution features are uncommon.

(viii) *Volcanic Structural Benches.*—These benches occur adjacent to the limestone structural bench in the eastern part of the area. The benches represent exposure of resistant flows in the volcanic sequence and have mainly shallow red earth soils. The altitude of the benches ranges from 300 to 700 ft.

(ix) *Volcanic Mesas and Buttes.*—These have been formed where the Cambrian volcanics have been more actively dissected. Resistant flows cap the mesas and also crop out as structural benches on steep slopes. Their altitude ranges from 550 ft in the east to over 1300 ft in the south-west.

(x) *Ridges Capped by Lacustrine Sediments.*—At location 129°00′E., 17°15′S., several ridges are capped by maturely dissected lacustrine sediments of White Mountain Formation. Then sediments, mainly cherts, siltstone, and marls, crop out at altitudes of 700–1000 ft on the steep ridge slopes.

(*f*) *Inland Erosional Plains*

The largest area of these plains occurs in the upper part of the Victoria River basin where they are eroded in Cambrian volcanics and limestone. The undulating plains are interspersed with occasional mesas and buttes and drainage is clearly defined with a dendritic pattern. In the middle Ord River basin, broadly undulating erosional plains have been formed on Cambrian shale. There are also small areas of these plains scattered through erosional landscapes in the southern half of the area.

(*g*) *Coastal Erosional Plains*

These are most extensive along the lower Ord River extending northward to the mouth of the Daly River, but smaller areas occur as far inland as Victoria River Downs. In general their surfaces are smoothly undulating and they are interspersed with low residuals.

(*h*) *Interior Swamp Plains*

Saline alluvia have been deposited in four swampy depressions on the Sturt plateau. Lake Nongra is a salina fringed by a low lunette on its north-western margin. At the other localities, the shallow swamps which are flooded each wet season are characterized by grey soils of heavy texture.

(*i*) *Interior Fluvial Plains*

Areas of fluvial deposition occur along the major channels of Sturt Creek and in Birrindudu swamp, and are characterized by grey soils of heavy texture. This unit also includes small sandy alluvial fans on the northern edge of Mt. Winnecke.

(*j*) *Coastal Fluvial Plains*

The lower valleys of all the major rivers are deeply alluviated but the width of the fluvial plains is variable, ranging up to 20 miles. The continuity of deposits along most streams is frequently broken by narrow gorges which isolate many small pockets of alluvia.

(i) *Fine-textured Fluvial Plains*.—Derived primarily from basic igneous or argillaceous metamorphic and sedimentary rocks, these plains are characterized mainly by grey soils of heavy texture. Their gradients are very gentle except where cut by stream channels, and drainage patterns may range from major incised channels such as the lower Ord River to intensive braided systems. The most northerly occurrences have no defined drainage channels and are flooded each year, some parts remaining swampy throughout the dry season.

(ii) *Coarse-textured Fluvial Plains*.—These plains have been derived largely from arenaceous sedimentary and metamorphic rocks or acid igneous rocks. Their topography is more irregular than the fine-textured alluvia and they mainly have yellow earth soils.

(*k*) *Estuarine–Deltaic Plains*

These plains are formed around the mouths of all the major rivers where the marine influence still has significant effect. Most of these plains are liable to saline flooding at king tides and the highest parts are believed to be subject to freshwater flooding when high stream flooding and high tide coincide.

(*l*) *Coastline Plains*

This unit includes the minor coastal features produced by waves, currents, and winds such as bay-head deltas, beaches, tombolos, sand dunes, and beach ridges.

PART VI. SOILS OF THE ORD–VICTORIA AREA

By G. A. Stewart*

I. Introduction

(a) *Previous Soil Investigations*

The only significant soil investigation in this area at the time of the survey was the soil survey of some of the potentially irrigable land in the lower Ord River valley (Burvill, unpublished data†). These investigations involved detailed soil surveys of two areas totalling 86,000 acres, and a general reconnaissance of 750,000 acres between Wyndham and the Western Australian border.

More recent surveys by the Department of Agriculture, Western Australia, have revealed a total potential irrigable area of 186,000 acres (S. T. Smith, unpublished data). In the course of agronomic studies at Kimberley Research Station, more detailed information has been obtained on Cununurra, Cockatoo, and Ord soils (Parbery, Rose, and Stern, unpublished data‡). Profiles of Cununurra (Profile 10A), Pago (Profile 5B), Frayne (Profile 8A), and Elliott (Profile 26A) soils are described in the Handbook of Australian Soils (Anon. 1968).

(b) *General Soil Relationships*

Much of the area is characterized by steep tablelands and hills with rock outcrops and shallow immature skeletal soils, while deep soils are confined to gentle slopes. On the interior plateau the soils are generally leached and deeply weathered, being mainly red and yellow earths and lateritic podzolic soils. It is believed that these soils were formed during a past period of wetter climate as the southern lower-rainfall part of the area generally has less weathered and leached soils on the younger erosional and alluvial plains than on the interior plateau.

On erosional plains and alluvial plains there are clearly marked relationships between the soils and the climate, drainage, and parent materials. Basic igneous rocks have red earths on better-drained slopes and cracking clays on lower gentle slopes, with minor areas of calcareous desert soil in the low-rainfall parts. Limestone and finer-textured dolomitic and calcareous sediments have medium-textured red earths and yellow earths in better-drained sites in higher-rainfall parts and calcareous desert

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† Burvill, G. H. (1945).—Soil surveys in the Kimberley Division of Western Australia. Soil surveys and related investigations in the Ord River area, East Kimberley 1944. Dep. Agric. West. Aust. (unpublished report).

‡ Parbery, D. B., Rose, C. W., and Stern, W. R. (1968).—Characteristics of the three main agricultural soils in the lower Ord River valley, Western Australia. CSIRO Aust. Div. Land Res. tech. Memo. No. 68/7 (unpublished).

soils on better-drained parts in lower-rainfall areas, while more poorly drained sites in both landscapes have cracking clays. Sandstone and calcareous sandstone generally have sandy red earths, some yellow earths, and lateritic podzolic soils, with minor solonetzic soils in poorly drained sites. Granites have red-brown earths or skeletal soils in the dry south; in the intermediate-rainfall areas highly quartzose granites have deep gritty yellow earths on gentle slopes and solonetzic soils in depressions, while in the high-rainfall coastal area granites have a catenary sequence of sandy yellow earths, lateritic podzolic, and meadow podzolic soils. Non-calcareous shale in the north characteristically has yellow earth soils. Yellow earths are also extensive on non-calcareous flood-plain deposits while red earths are mainly confined to levees and higher margins of flood-plains. Flood-plain alluvia derived from calcareous or dolomitic sedimentary rocks or basic and intermediate igneous rocks almost invariably have cracking clay soils.

TABLE 6

GENERAL PROFILE GROUPS WITH THEIR GREAT SOIL GROUPS AND SOIL FAMILIES

General Profile Group	Great Soil Groups	Soil Families
Leached gradational soils	Red earths—sandy surface	Blain, Cockatoo, Chunuma, Manbulloo
	Red earths—loamy surface	Tippera, Camil, Wonorah, Berrimah, Katherine, Frayne
	Yellow earths—sandy surface	Cullen, Pago
	Yellow earths—loamy surface	Elliott, Batten, Argada
	Lateritic podzolic soils	Koolpinyah, Florina
	Meadow podzolic soils	Marrakai, Card
	Acid swamp soils	Dashwood
Cracking clay soils	Grey and brown soils of heavy texture	Cununurra, Barkly, Argyle, Legune, Wildman
Texture-contrast soils	Red-brown earths	Moonah
	Solonetzic soils	Hooper, Flapper
Calcareous soils	Rendzina	Springvale
	Grey and brown calcareous desert soils	Tobermorey, Negri
Undifferentiated soils	Skeletal soils	—
	Alluvial soils	Ord, and miscellaneous
	Solonchak	—
	Aeolian sand	—

II. Soil Classification and Description

The classification largely follows that used by Stewart (1956) for the adjacent Katherine–Darwin area, but has been extended to cover the range of soils of this area. To simplify the presentation, five broad profile groups are described and these are further subdivided into great soils groups and named families or unnamed miscellaneous groups. Table 6 lists the general profile groups, great soil groups, and soil families and Table 7 shows their distribution in relation to land systems and pasture lands.

TABLE

DISTRIBUTION OF GREAT SOIL GROUPS*

Pasture Land	Land System	Red Earths Sandy† Surface	Red Earths Loamy Surface	Yellow Earths Sandy‡ Surface	Yellow Earths Loamy Surface	Great Lateritic Podzolic
Rugged hilly country	Pinkerton		m		m	
	Wickham				m	
	Weaber	m		m		
	Elder	m	m			
	Brocks Creek				m	
	Dockrell				m	
	Pompey					
	Mullaman					m
Hilly country with useful lowlands	Napier		m			
	Antrim		m			
	Tanmurra		m		m	
	Humbert		m		m	
	Headley					
	Richenda					
Low hilly country	Cockburn				m	
	Franklin		S			
	Ruby	m	D			
	Koongie		m			
	Winnecke	S			m	
Upland tall grass plains	Wingate	D				D
	Moyle	D		m		S
	Cockatoo	D	m	S		
	Litchfield			S		D
	Macphee			D		S
Three-awn plains	Birrimbah	m	m		m	D
	Buchanan	D	m	m		
Soft spinifex plains	Coolindie	D		m	m	
	Redsan	D		m	m	m
	Barry		D		S	
	Geebee		D		m	
Tippera tall grass plains	Matheson		S		S	S
	Jindara		D		m	S
	Wriggley		D		m	
	Dinnabung		S		D	
	Frayne		D		m	
	Angallari	m	m	S	D	
Arid short grass plains	Nelson					
	Gordon					
	Montejinni		m			
	O'Donnell			m		
Barley Mitchell grass plains	Inverway					
Mitchell and other grass plains	Wave Hill		m			
	Argyle					
	Hawk				S	m
Blue grass plains	Willeroo		m		m	
	Dillinya		m		S	
	Ivanhoe	m	m			
	Legune					
Lowland tall grass plains	Subcoastal Plain					
Coastal country	Carpentaria					

* D, dominant; S, subdominant; m, minor. † Blain, Cockatoo, Chunuma, and Manbulloo

7

IN LAND SYSTEMS AND PASTURE LANDS

Soil Groups										
Meadow Podzolic	Acid Swamp	Cracking Clays	Red-brown Earth	Solonetzic	Rendzina	Calcareous Desert	Skeletal Soil	Alluvial Soil	Solonchak	Aeolian Sand
							D	m		
						m	D	m		
							D			
							D			
m							D			
			m	m			D			
				m			D			
							D			
		m					D	m		
		m					D	m		
		m				m	D	m		
		m				m	D	m		
						m	D			
			m			m	D	m		
							D			
						m	D			
			m	m			S			
			m				D			
							D			
m										
m							m			
				m			m			
m							m			
				m			m			
		m					m			
							m			
							m			
							m			
m		m					m			
m		m					m			
		m			m	m	S			
		m				m	S			
m				m						
		m				D	m			
		m				D	m			
		m				D	S			
		m	m				D	m		
		D								
		D				m	m			
		D				m	m			
		D					m			
		D					m			
		D								
		D						m		
		S		S					m	
	D	S								
		m		m					D	m

families. ‡ Cullen and Pago families.

(a) Leached Gradational Soils

These soils are all characterized by gradual increases in clay content and colour intensity with depth. They are mostly structureless soils with many fine pores. Their reaction is generally nearly uniform throughout the profile and may range from moderately acid to mildly alkaline, and their content of soluble salts is very low.

Five great soil groups are differentiated primarily on colour and drainage status.

(i) *Red Earths.*—These soils have a brown or grey-brown to reddish brown surface horizon which merges gradually into a brown to red or dark red subsoil. Textures may range from deep sands to sands over clay subsoils up to clay loams over clay subsoils. They are well drained and are rarely shallower than 3 ft, mostly more than 6 ft deep.

Blain family has a brown sand surface horizon merging gradually into dark red clay between 12 and 36 in. depth. It occurs only in Moyle land system in the extreme north of the area.

Cockatoo family has brown medium sand surface horizons merging into red or red-brown clayey sand subsoils. It occurs on sandstone on the Sturt plateau in the south and also in the north-western part of the area.

Chunuma family has grey-brown medium sand surface horizons merging into brown or light brown medium sand subsoils. The deep phase is restricted to small areas of alluvia derived from Carpentarian sandstone in the north-western part of the area, and the shallow phase (less than 3 ft deep) occurs on the Sturt plateau in the east overlying laterite horizons.

Manbulloo family comprises deep fine sandy soils with grey-brown or brown surface horizons merging into yellow-brown or red-brown subsoils. These soils are confined to levee crests of the major streams except the Ord River.

Tippera family has sandy loam to clay loam surface horizons merging gradually into dark red clay subsoils by 12 in. depth. They occur on limestone or other permeable calcareous and dolomitic sediments and are largely confined to the north-eastern part of the area.

Camil family has similar morphology to Tippera family and is also formed on permeable calcareous and dolomitic sediments, but it occurs only on the Sturt plateau in the southern part of the area. It has been separated from the Tippera family because analyses of samples from other regions indicate that its exchange capacity is considerably higher than in Tippera soils, and it probably has a wider range of available water than Tippera.

Wonorah family has similar colour and texture to Tippera but overlies laterites and mottled and pallid material. It occurs only in the southern lower-rainfall parts of the region on the Sturt plateau. Deep phases of this soil are not common but the shallow phase with red clay containing large amounts of ferruginous concretions over laterite at less than 2 ft is common.

Berrimah family has grey-brown sandy loam or loam surface horizons with weak fine subangular blocky structure, merging gradually into massive red clay subsoils overlying laterite. Reaction is slightly more acid than other red earths, and the subsoil is not so hard when dry. They are considered to be "latosols" by Dr. G. D. Smith (personal communication).

Katherine family is similar to the Manbulloo family but the subsoil texture is fine sandy clay loam or fine sandy clay. It occurs in association with Manbulloo on the back slopes of the river levees.

Frayne family, formed on basic and intermediate igneous rocks, has similar colour and texture to Tippera family. However, the subsoils normally have a weak to moderate grade of angular blocky structure and a relatively high cation exchange capacity. Depth ranges from 2 ft to more than 6 ft. These soils occur on basic igneous rocks and are widely scattered throughout the region.

(ii) *Yellow Earths*.—These soils have a similar textural range to the red earths, but their colours range from grey or grey-brown at the surface and from yellow to yellow-brown with varying degrees of reddish mottling in the subsoil. One family has a bleached subsurface horizon which merges gradually with both the overlying and underlying horizons. All of these soils are massive with fine pores. Those without mottling are well-drained soils, but those with mottled subsoils are only moderately drained. They are generally more than 3 ft deep and many profiles are more than 6 ft.

Cullen family has surface horizons of grey or yellowish grey coarse sand merging gradually into yellow-brown to yellow-grey sand or clayey sand with rusty mottles. These soils occur on granite and sandstone, and on alluvia derived from these rocks. They are not extensive and occur only in the northern part of the area.

Pago family has yellowish grey medium sand surface horizons merging into yellow medium sand or clayey sand subsoils. Except for their yellow colour, they are very similar to Cockatoo family and occur in association with it. A gritty phase of Pago family occurs on granite in the north-western part of the area.

Elliott family has surface horizons of grey or yellowish grey sandy loam to clay loam merging gradually into yellow or yellow-brown clay with rusty red-brown mottling. The surface and subsurface horizons may contain ferruginous concretions. This soil is mainly associated with shale and fine-grained sandstone and alluvia derived from these rocks and is most common in the northern part of the area.

Batten family has surface horizons of grey or brownish grey sandy loam over a light grey bleached subsurface horizon with ferruginous concretions which merges into a yellow-grey mottled clay subsoil. It is much less extensive than Elliott family and occurs only on some of the alluvia derived from non-calcareous rocks in the northern part of the area.

Argada family has similar morphology to Elliott family but occurs only in the south on the Sturt plateau on sedimentary rocks. From analyses of samples taken in other regions the soils appear to be less acid and to have a higher exchange capacity than Elliott and for this reason have been made a separate family.

(iii) *Lateritic Podzolic Soils*.—These soils are characterized by coarse-textured greyish or yellowish surface horizons overlying either hard laterite or horizons with high amounts of ferruginous concretions. The deep subsoil is always mottled or pallid clay. These are poorly drained soils in which the concretionary layer is a zone of fluctuating water-tables during the wet season.

Koolpinyah family has yellow-grey or grey sandy surface horizons merging into yellow-grey sand or sandy loam subsurface with ferruginous concretions and overlying laterite hardpan at depths of 12–36 in. These soils are associated with the Tertiary weathered land surface except for minor areas in the northern higher-rainfall part where they are formed on granitic rocks on younger landscapes.

Florina family has grey or yellowish grey surface horizons merging gradually into light yellow-grey clay horizons with high amounts of ferruginous concretions and overlying light grey clay with rusty mottlings. These soils are generally more than 6 ft deep. They occur mainly on granite and sandstone in the higher-rainfall parts of the area, and to a lesser extent on the Tertiary land surface in the east.

(iv) *Meadow Podzolic Soils*.—These are poorly drained light-coloured soils with rusty mottling throughout the profile. They range in texture from deep sand to loam over clay, and are more than 3 ft deep and commonly over 6 ft. They are very minor in extent and are confined to the higher-rainfall northern parts of the region, occurring either on poorly drained alluvia derived from non-calcareous rocks or in depressions in the northern part of the Tertiary weathered land surface.

Marrakai family has surface horizons of grey sandy loam or loam with rusty staining around roots and merging gradually into light grey clay with rusty red mottling.

Card family has light grey sand surface horizons with rusty staining along roots over a subsoil of light grey or light yellowish grey sand with rusty mottlings.

(v) *Acid Swamp Soils*.—These soils have a water-table above the soil surface during the wet season and at less than 18 in. during the dry season. They occur only on the swampy parts of alluvial plains in the extreme north of the area where seepage or spring-fed streams maintain the water supply throughout the dry season.

Dashwood family is the only one in this group. It has dark grey to black peaty clay loam or peaty clay surface horizons which merge gradually into grey clay subsoils with rusty red-brown and yellow mottling. Below 30 in. the texture is variable.

(*b*) *Cracking Clay Soils*

(i) *Grey and Brown Soils of Heavy Texture*.—These are heavy clay soils that crack widely and deeply on drying out each dry season. When dry, they have granular or angular blocky surface horizons which merge with depth into large blocks separated by cracks. The colour is uniform throughout the 3–4-ft solum, except in the poorly drained Wildman family which becomes slightly lighter in colour with depth. They may contain small manganiferous concretions or carbonate concretions and some soils have low amounts of gypsum crystals. They are formed on fine-textured calcareous rocks or intermediate to basic igneous rocks, or alluvium largely derived from these rocks, or Tertiary swamp deposits of the Sturt plateau. The soils formed from hard rocks have variable amounts of stones from 1 to 10 in. diam. on the surface but are relatively stone-free within the profile. Drainage ranges from imperfect in the first three families to poor in Wildman family.

Cununurra family ranges in colour from grey, yellowish grey, dark grey, to dark grey-brown. It contains small carbonate concretions and small manganiferous concretions and is most common in the northern part of the area.

Barkly family is similar to Cununurra family except that manganiferous concretions are absent and low amounts of gypsum may be present. It is less extensive and occurs only in the southern lower-rainfall parts of the area on volcanic rocks.

Argyle family is similar to Cununurra family except that its colour is dark brown or dark reddish brown. It is less extensive than Cununurra but always occurs associated with it on higher better-drained sites.

Wildman family has surface horizons of grey or dark grey heavy clay which may have rusty or yellow mottlings and low amounts of ferruginous concretions. The lower part of the surface horizons is slightly lighter in colour and may contain gypsum crystals. In some profiles, low amounts of carbonate concretions are present. At depths ranging from 2 to 3 ft, this upper horizon merges with a waterlogged subsoil of grey or light grey clay with red and yellow-grey mottling. These soils occur on nearly flat alluvial plains only a few feet above high-tide level and are always associated with Dashwood soils. They are flooded for prolonged periods each wet season, but dry out to at least 2 ft in the dry season.

Legune family appears to be intermediate between Wildman family and Cununurra family. It is grey to dark grey heavy clay, merging into mottled clay below 30 in. It may have low amounts of small carbonate and/or manganiferous concretions. The surface horizon is more self-mulching than in Wildman family, and hydromorphic characteristics are considerably less marked. Both soil and vegetation indicate that flooding is much less prolonged than in Wildman family. Sodium chloride contents are high, exceeding 0·4% in the subsoil, as in Wildman family. These soils occur on low-lying estuarine alluvia only a few feet above high-tide level, near the mouth of the Keep River. A shallow phase, with 12–24 in. of grey to dark grey heavy clay overlying stratified alluvial deposits of medium to fine texture, also occurs on low-lying estuarine alluvia near the mouth of the Keep River.

(*c*) *Texture-contrast Soils*

Soils with an abrupt textural change from the A horizon to the B horizon are very common in south-eastern Australia, but are rare in northern Australia.

(i) *Red-brown Earths*.—These soils occur on basic and intermediate igneous rocks as a minor soil in the south-western part of the area.

Moonah family is the only one in this group. These soils have grey-brown or brown loamy sand or sandy loam surface horizons with little or no bleaching in the lower part, and change abruptly to a red-brown or dark red clay subsoil at 3–9 in. The subsoil is either massive or prismatic blocky in structure. At depths ranging from 2 to 3 ft the subsoil merges with decomposing parent material containing carbonate concretions. The reaction changes from mildly acid at the surface to moderately alkaline in the deep subsoil. Exchangeable sodium is very low even in the deep subsoil.

(ii) *Solonetzic Soils*.—These soils have greyish sandy surface horizons changing abruptly to mottled brownish clay subsoil with columnar, prismatic, or angular blocky structure. The reaction of the surface soil is mildly acid, but the deep subsoil is strongly alkaline and has high exchangeable sodium.

Hooper family has a light brownish or yellowish grey sandy surface horizon overlying yellowish grey, grey-brown, or dark brown clay with mottles. At depths of 15–30 in. the subsoil merges into decomposing parent material with carbonate concretions. These soils are associated with acid granites or sandstones or alluvium derived from those rocks.

Flapper family has a surface horizon of grey fine sandy loam over grey to olive-grey or dark grey heavy clay, over mottled clay or stratified alluvium at 12–18 in. depth. This family occurs only on low-lying estuarine alluvia near the coast.

(*d*) *Calcareous Soils*

These soils have low to high amounts of carbonate fragments and concretions throughout their shallow profiles and profile development is restricted to slight textural differentiation.

(i) *Rendzina Soils*.—These occur only in the north-eastern part of the area.

Springvale family is the only one in this group. These soils have dark grey to dark grey-brown clay loams to light clays of medium to strong fine angular blocky structure, and contain medium to high amounts of carbonate fragments and concretions. They are normally only 9–15 in. deep and overlie rather soft limestone.

(ii) *Grey and Brown Calcareous Desert Soils*.—These soils are similar to rendzinas but are lighter in colour and occur in more arid areas.

Tobermorey family includes shallow soils less than 18 in. in depth on soft limestone. They range in colour from grey through grey-brown to yellow-brown and texture ranges from sandy loam to light clay. The surface ½ in. of the soil shows a laminated structure and is powdery, while the underlying horizon has weak fine subangular blocky structure. In most profiles the soil mass is highly calcareous. These soils occur mainly in the southern part of the area.

Negri family is formed on soft calcareous shale in the south-western part of the area. It has a ½-in. laminated surface layer of brown calcareous loam overlying brown calcareous clay loam with moderate subangular blocky structure and soft powdery consistence. The lower part of this horizon contains a low to moderate amount of carbonate concretions and it merges with soft brown shale at 3–4 ft depth. These soils have suffered severe wind and water erosion as a result of over-grazing, and an extensive reclamation project is now being undertaken by the Western Australian Department of Agriculture.

(e) *Undifferentiated Soils*

These are soils in which profile development has not proceeded beyond the formation of weak organic surface horizons. They include four great soil groups.

(i) *Skeletal Soils*.—These are shallow soils with large amounts of rock fragments and occur on moderate to steep slopes. They are the most extensive group of soils in the area. Their texture and colour, which vary with parent materials, have been described in the tabulated land systems where important.

(ii) *Alluvial Soils*.—These soils occur on little-weathered alluvial deposits and have a considerable range of properties.

Ord family has grey-brown or dull brown sandy loam surface horizon merging into brown micaceous sandy clay loam. It occurs on the levees of the Ord River and its major tributaries. Although occurring high above the present river bed and showing weak profile development, it is classed as an alluvial soil because of its high mica content and very high cation exchange capacity.

Miscellaneous alluvial soils occur in low-lying situations near stream channels and appear to be liable to flooding. They have variable profiles with sedimentary stratification at shallow depth.

(iii) *Solonchak Soils*.—These soils occur extensively on coastal and estuarine alluvia. They appear to be liable to saline flooding at very high tide, and their salt content is so high that they support only samphire or mangrove vegetation. They are generally brownish grey or grey-brown or yellowish grey mottled clays overlying stratified sediments or bluish clay at about 24 in.

(iv) *Coastal Aeolian Sands*.—These soils occur only on the small areas of coastal sand dunes that were formed by wind transport of beach deposits and are now fixed by vegetation. These dunes could not be examined in this area, but in the Katherine–Darwin area similar dunes have yellowish grey sands with many shell fragments.

III. Agricultural Characteristics of the Soils

(a) *Introduction*

Although commercial agriculture is just commencing in this area, sufficient agricultural experiments have been carried out on a wide range of soils in this and adjoining areas to make possible a reasonable assessment of the agricultural reactions of the soils. A brief account of agricultural experimentation and development is given in Part IX.

The skeletal soils and saline soils are quite unsuited for any agriculture while the acid swamp soils could only be developed for agriculture with major reclamation projects. Meadow podzolic soils, red-brown earths, solonetzic soils, rendzinas, alluvial soils, and coastal aeolian sands are all of minor extent and of little regional significance for agriculture. The grey and brown calcareous desert soils occur in the southern part of the area which is too dry for agricultural development. The agricultural characteristics of the remaining soils (red earths, yellow earths, lateritic podzolic soils, and grey and brown soils of heavy texture) are discussed below.

The phosphate contents of virtually all of the soils are low and crops have responded to phosphatic fertilizer in almost all cases. The nitrogen content of the soils is low and all non-legume crops respond to nitrogen fertilizer, but responses to other elements have not been recorded.

(b) *Soil Moisture Characteristics*

The water retention characteristics of some soils at Katherine and Kimberley Research Stations are shown in Table 8. In general, the red and yellow earths with sandy loam to clay loam surface horizons have high wilting points and a low range of available moisture. Because of the wide difference between field dry moisture content

TABLE 8

MOISTURE RETENTION CHARACTERISTICS OF SOME SOILS FROM KIMBERLEY AND KATHERINE RESEARCH STATIONS*

Soil	Moisture Retention† of Plough Layer (0–8 in.)			Available Water Storage in 4 ft Depth (in.)
	At 1/3 Bar	At 15 Bar	Field-dry Soil	
Cununurra	29·2	18·1	8–9	5·1
Cockatoo	4·7	2·8	0·5–1·5	1·7
Tippera	17·9	13·0	4–6	3·2
Blain	6·2	2·9	N.d.	N.d.
Manbulloo	11·0	4·2	N.d.	5·2

* R. O. Slatyer, personal communication.

† G water/100 g oven-dry soil.

N.d., not determined.

and wilting point, much of the water from small falls of rain will not be readily available to plants and would be lost by evaporation. This factor is particularly pertinent in this environment as evaporation rates are very high at the commencement of the wet season when crops are normally sown. The sandy soils are much more favourable in this respect as only small amounts of water would be lost in this way, but in general their moisture storage capacity is low. The most favourable soils agronomically are the Manbulloo and Katherine families which have a low water content at wilting point and a high water storage capacity. The red earths with high exchange capacity (Frayne and Camil families) are likely to be more similar to Manbulloo in moisture characteristics than Tippera. Chunuma family probably has a lower storage capacity than Cockatoo sand and Berrimah family is unlikely to be better than Tippera family in its moisture characteristics.

For the yellow earths, the moisture characteristics of Elliott are very similar to those of Tippera, and Batten is also likely to be similar. Argada family is likely to have better moisture storage characteristics, while Cullen and Pago are likely to be very similar to Cockatoo family. The poorer drainage in the subsoil of some yellow earths is only likely to be of agricultural significance for crops that are very sensitive to waterlogging in the root zone.

No measurements of moisture characteristics have been made on lateritic podzolic soils, but the shallow depth of Koolpinyah soils and the strongly waterlogged subsoil in Florina soils are unfavourable to crop growth.

It is likely that all the cracking clay soils will have the undesirable characteristic of a wide difference between field dry moisture content and wilting capacity as in the Cununurra sample reported in Table 8. Storage of water is only moderate but both of these disadvantages would be less serious under irrigation than for dryland agriculture. Infiltration rate is very high when the soils are dry and cracked, but is slow after the soil has swollen and filled the cracks. Small amounts of water ponding can seriously affect the growth and yield of sensitive crops such as cotton (Thomson and Basinski 1962), and good surface drainage is essential so that surplus surface water can be rapidly removed.

Red earths and yellow earths of sandy loam to clay loam surface texture appear to be moderately permeable and the sandy surface soils of those groups and also the lateritic podzolic soils appear to be rapidly permeable.

(*c*) *Conservation and Cultivation*

Appreciable run-off occurs from the medium-textured surface soils under natural pastures, but from observations near Katherine the pasture cover can be gradually reduced by heavy grazing without any obvious signs of accelerated erosion. However, cultivation of both medium- and coarse-textured surface soils appears to result in appreciable soil erosion. This will not be of great significance if the land is cultivated only once or twice for the establishment of improved pastures, but must be given very serious consideration in any plans to develop regular arable cropping.

The medium-textured red earths (Tippera family) are very prone to surface crusting caused by raindrop impact and subsequent drying (Arndt 1965), and those crusts can markedly reduce seedling emergence. Also, Arndt (1966) has shown the marked effect of traffic compaction on a number of properties of Tippera soils and the need to take traffic into account in planning cultivation regimes.

The coarser-textured surface soils can be ploughed quite easily either wet or dry, but the medium-textured surface soils set hard when dry and dry-season ploughing is very difficult. Also, with clay loam soils at least, the period between being too moist for satisfactory cultivation and too dry for satisfactory cultivation is only 4 or 5 days (L. J. Phillips, personal communication). The grey and brown soils of heavy texture similarly have a short period when a satisfactory tilth can be produced in cultivation, but on some of these soils dry ploughing is possible because of the self-mulching nature of the surface soils.

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PART VII. VEGETATION OF THE ORD–VICTORIA AREA

By R. A. PERRY*

I. INTRODUCTION

Structurally and floristically, the vegetation of the Ord–Victoria area is similar to that of a great belt stretching from east to west across the continent in similar latitudes. It is representative of the vegetation of low-latitude summer-rainfall Australia. The vegetation of other areas within the belt has been described by Perry and Christian (1954), Perry and Lazarides (1964), Pedley (1967), and Speck (1960, 1964, 1965).

II. COMMUNITY TYPES IN RELATION TO ENVIRONMENT

Structurally, the vegetation of all but the lowest-rainfall parts is typified by woodlands with grassy understoreys. These woodlands vary from about 20 to about 70 ft in height. North of about the 27-in. mean annual rainfall isohyet they are taller and denser (Plate 1, Fig. 2; Plate 2, Fig. 1) than those to the south and are characterized by a different set of tree species. Grasslands (either completely treeless or with scattered low trees) are characteristic of cracking clay soils (Plate 3, Fig. 1). These grasslands also are taller and denser with different species assemblages north of about the 27-in. mean annual rainfall isohyet. In the arid south (mean annual rainfall less than about 15 in.) the woodlands give way to shrublands.

Thus, on the basis of natural vegetation, the area can be divided into three broad climatic zones:

The high-rainfall zone, characterized by woodlands and tall grasslands, where mean annual rainfall exceeds about 27 in., the mean length of agricultural growing period exceeds 12 wk, and the mean duration of useful pasture growth exceeds 16 wk.

An intermediate-rainfall zone, characterized by sparse low woodlands and mid-height grasslands, between the 15- and 27-in. mean annual rainfall isohyets and with the mean length of agricultural growing season between 5 and 12 wk and the mean duration of useful pasture growth between 10 and 16 wk.

A low-rainfall zone characterized by shrublands, where mean annual rainfall is less than about 15 in., the mean length of agricultural growing season is less than 5 wk, and the mean duration of useful pasture growth is less than 10 wk.

Within these climatic zones the major influence on species distribution appears to be lithology or some factor or factors associated with lithology. Largely different suites of species occur on basic rocks compared with acid rocks and laterites. The major communities on acid and basic rocks within the three climatic zones are listed in Table 9.

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III. Plant Types in Relation to Environments

The long winter dry period has had a dominant role in the selection of plant species in the area. According to their method of surviving the long dry period the species can be classified into three groups:

Table 9

MAJOR VEGETATION COMMUNITIES ON ACID AND BASIC ROCKS IN THE THREE CLIMATIC ZONES

Mean Annual Rainfall	Acid Rocks and Laterite	Basic Rocks	
		Soils other than Cracking Clays	Cracking Clays
>27 in.	Stringybark–bloodwood woodland	Northern box–bloodwood woodland	Blue grass grassland
15–27 in.	Snappy gum sparse low woodland	Bloodwood–southern box sparse low woodland	Barley Mitchell grass grassland and Mitchell and other grass grassland
<15 in.	Desert shrubland	—	—

Perennial Drought-resisting Species.—The leaves and stems of these plants remain in a growing condition through the dry period. The group includes most of the trees and shrubs and also the spinifexes (*Triodia* spp.) which are evergreen perennial grasses.

Perennial Drought-evading Species.—This group includes those species in which at least the leaves die at the end of the wet season but new growth in the following wet season is initiated from vegetative organs. The group includes most of the perennial tussock grasses and deciduous trees and shrubs.

Annual Drought-evading Species.—Plants in this group germinate from seed each growing season. It includes most of the forbs and short grasses but also a number of tall annual grasses.

IV. Classification of the Vegetation

The vegetation is simple structurally with generally two prominent layers—a grass layer and a tree layer. In smaller areas the vegetation has only one layer (e.g. grasslands, mangrove scrubs), or the two layers are grasses and shrubs, or three layers (grasses, low trees–shrubs, and trees) occur.

On any site each layer tends to be characterized by one or a few prominent species which account for a high proportion of the biomass. Generally, the many other species together contribute little to the total biomass. Considering only the prominent species, each layer can be classified into reasonably homogeneous and reasonably discontinuous communities (or synusiae). While it is common for a particular grass and a particular tree synusia to be associated over large areas, it is also common for several different grass synusiae to be associated with one tree synusia (and vice versa) on various sites. That is, the distribution of grass synusiae is

TABLE 10

COMBINATIONS OF TREE, SHRUB, AND GRASS LAYER COMMUNITIES

	Grass Layer Absent (or nearly so)	Grass Layer of Water Plants	Grass Layer Short (c. 1 ft) and Short-lived		Grass Layer Mid-height (c. 2–3 ft), Perennial, Drought-evading				Grass Layer Tall (>5 ft), Drought-evading						Grass Layer Mid-height (c. 2–3 ft), Perennial, Evergreen	
		Lagoon Vegetation	Arid Short Grass	Saline Soil Short Grass	Barley Mitchell Grass	Mitchell and Other Grasses	Marrakai Mid-height Grass	Three-awn Mid-height Grass	Blue Grass–Tall Grass	Tippera Tall Grass	Upland Tall Grass	Lowland Tall Grass	Frontage Tall Grass	Fringing Tall Grass	Soft Spinifex	Hard Spinifex
Trees and shrubs absent (or nearly so)	x	x	x	x	x	x	x		x		x	x			x	
Shrub layer sparse																
Samphire	x															
Shrub layer moderately dense																
Desert shrubland																x
Bluebush shrubland			x													
Shrub layer dense																
Bulwaddy scrub	x															
Mangrove scrub	x															
Tree layer sparse and low (c. 20 ft)																
Volcanics sparse low woodland						x										
Arid sparse low woodland			x					x								
Deciduous sparse low woodland			x								x					x

Downs sparse low woodland						x						
Snappy gum sparse low woodland			x		x,a			x			x,a	x
Silver-leaved box sparse low woodland			x		x,a		x	x	x		x,a	x
Bloodwood–southern box sparse low woodland			x,b		x		x	x,b			x	x
Desert sparse low woodland					x,a						x,a	
Mesa gum sparse low woodland	x							x				
Ironbark sparse low woodland								x			x	
Tree layer moderately dense and low (*c.* 20 ft)												
Paperbark low woodland				x			x	x				
Tristania–Grevillea–Banksia low woodland								x				
Tree layer moderately dense and medium-height (30–70 ft)												
Northern box–bloodwood woodland			x,b		x		x,b	x,b	x			
Stringybark–bloodwood woodland								x,b			x,a	
Frontage woodland			x				x	x	x			
Tree layer dense and medium-height (30–60 ft)												
Lancewood forest	x				x							
Paperbark forest	x											
Fringing forest										x		
Rain forest	x											

x, Combination of tree and grass layer but no intermediate layer; a, desert shrubland occurs as an intermediate layer; b, deciduous sparse low woodland occurs as an intermediate layer.

independent of the tree synusiae (and vice versa) and a large number of combinations occur. For these reasons the tree and shrub communities and the grass communities are defined and described separately in the following section. The combinations of the various layer communities are presented in Table 10. Such combinations are equivalent to associations as understood by most Australian ecologists.

Plant names are used for naming communities where they can be typified by one or two highly constant species, otherwise geographic, environmental, or descriptive names are used.

V. Tree and Shrub Layer Communities

(a) *Trees and Shrubs Absent or Nearly Absent*

The cracking clay soils on alluvium in the intermediate-rainfall zone are devoid of trees and shrubs. Similar soils on basalt support only scattered bushes of *Terminalia volucris* (rosewood) and/or *T. arostrata* (nutwood). These areas carry grassland of either barley Mitchell grass or Mitchell and other grasses.

The deep calcareous desert soils of Nelson land system carry a short grass–forb grassland (probably originally Mitchell grass) where they are not eroded and bare.

Other treeless habitats include the saline soils of the salt flats and meadows of Carpentaria land system and small areas of spinifex country in the deserts in the south.

(b) *Shrub Layer Sparse*

(i) *Samphire Flats.*—Small areas of saline mud flats in Carpentaria and Legune land systems carry scattered low shrubs of samphire.

(c) *Shrub Layer Moderately Dense*

(i) *Desert Shrubland.*—The deep red sandy soils and some shallow gravelly or stony soils in the most arid parts of the area carry a low shrubby community characterized by mainly eucalypts and acacias over soft spinifex. The most common species are *Acacia lysiphloia*, *A. stipuligera*, *A. monticola*, *A. coriacea*, *A. luerssenii*, *A. ancistrocarpa*, *A. cunninghamii*, *Eucalyptus pachyphylla*, *E. odontocarpa*, and *E. setosa*. *Mirbelia oxyclada* is common and many other shrubby species occur less frequently. Low trees, 10–15 ft high, of *E. pruinosa*, *E. brevifolia*, *E. terminalis*, *E. setosa*, *E. microtheca*, and others occur at a very low density.

The community is widespread in the Northern Territory between about the 12- and 15-in. mean annual rainfall isohyets. With higher rainfall it grades into the snappy gum low woodland and under more arid conditions into spinifex grasslands.

(ii) *Bluebush Shrubland.*—This community is restricted to areas of cracking clay soils subject to shallow periodic flooding. It is characterized by moderately dense stands of *Chenopodium auricomum* (bluebush), a shrub about 3 ft high and 2–3 ft in diameter. *Muehlenbeckia cunninghamii* grows along stream lines and small distributary channels. Scattered trees of *E. microtheca* or *Acacia stenophylla* occur in some areas.

As the floodwaters recede a dense stand of grasses and forbs develops between the shrubs. The most common are short and include *Psoralea cinerea*, *Alternanthera sessilis*, *Elytrophorus spicatus*, *Fimbristylis* spp., *Cyperus* spp., *Pterocaulon sphacelatum*, *Gnaphalium indicum*, *Ammania multiflora*, and *Ludwigia parviflora*, but medium-height perennial grasses such as *Panicum whitei*, *Eriachne nervosa*, and *Astrebla elymoides* also occur.

The community is widespread in northern Australia, being most extensive on the Barkly Tableland (Perry and Christian 1954). In the Ord–Victoria area it is confined largely to a swampy area near Birrindudu and along Sturt Creek. One small area was recorded near Legune.

(*d*) *Shrub Layer Dense*

(i) *Bulwaddy Scrub.*—*Macropteranthes kekwickii* (bulwaddy) is a dense spreading shrub forming dense thickets 10–12 ft high. Associated plants are rare and the ground is mostly bare. Patches occur on the sandy lateritic soils of the south-eastern part of the area and extend northwards to about Birrimbah on shallow gravelly lateritic soils.

(ii) *Mangroves.*—Several species of mangroves varying in height from 3–4 ft to about 15 ft form dense stands along muddy shore lines and creeks in Carpentaria and Subcoastal Plain land systems.

(*e*) *Tree Layer Sparse and Low* (*about 20 ft high*)

(i) *Volcanics Sparse Low Woodland.*—Widely spaced low trees or bushes of *Terminalia arostrata* (nutwood) and *T. volucris* (rosewood) occur on cracking clay soils developed on Antrim Plateau Volcanics and, to a lesser extent, limestones. The grass layer is the Mitchell and other grasses community. With decreasing soil depth the community grades into deciduous sparse low woodland.

(ii) *Arid Sparse Low Woodland.*—This community occurs as linear bands a few chains wide on variable transition soils between grasslands on cracking clay soils and various woodlands on "deserts". It is variable and characterized by many low trees of which *Ventilago viminalis* (supplejack) is the most constant. Others include *Hakea lorea*, *H. arborescens*, *Grevillea striata*, *Atalaya hemiglauca*, *Bauhinia cunninghamii*, *Capparis umbonata*, *Eucalyptus pruinosa*, and *E. papuana*. Scattered shrubs or patches of shrubs occur in most stands. *Carissa lanceolata* is the most common but several *Acacia* spp. and *Eremophila* spp. are represented.

The grass layer is characterized by three-awn or short grasses and forbs.

(iii) *Deciduous Sparse Low Woodland.*—A variable community characterized by scattered low (10–15 ft) mostly deciduous trees occurs on shallow soils and outcrops over a wide climatic range.

Each stand contains one to several of the characteristic species, *Terminalia* spp. (*T. arostrata*, *T. volucris*, *T. canescens*, *T. platyptera*, *T. ferdinandiana*) and *Cochlospermum fraseri* being the most constant. Others include *Bauhinia cunninghamii*, *Gyrocarpus americanus*, *Hakea arborescens*, *Xanthostemon paradoxus*, *Croton arnhemicus*, *Erythrophleum chlorostachys*, *Strychnos lucida*, *Gardenia* spp., *Owenia* *vernicosa*, *Erythrina vespertilio*, *Brachychiton diversifolium*, *Planchonia careya*, *Ficus* spp., *Alstonia actinophylla*, *Adansonia gregorii*, *Wrightia saligna*, *Atalaya hemiglauca*, *Buchanania obovata*, and many more. Some species tend to be confined to acid rocks and others to basic rocks but many species are common to both.

Most stands contain scattered shrubs but, as with the trees, composition of the shrub layer is variable. Some of those recorded are *Carissa lanceolata*, *Phyllanthus* sp., *Capparis lasiandra*, *Acacia farnesiana*, *Atalaya hemiglauca*, *Celtis philippinensis*, *Dodonaea oxyptera*, *Distichostemon filamentosus*, *Calytrix microphylla*, and *Petalostigma quadriloculare*.

The normal ground storey is upland tall grass, but in low-rainfall areas it is arid short grass or hard spinifex.

Many of the low trees and shrubs occur as a mid storey in eucalypt woodlands and transitions between eucalypt woodlands and this community occur on intermediate sites.

(iv) *Downs Sparse Low Woodland*.—In the higher-rainfall parts of the area scattered trees, 15–20 ft high, of one or more of *Eucalyptus microtheca*, *Bauhinia cunninghamii*, *Acacia sutherlandi*, *Terminalia arostrata*, *T. volucris*, *T. platyphylla*, and *Excoecaria parvifolia* occur on cracking clay soils. The shrubs *Acacia farnesiana* and *Carissa lanceolata* occur sparsely. The normal grass layer is blue grass. The community grades into the volcanics sparse low woodland on shallower soils.

(v) *Snappy Gum Sparse Low Woodland*.—This community has a larger area than any other within the area and is widespread beyond it, extending from the western margin of the Great Artesian Basin in Queensland westward to the coast of Western Australia, between the 15- and 27-in. mean annual rainfall isohyets. It occurs on skeletal soils on acid rocks, on lateritic soils, deep sandy soils, and to a lesser extent on many other soils.

The characteristic tree, *E. brevifolia* (snappy gum), is straggly, widely spaced, and 10–25 ft high. Only a few other scattered trees occur.

In most places shrubs are widely spaced or absent but some areas have a moderately dense layer or patches of shrubs. The most common are a multitude of *Acacia* spp., but *Grevillea* spp., *Dodonaea* spp., *Calytrix* sp., *Petalostigma* sp., *Eucalyptus* spp., and many others occur.

Mostly the associated ground layer is soft spinifex, but smaller areas occur over hard spinifex, three-awn, upland tall grass, and arid short grass communities.

Towards the low-rainfall edge of its range the community grades into desert shrubland or spinifex communities.

(vi) *Silver-leaved Box Sparse Low Woodland*.—This community is widespread throughout the area but is rarely extensive. It occurs over a wide range of climatic conditions (mean annual rainfall 15–35 in.) and on a wide variety of soils and rocks. Most commonly it occurs on medium-textured red soils, on basic volcanic rocks, and on yellow earths. To a lesser extent it occurs on the locally lower parts of lateritic landscapes, on skeletal soils and outcrop areas on acid rocks, on sandy levees, and on some calcareous desert soils.

The characteristic tree is *Eucalyptus pruinosa* (silver-leaved box) which is low (mostly < 20 ft), straggly, and widely spaced. In most stands associated trees and shrubs are rare but in some stands a moderately dense shrub layer or patches of shrubs occur. *Acacia* spp. are the most common of these. Although rare, many species of trees and shrubs are represented.

The associated ground layer is variable. In the northern parts Tippera tall grass occurs on red volcanic soils and yellow earths, and upland tall grass or hard spinifex on shallow skeletal soils. In the southern half three-awn mid-height grass occurs on yellow earths, soft spinifex on better-drained habitats, and arid short grass on calcareous desert soils. On levees, frontage grasses form the understorey.

(vii) *Bloodwood–Southern Box Sparse Low Woodland*.—This is restricted mostly to that part of the area south of the 27-in. mean annual rainfall isohyet. It occurs on skeletal and medium-textured red soils on basic rocks (limestones, dolomites, and volcanics) and to a lesser extent on red lateritic and yellow earth soils.

The tree layer is sparse and low and characterized by one or more of a group of *Eucalyptus* spp., of which *E. terminalis* (bloodwood) and three forms of *E. argillacea* (southern box) are the most constant. *E. confertiflora* occurs in some stands.

Many lower tree species, mostly deciduous, occur, their density varying with habitat. On deeper soils the lower trees are very sparse but on shallower soils their combined densities commonly are greater than that of the characteristic eucalypts and the community grades into the deciduous sparse low woodland.

Only scattered shrubs occur, *Carissa lanceolata*, *Phyllanthus* sp., and *Atalaya hemiglauca* being fairly constant and *Cassia* spp., *Eremophila* spp., and *Acacia* spp. being more common in the lower-rainfall parts.

The most common associated grass community is arid short grass which occurs on limestone outcrops and skeletal soils in the higher-rainfall parts and on calcareous desert and red earth soils over most of the community range. Both soft and hard spinifex and three-awn grass are common in the lower-rainfall parts, and Tippera tall grass and upland tall grass occur on small areas in the higher-rainfall parts.

There is no sharp discontinuity with the northern box–bloodwood woodland that occurs on similar habitats under higher rainfall.

(viii) *Desert Sparse Low Woodland*.—This is restricted almost to Redsan land system where it grows on deep red and yellow sands under a mean annual rainfall of about 15 in. (Plate 2, Fig. 2). Small patches occur in other low-rainfall parts and on the lateritic plain near Birrimbah.

It is characterized by widely spaced low (20–30 ft) eucalypts, including *E. polycarpa*, *E. argillacea*, *E. setosa*, *E. pruinosa*, *E. microtheca*, *E. ferruginea*, *E. grandifolia*, and *E. confertiflora*. Of these, *E. polycarpa* (grey bloodwood) is the most constant and is normally somewhat taller than the others. Generally two or three eucalypts occur on each stand.

A sparse lower (10–15 ft) tree layer is normal. Numerous species (but only a few in any stand) are represented. They include *Ventilago viminalis*, *Hakea arborescens*, *H. lorea*, *Grevillea pteridifolia*, *G. juncifolia*, *Wrightia saligna*, *Terminalia platyptera*, *T. canescens*, *Melaleuca* sp., *Erythrophleum chlorostachys*, *Bauhinia cunninghamii*, *Gyrocarpus americanus*, *Capparis umbonata*, *Gardenia* sp., *Alphitonia excelsa*, *Atalaya hemiglauca*, *Brachychiton* sp., and *B. paradoxum*.

Shrubs are present typically as a sparse but diverse layer 3–6 ft high but also in dense patches. The most common are *Acacia* spp. (particularly *A. lysiphloia*). Others include *Cassia pruinosa*, *Mirbelia oxyclada*, *Carissa lanceolata*, *Phyllanthus* sp., *Distichostemon filamentosus*, *Dodonaea oxyptera*, and *Brachychiton paradoxum*.

The common ground storey is soft spinifex containing more three-awn and other softer grasses than usual. In the area near Birrimbah three-awn mid-height grass is the ground storey.

(ix) *Mesa Gum Sparse Low Woodland*.—This is a distinct but very restricted community. It occurs near the top of the steep breakaways of Mullaman land system and on small areas of shallow stony soils in Birrimbah land system.

It is characterized by a single eucalypt (*E. umbrawarrensis*, mesa gum) which does not occur in any other communities. Low tree and shrub species are infrequent and the ground is either bare or carries sparse upland tall grass.

(x) *Ironbark Sparse Low Woodland*.—Only two stands, about 200 miles apart and each a few square miles in extent, were recorded. One was a few miles west of Newry homestead and the other east of Limbunya homestead. *E. jensenii* is the only ironbark in the Northern Territory. The stand near Limbunya is on Wonorah soils and the trees form a sparse, monospecific woodland about 20 ft high with an understorey of soft spinifex. Several other eucalypts and some lower trees and shrubs are associated with the Newry stand which is on Elliott soils and has an upland tall grass ground storey.

(*f*) *Tree Layer Moderately Dense and Low* (*about 20 ft*)

(i) *Paperbark Low Woodland*.—This community occurs on yellow earths or shallow or skeletal soils developed on alluvium, shales, greenstones, and phyllites, and, to a lesser extent, sandstones and granites. It is most common between the 25- and 35-in. mean annual rainfall isohyets but extends as far south as the 17-in. isohyet.

The characteristic trees are *Melaleuca* spp. (paperbarks) 10–15 ft high and fairly closely spaced. One or two of *M. minutifolia*, *M. alsophila*, *M. acacioides*, and *M. viridiflora* occur in each stand. Other trees are sparse but include *Eucalyptus grandifolia*, *E. brevifolia*, *E. pruinosa*, *E. argillacea*, *Erythrophleum chlorostachys*, *Terminalia canescens*, *Grevillea striata*, *Cochlospermum fraseri*, *Bauhinia cunninghamii*, and *Adansonia gregorii*. Shrubs are sparse but *Carissa lanceolata* and *Dodonaea oxyptera* are fairly constant. Others include *Calytrix microphylla*, *Acacia lysiphloia*, and *A. monticola*.

Several ground storey communities are associated. Marrakai mid-height grass or a rather sparse variant of Tippera tall grass occurs on deeper soils (mostly on alluvium) and upland tall grass or soft spinifex on shallow and skeletal soils. On some stony areas the trees are sparser and the community grades into a grassland characterized by *Plectrachne pungens* (see upland tall grass).

(ii) Tristania–Grevillea–Banksia *Low Woodland*.—This community was not observed during the survey but is known to occur in the northern part of the area.

The following description is from the report on the Katherine–Darwin region (Christian and Stewart 1953). The community occurs as a narrow zone on sandy soils between seasonally flooded flats carrying grassland and upland areas carrying stringybark–bloodwood woodland.

It consists of fairly dense stands of low-branched trees about 20 ft high. The characteristic trees are *Tristania lactiflua*, *Grevillea pteridifolia*, and *Banksia dentata*. *Acacia* spp. are also common and scattered *E. papuana* or *E. polycarpa*, taller trees, occur in some stands. The ground flora is sparse to medium dense and includes *Sclerandrium grandiflorum*, *Eriachne triseta*, *Coelorachis rottboellioides*, and low annual species such as *Pseudopogonatherum* sp., *Setaria apiculata*, and several sedges and forbs.

(g) *Tree Layer Moderately Dense and Medium Height (30–70 ft)*

Most of the northern half of the area carries eucalypt woodlands that can be separated into two main suites of species, the northern box–bloodwood community generally associated with basic rocks, and the stringybark–bloodwood community on acid rocks and lateritic areas.

(i) *Northern Box–Bloodwood Woodland*.—This occurs on flat, undulating, or low hilly country mostly on red or yellow earth soils developed on basic rocks (Plate 1, Fig. 2), on skeletal soils on shales, limestones, and volcanics, and, to a lesser extent, on sandstones and quartzites. The characteristic trees are mostly 30–40 ft high but in some stands are as low as 20 ft or as high as 50 ft. The most constant species are *E. tectifica* (northern box) and *E. foelscheana* (bloodwood) but *E. confertiflora*, *E. latifolia*, *E. patellaris*, and *E. grandifolia* are common and *E. argillacea*, *E. terminalis*, *E. tetrodonta*, and *E. clavigera* less common. A few non-eucalypts such as *Brachychiton diversifolium* and *Erythrophleum chlorostachys* occur infrequently in the tree layer.

On shallow soils numerous species 10–20 ft high form a sparse (locally moderately dense) lower tree layer. In such areas the eucalypts tend to be sparser and the community grades into deciduous sparse low woodland. On deeper soils some of the species of the deciduous sparse low woodland occur scattered throughout the stands. Only scattered shrubs occur, *Carissa lanceolata*, *Desmodium* sp., and *Phyllanthus* sp. being the most common. Shrubby herbaceous species, particularly *Triumfetta appendiculata*, but also *Corchorus sidoides*, *Grewia retusifolia*, and *Notoxylinon australe* are constant but sparse.

The most common ground storey, particularly on deeper soils, is Tippera tall grass but upland tall grass is common on shallow and skeletal soils. In small areas three-awn mid-height grass, frontage tall grass, and arid short grass occur.

(ii) *Stringybark–Bloodwood Woodland*.—This is a variable community widespread across northern Australia (Plate 2, Fig. 1) and occurring mainly on lateritic areas or on acid rocks under a mean annual rainfall more than about 27 in.

The characteristic tree layer consists mostly of eucalypts 40–60 ft high, slightly taller in some higher-rainfall habitats and only 30–40 ft high in the lower-rainfall variants. The most constant species are *E. tetrodonta* (stringybark), *E. dichromophloia* (bloodwood), *E. bleeseri* (bloodwood), and *E. miniata* (woollybutt), but others include *E. ferruginea*, *E. phoenicea*, *E. foelscheana*, *E. tectifica*, *E. grandifolia*, *E. polycarpa*, and, in the north-western corner of the area, an unnamed gum (Perry 3091). *Erythrophleum chlorostachys* occurs sparsely in many stands. *Callitris columellaris*, a valuable timber tree, was once probably more common. Many of the eucalypts do not extend to the lower-rainfall margin where the community is mainly represented by stands of *E. dichromophloia* and *E. ferruginea*.

A sparse lower (10–20 ft) tree layer comprised of species of the deciduous sparse low woodland is normal. This layer is denser, and the eucalypts sparser and lower, on rocky areas where the community grades into deciduous sparse low woodland. In the higher-rainfall parts *Pandanus* sp. and *Livistona* sp. are common.

Shrubs are absent or occasional. They include *Calytrix microphylla*, *Distichostemon filamentosus*, and *Petalostigma quadriloculare*, *Acacia* spp., *Bossiaea phylloclada*, and *Jacksonia* sp.

The common ground storey is upland tall grass with soft spinifex characteristic near the lower-rainfall margins.

(iii) *Frontage Woodland*.—The levees of the watercourses carry a community similar in many respects to the northern box–bloodwood woodland. The most constant trees are *E. papuana*, *E. polycarpa*, *E. patellaris*, and *E. confertiflora*, but several other eucalypts also occur in some stands. *Adansonia gregorii* is a feature of levees in the north-west. Under lower rainfall the frontages are more similar to the bloodwood–southern box low woodland and *E. terminalis* and *E. papuana* are the most constant species. *E. pruinosa* is characteristic of some sandy levees under low rainfall.

The common ground storey is frontage tall grass but small areas of upland tall grass, Tippera tall grass, and arid short grass also occur.

(h) Tree Layer Dense and Medium Height (30–60 ft)

(i) *Lancewood Forest*.—Only small areas of this widespread northern Australian community occur in the area. In the central and north-eastern part it occurs on the steep scarps of mesas and tablelands capped with lateritic horizons and in the south-east on sandy lateritic soils.

The characteristic tree is *Acacia shirleyi* (lancewood) which is an erect tree growing in dense almost pure stands. A few low tree and shrub species are scattered throughout. The ground is mostly bare with scattered clumps of grass, mostly three-awn.

(ii) *Paperbark Forest*.—A tall *Melaleuca* sp. characterizes dense communities with abrupt margins which occur in the subcoastal plain.

(iii) *Fringing Forest*.—Tall dense communities characterized by *E. camaldulensis*, *Melaleuca leucadendra*, and *M. argentea*, and commonly with *Terminalia platyphylla*, *Tristania lactiflua*, and *Nauclea orientalis*, line the major streams.

In low-rainfall areas the community is lower and sparser and *E. camaldulensis* is commonly the only large tree represented. *Terminalia bursarina* is common on rocky tributary streams and *E. microtheca* along streams with banks of heavy clay.

(iv) *Rain Forest.*—Only very small areas of rain forest occur in the area. The main stands are associated with the Daly River in the far north either as a gallery forest or on alluvial plains. Other stands are very small and isolated, e.g. Point Spring.

VI. Grass Layer Communities

(*a*) *Grass Layer Absent or Nearly Absent*

(i) *Bare Ground.*—The major areas of bare ground are the salt flat and mangrove areas along the coast. Smaller areas are associated with the lancewood forest, bulwaddy scrub, mesa gum sparse low woodland, paperbark forest, and rain forest communities.

(*b*) *Grass Layer of Water Plants*

(i) *Lagoon Vegetation.*—Small shallow lagoons occur in the higher-rainfall areas. Their vegetation is variable and depends on the length, depth, and frequency of flooding. Characteristic plants are water-lilies, *Pseudoraphis spinescens*, *Marsilea* sp., and *Eragrostis* spp.

(*c*) *Grasses Short, Annuals or Short-lived Perennials*

(i) *Arid Short Grass.*—This occurs on calcareous desert soils or shallow and skeletal soils and outcrops on limestones and basic volcanics in the lower-rainfall part of the area.

The grass layer is mostly less than 12 in. high and is composed mainly of grasses with some forbs. The common species are *Enneapogon* spp., *Aristida contorta*, *Sporobolus australasicus*, *Tragus australianus*, *Chloris scariosa*, *Sida fibulifera*, *Portulaca oleracea*, and *Cleome viscosa*.

On some areas, particularly on the deep calcareous desert soils on Negri shales (where it is probably a disclimax Mitchell grass community), it is a grassland with no tree or shrub layer but mostly it is a ground storey in the bloodwood–southern box woodland. Smaller areas are associated with arid sparse low woodland, deciduous sparse low woodland, snappy gum sparse low woodland, silver-leaved box sparse low woodland, frontage woodland, and northern box–bloodwood woodland.

(ii) *Saline Soil Short Grass.*—This is restricted to saline soils in Carpentaria, Legune, and Angallari land systems.

The grass layer is short and fairly dense and mainly composed of *Xerochloa imberbis* and/or *Sporobolus virginicus*. Associated plants include *Brachyachne convergens*, *Dactyloctenium radulans*, *Salsola kali*, *Neptunia* sp., *Fimbristylis* spp., and others.

Occasional trees of *Excoecaria parvifolia*, *Pandanus* sp., *Grevillea striata*, or *Eucalyptus papuana* occur in some parts but the community is treeless in most places.

(*d*) *Grasses Mid-height (about 2–3 ft), Perennial, Drought-evading*

(i) *Barley Mitchell Grass.*—This occurs on the cracking clay soils on Tertiary alluvium in Inverway land system.

The characteristic grass, *Astrebla pectinata* (barley Mitchell grass), is a perennial tussock grass 12–30 in. high and 9–12 in. in diameter. The tussocks are 18–36 in. apart. The few other perennial tussock grasses such as *Astrebla squarrosa*, *A. elymoides*, *Dichanthium fecundum*, *Aristida latifolia*, and *Chrysopogon fallax* are scattered and unimportant. *Themeda avenacea* grows in small depressions. In low-rainfall years and towards the end of the dry season the spaces between the perennial tussock grasses are almost bare but with high rainfall *Sorghum* spp. are prominent in patches especially where water lies for several weeks. Under average to good rainfall the spaces are almost completely covered by short grasses and forbs, 3–12 in. high, including *Iseilema* spp., *Echinochloa colonum*, *Eragrostis japonica*, *Brachyachne convergens*, *Malvastrum spicatum*, *Neptunia* spp., *Crotalaria medicaginea*, *Sida fibulifera*, *S. spinosa*, *Alysicarpus rugosus*, *Rhynchosia minima*, and many others.

The community occurs as treeless grasslands.

(ii) *Mitchell and Other Grasses*.—This is similar to the preceding but is characterized by a greater mixture of perennial tussock grasses and has a greater diversity of associated herbaceous plants (Plate 3, Fig. 1). It is confined to cracking clay soils mostly on basic volcanic rocks in the southern half of the area.

The perennial grasses are similarly spaced (12–36 in. apart) and much the same size as in the preceding community but include *Astrebla pectinata*, *A. squarrosa*, *A. elymoides*, *Dichanthium fecundum*, *D. annulatum*, *Panicum whitei*, *P. decompositum*, *Chrysopogon fallax*, and *Aristida latifolia*. The short grasses and forbs include *Iseilema* spp., *Trichodesma zeylanicum*, *Hibiscus ficulneus*, *Rhynchosia minima*, *Maughania pauciflora*, *Ipomoea* spp., *Boerhaavia diffusa*, *Crotalaria medicaginea*, *Ptilotus spicatus*, *Sida fibulifera*, *S. spinosa*, and *Neptunia* spp.

In some parts the community is a grassland but in most places it occurs with the volcanics sparse low woodland.

(iii) *Marrakai Mid-height Grass*.—A grass community consisting mainly of perennial species of medium height with some shorter perennials and tall and short annuals occurs on small areas of gently sloping poorly drained plains particularly in granite areas.

The characteristic mid-height perennials are *Eriachne* spp. (*E. sulcata*, *E. obtusa*, *E. squarrosa*, *E. burkittii*) and *Themeda australis*. Less common are *Alloteropsis semialata*, *Chrysopogon fallax*, *Eulalia fulva*, *Aristida pruinosa*, and *Panicum cymbiforme*.

A tall annual *Sorghum* sp. occurs sparsely in some stands and densely in others.

The short grass–forb layer is floristically rich and includes *Ectrosia leporina*, *E. schultzii*, *Eriachne avenacea*, *Schizachyrium obliquiberbe*, *Aristida hygrometrica*, *A. browniana*, *Fuirena* spp., *Borreria* spp., *Fimbristylis* spp., *Xyris complanata*, *Bulbostylis barbata*, *Stylidium* spp., and many others.

Most commonly the community is a grassland (in some places with occasional pandans) but it also occurs under paperbark low woodland particularly around the margins of the small plains.

(iv) *Three-awn Mid-height Grass*.—This occupies better-watered parts (yellow earth soils) of the lateritic landscapes in the southern half of the area and drier sites in the north.

It is characterized by moderately dense stands of *Aristida pruinosa* (three-awn) with *Chrysopogon fallax* (ribbon grass), commonly in patches. Other mid-height perennial grasses such as *Themeda australis*, *Sehima nervosum*, and *Cymbopogon bombycinus* occur sparsely. Numerous short grasses and forbs occupy the spaces between the perennial grasses.

The community is associated mostly with the silver-leaved box and bloodwood–southern box sparse low woodlands but occurs to a lesser extent with desert sparse low woodland, snappy gum sparse low woodland, arid sparse low woodland, northern box–bloodwood woodland, and lancewood forest.

(*e*) *Grasses Tall* (*more than 5 ft*), *Drought-evading*

(i) *Blue Grass Tall Grass*.—On the cracking clay soils in the northern half of the area the grass community is characterized by tall (about 6 ft) mainly perennial grasses of which *Dichanthium* spp. (*D. superciliatum*, *D. fecundum*—blue grasses), *Sorghum plumosum*, *Sorghum* spp., *Eulalia fulva*, *Ophiuros exaltatus*, and *Astrebla squarrosa* are the most common. Others include *Panicum* spp., *Aristida latifolia*, *Chrysopogon* spp., *Themeda australis*, *Sehima nervosum*, and *Arundinella nepalensis*. The tall forbs *Sesbania benthamiana*, *Aeschynomene indica*, *Trichodesma zeylanicum*, and *Hibiscus* spp. are also common.

Short grasses and forbs include *Iseilema* spp., *Echinochloa* sp., *Chionachne hubbardiana*, *Brachyachne convergens*, *Pseudopogonatherum contortum*, *Flaveria australasica*, *Wedelia asperrima*, *Rhynchosia minima*, *Boerhaavia diffusa*, *Desmodium filiforme*, *Ptilotus spicatus*, *Crotalaria* spp., *Indigofera* spp., *Sida* spp., *Maughania pauciflora*, *Alysicarpus rugosus*, *Neptunia* spp., *Euphorbia* spp., *Hibiscus* spp., and many others.

In small areas the community is a grassland but mostly it is associated with downs sparse low woodland.

(ii) *Tippera Tall Grass*.—This is widespread on red and yellow earth soils in the northern half (Plate 1, Fig. 2).

The tall perennial grass layer varies in composition from place to place and, according to Arndt and Norman (1959), from year to year. Normally one or more of *Themeda australis*, *Sorghum plumosum*, *Sehima nervosum*, or *Chrysopogon fallax* are prominent in each stand. *Aristida pruinosa*, *Chrysopogon latifolius*, *Heteropogon contortus*, *H. triticeus*, *Alloteropsis semialata*, and *Coelorachis rottboellioides* occur more sparsely in some stands. *Themeda australis* and *Sehima nervosum* tend to dominate the drier sites.

In its natural state the spaces between the perennials are mainly bare but numerous species of short grasses and forbs occur sparsely. They include *Aristida browniana*, *A. hygrometrica*, *Eriachne* sp., *Brachyachne convergens*, *Schizachyrium obliquiberbe*, *Panicum majusculum*, *Borreria* spp., *Crotalaria medicaginea*, *Indigofera* spp., *Maughania pauciflora*, and several creeping legumes.

It is the common ground storey associated with the northern box–bloodwood woodland but also occurs with silver-leaved box and bloodwood–southern box sparse low woodlands and, to a minor extent, with several other tree communities.

(iii) *Upland Tall Grass.*—This occurs in the northern half of the area on most of the coarse-textured soils and on skeletal and stony areas (Plate 2, Fig. 1). It is variable and characterized by various mixtures of tall annual sorghums with *Plectrachne pungens*. *Sorghum australiense* is prominent over most of the stony volcanic country and *S. stipoideum* and *S. intrans* further north. The extreme forms—dense stands of *Sorghum* up to 12–14 ft high and areas dominated by *Plectrachne pungens* with little *Sorghum*—are quite different but all gradations occur. Tall perennial grasses such as *Alloteropsis semialata, Heteropogon triticeus, Sorghum plumosum, Chrysopogon latifolius,* and *Coelorachis rottboellioides* form only a small proportion of grass production. *Triodia stenostachya* occurs on very stony areas in the north-west.

Numerous short grasses and forbs, both perennial and annual, form a sparse short layer.

The community is the common understorey in the stringybark–bloodwood woodland and the deciduous sparse low woodland and also occurs under northern box–bloodwood woodland and, to a small extent, under several other tree communities.

(iv) *Lowland Tall Grass.*—This is restricted to coastal areas subject to annual flooding. It is characterized by dense stands of tall grasses and sedges including *Oryza rufipogon, Eleocharis* spp. (*E. dulcis, E. sphacelata, E. spiralis*), *Leersia hexandra, Hymenachne acutigluma, Panicum paludosum, Eulalia fulva,* and *Cyperus retzii*. In low swampy areas *Phragmites karka, Scleria poaeformis,* and *Pseudoraphis spinescens* are prominent and drier margins carry *Imperata cylindrica* and *Ischaemum arundinaceum* with *Bothriochloa intermedia* and *Xerochloa imberbis* in some stands.

The grassland does not occur under any tree communities.

(v) *Frontage Tall Grass.*—The levees of the major streams in the northern parts of the area carry a grass community similar to Tippera tall grass but normally somewhat taller and with a greater mixture of species. The tall annual, *Sorghum stipoideum*, is more common, as are *Chrysopogon latifolius* and *Panicum* sp.

In the south, frontages are smaller and *Aristida* spp. are the common grasses.

(vi) *Fringing Tall Grass.*—Tall perennial grasses line the banks of the streams in the north. Common species are *Chionachne cyathopoda, Vetiveria elongata, Arundinella nepalensis,* and *Coelorachis rottboellioides.*

In the south the fringing grasses are only mid-height and the common species are *Aristida* spp., *Chrysopogon fallax,* and *Sehima nervosum.*

(*f*) *Grasses Mid-height, Perennial, Evergreen*

(i) *Soft Spinifex.*—In the southern half most of the deep sandy soils, the lateritic landscape, and rocky areas (particularly on acid rocks) have a ground storey characterized by *Triodia pungens* (soft spinifex), a perennial tussock grass with sclerophyllous evergreen leaves. The tussocks are of irregular shape and vary from 1 to 3 ft high and from 1 to 5 ft diameter. *Triodia spicata* occurs on some hilly sites in the far south.

The spaces between the tussocks are largely bare but a few perennial grasses such as *Aristida pruinosa*, *A. browniana*, and *Chrysopogon fallax* occur sparsely as do numerous short grass and forb species.

The community is the common ground storey of the snappy gum sparse low woodland. It occurs to a lesser extent as a grassland or associated with desert shrubland, desert sparse low woodland, silver-leaved box sparse low woodland, bloodwood–southern box sparse low woodland, ironbark sparse low woodland, and stringybark–bloodwood woodland.

(ii) *Hard Spinifex*.—This is common on shallow stony soils and outcrop areas, particularly on basic rocks, in the lower-rainfall parts of the area. It is really several communities, each characterized by a species of hard spinifex including *Triodia wiseana* var. *wiseana*, *T. intermedia*, *T. brizoides*, *T. roscida*, *T. fitzgeraldii*, and *T. inutilis*.

Normally the tussocks are large (1–6 ft high, 1–10 ft diam.) with spiny sclerophyllous evergreen leaves. Small grasses and forbs occur sparsely in the interspaces.

The community is most commonly an understorey of the bloodwood–southern box sparse low woodland and also occurs with deciduous sparse low woodland, snappy gum sparse low woodland, and, to a minor extent, with silver-leaved box sparse low woodland.

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PART VIII. PASTURE LANDS OF THE ORD–VICTORIA AREA

By R. A. Perry*

I. Introduction

At present, virtually the only form of land use in the area is beef-cattle raising on native pastures (Plate 3, Fig. 2) and, because of climatic limitations, this situation is likely to continue in the future for most of the area.

The growth of the cattle industry in the area is illustrated in Figure 9. Although the statistical district boundaries extend outside the area surveyed, at the time of the survey there were very few cattle in the parts of the statistical districts that were not surveyed and the cattle populations shown in Figure 9 can be taken as a reasonable expression of the growth of the industry. From the first settlements in the 1880s the cattle numbers increased steadily until approximately 1920, when virtually all the useful land had been absorbed. Since that time, numbers have varied with the incidence of droughts, but have not changed appreciably. This was probably due to the depressed economic state of the cattle industry in the 1920–60 period, and factors associated with the isolation of the area. At the time of the survey there were 20 cattle properties wholly or partly in the survey area in Western Australia and 18 in the Northern Territory. In the Northern Territory the properties are generally considerably larger than in Western Australia and most were company-owned. The standard of improvements—fencing and water supply—was low, as were the standards of cattle management. Properties on the better country turned off salable bullocks at 3–4 years of age, but over most of the area store bullocks were turned off at 3–4 years of age or fat bullocks at 5–6 years of age. Few females were marketed, and overall turn-off percentage was generally less than 12.

In the 1960s a number of factors associated with the beef cattle industry changed significantly.

(1) Prices for beef were buoyant, particularly for lean beef for the manufacturing trade, and agricultural economists predict that good prices should continue in the future.

(2) Meatworks were established at Katherine and Darwin and now treat most of the cattle that were formerly exported by droving to Queensland.

(3) The improvements to roads led to the rapid development of cattle transport by road trains, which get the cattle to market in much better condition.

These changes have had an immediate effect on the cattle industry, particularly in encouraging investment in capital improvements and improved breeding stock on existing properties.

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As far as future prospects are concerned recent research has demonstrated that improved pastures of Townsville stylo in higher-rainfall areas, e.g. Katherine and further north, can give dramatic improvements in carrying capacity as well as breeding and growth performance of cattle. Commercial development of these pastures is now

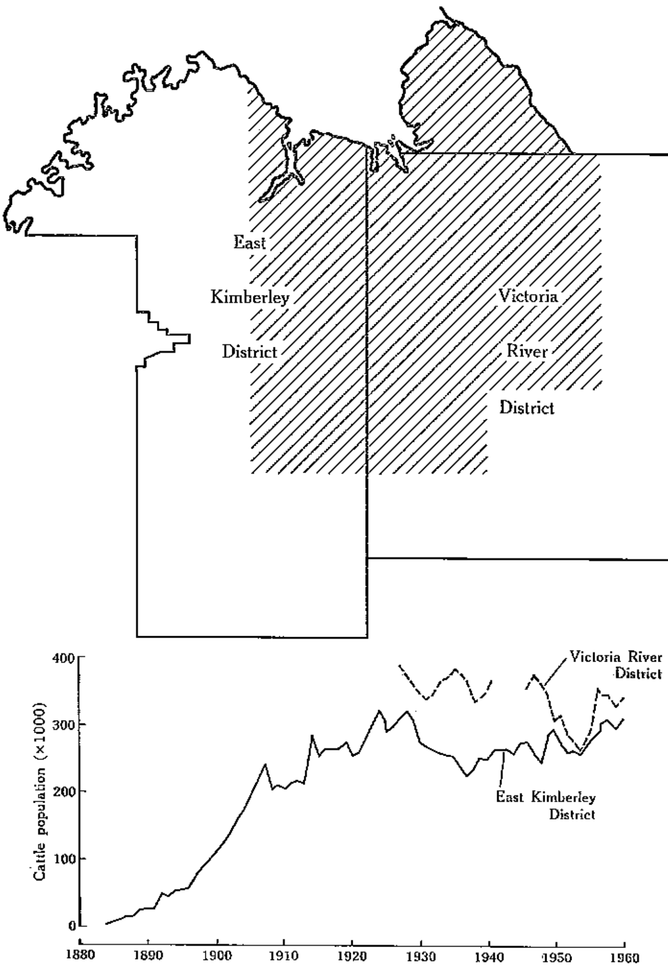

Fig. 9.—The cattle industry in the East Kimberley and Victoria River districts, 1800–1960.

beginning and should eventually spread into the higher-rainfall parts of this area. Irrigation development on the lower Ord River has also commenced. At present the emphasis is on cash cropping for export, mainly cotton. However, in the long term the irrigation development can be expected to provide protein-rich by-products, cereal grain, grazable stubbles, and perhaps some irrigated forage crops and pastures.

II. Pasture Lands

The pasture lands described below are groupings of land systems based on similarity in their potential for beef cattle grazing on unimproved pastures. This potential is reduced by a number of factors, e.g. in rugged terrain the topography imposes low potential irrespective of pasture type. However, the potential of gently sloping terrain is largely determined by pasture types.

Table 11

AREAS OF PASTURE LANDS

Pasture Land	Area (sq miles)	(%)
Rugged hilly country	28,350	31·6
Hilly country with useful lowlands	13,250	14·8
Low hilly country	4600	5·1
Upland tall grass plains	5450	6·1
Three-awn plains	1500	1·7
Soft spinifex plains	12,200	13·6
Tippera tall grass plains	5990	6·7
Arid short grass plains	3500	3·9
Barley Mitchell grass plains	2800	3·1
Mitchell and other grass plains	5450	6·1
Blue grass plains	3550	4·0
Lowland tall grass plains	950	1·0
Coastal country	2100	2·3
Total	86,690	100·0

Thirteen pasture lands have been defined. They are listed with their areas in Table 11, described below, and shown on the land system map together with summary descriptions of pasture lands and land systems.

(a) *Rugged Hilly Country*

This pasture land is mostly too steep or stony for stock (Plate 1, Fig. 1). Valleys in areas adjacent to better country may be useful for grazing but are difficult to manage and provide havens for scrub cattle, wild horses, donkeys, and predators.

In the northern half of the area where the mean annual rainfall exceeds 27 in. the major vegetation is stringybark–bloodwood woodland over upland tall grass (Pinkerton, Weaber, Brocks Creek, and Mullaman land systems), but in the drier south it is sparse low woodland with a predominantly soft spinifex (Wickham and Elder land systems) or a hard spinifex (Dockrell and Pompey land systems) ground vegetation.

(*b*) *Hilly Country with Useful Lowlands*

Basic rocks (volcanics, dolomites, or limestones) predominate in this pasture land. It is less rugged than the previous one and has a higher proportion of valleys with better-quality pastures.

Napier (on basalt or dolerite) and Tanmurra (on dolomite or limestone) land systems both occur in the northern half (mean annual rainfall greater than 27 in.) of the area and have mainly upland tall grass pastures. Antrim (on basalt or dolerite) and Humbert (on dolomite) are their equivalents in the south and have arid short grass pastures. Headley and Richenda land systems also are restricted to the south, Headley on limestones and carrying mostly hard spinifex and Richenda on granite and carrying mostly soft spinifex.

The carrying capacity varies from 0 to 10 cattle per sq mile, depending on topography and proximity to better country.

(*c*) *Low Hilly Country*

On this pasture land the topography is undulating to low hilly. It is mostly gentle enough not to deter access by stock but most of the soils are shallow and skeletal or lateritic. Cockburn land system occurs on shales in the northern half of the area and has a characteristic vegetation of paperbark low woodland over upland tall grass. Of the other four land systems, all of which are southern, Ruby and Koongie are both derived from lateritic plains, Ruby having soft spinifex or arid short grass and Koongie hard spinifex pastures. Franklin land system has laterite-capped mesas and steeper slopes predominantly with soft spinifex with Tippera tall grass pastures on lower slopes and in the valleys. Winnecke land system occurs only in the far south and has predominantly soft spinifex pastures.

(*d*) *Upland Tall Grass Plains*

These flat to gently undulating plains have infertile sandy or gravelly soils and upland tall grass pastures (Plate 2, Fig. 1) and are restricted to the northern part of the area. Litchfield and Macphee land systems are on granite and have a northern box–bloodwood woodland, Cockatoo and Moyle land systems occur on sedimentary rocks and have a stringybark–bloodwood woodland as does Koolpinyah land system which is developed on lateritic plains.

The carrying capacity of the native pastures is low (<5 cattle per sq mile) but where mean annual rainfall exceeds 30 in. the land has a potential for sown Townsville stylo pastures. The country is burned annually during the dry season to remove the bulk of tall poor-quality grass.

(*e*) *Three-awn Plains*

This is the southern, low-rainfall equivalent of the previous pasture land. It is flat to gently undulating with infertile sandy soils and the pasture is characterized by three-awns. Birrimbah land system is lateritic in origin and has a stringybark–bloodwood woodland and Buchanan is formed on sandstone and has silver-leaved box sparse low woodland.

The stock-carrying capacity is low during the wet season and very low in the dry season.

(*f*) *Soft Spinifex Plains*

This pasture land is restricted to plains of the Sturt plateau in the southern part of the area (Plate 2, Fig. 2). The soils are mostly sandy and the vegetation low eucalypt woodlands or desert shrublands over soft spinifex. Coolindie, Redsan, and Geebee land systems all occur on lateritic plains and support desert shrubland, desert sparse low woodland, and snappy gum sparse low woodland respectively. Barry land system is on limestone and supports desert shrubland.

The soft spinifex pastures have a low carrying capacity which, however, is little affected by droughts. The country tends to be stocked only where it is adjacent to better country. The pastures are burned regularly because young spinifex is more palatable than old and burning, by reducing the competition from spinifex, allows better-quality grasses to grow for a year or two.

(*g*) *Tippera Tall Grass Plains*

This pasture land consists of plains or gently undulating country with leached loam soils (Plate 1, Fig. 2) in the northern half of the area. The vegetation is eucalypt woodland and the major pastures are characterized by one or more of *Themeda australis* (kangaroo grass), *Sorghum plumosum* (perennial sorghum), *Chrysopogon fallax* (razor grass), and *Sehima nervosum*, all of which are tall perennial tussock grasses. Burning to remove the old growth of the tall grasses is practised regularly. Under extensive management conditions the stock-carrying capacity is about 5 cattle per sq mile but experience at Katherine Research Station indicates that 15–20 cattle per sq mile can be carried under more intensive conditions. Much of the area has a potential for sown Townsville stylo pastures.

Of the six land systems Matheson, Jindara, Wriggley, and Dinnabung occur mainly on limestones and differ in the proportions of laterite or limestone outcrops. Frayne land system is developed on basalt and contains some low basalt hills and Angallari land system is on alluvium.

(*h*) *Arid Short Grass Plains*

This pasture land occurs in the southern half of the area. It is flat to gently undulating and occurs mostly on basic rocks, and the soils are mostly calcareous earths.

The pastures are characteristically of short grasses such as *Enneapogon* spp. and *Aristida contorta* and are of somewhat better quality than the tall coarse pastures to the north. However, forage production is low and the stock-carrying capacity is only 5–10 cattle per sq mile.

Nelson land system has deep calcareous soils developed on shales. It is likely that this land system, now severely eroded, once carried Mitchell grass and that the present short grass pastures have developed because of heavy grazing pressure. Gordon and Montejinni land systems are both developed on limestone and differ in topography and the proportion of limestone outcrop. O'Donnell land system consists of undulating country with rock outcrop or shallow skeletal soils on granite.

(*i*) *Barley Mitchell Grass Plains*

A single land system, Inverway, comprises this pasture land. It is restricted to the south of the area and consists of plains with cracking clay soils developed on Tertiary alluvium. It is similar to the Barkly Tableland. The plains are treeless and the pasture is dominated by *Astrebla pectinata* (barley Mitchell grass) which is a perennial tussock grass 2–3 ft high. As far as possible the pastures are protected from fires.

The country has a moderate to high (15–20 cattle per sq mile) carrying capacity.

(*j*) *Mitchell and Other Grasses Plains*

Undulating country with heavy clay soils developed on basic rocks in the south comprises this pasture land (Plate 3, Fig. 1). It is treeless or nearly so and carries a pasture in which barley Mitchell grass is prominent but which also includes other perennial grasses of similar height. Stocking rate is moderate to high (15–20 cattle per sq mile).

Wave Hill land system is developed on basalt and Argyle on limestone. Hawk land system is developed on mudstones and sandstones and includes appreciable proportions of Tippera tall grass pastures.

(*k*) *Blue Grass Plains*

This pasture land consists of flat to gently undulating country with cracking clay soils developed on basalt or alluvium in the northern half of the area. The common vegetation consists of scattered low trees (*Terminalia arostrata*, *Bauhinia cunninghamii*, *Eucalyptus microtheca*) over tall perennial tussock grasses such as *Dichanthium* spp. (blue grasses), *Astrebla squarrosa* (bull Mitchell grass), and *Eulalia fulva* (browntop). The stock-carrying capacity is moderate (about 10 cattle per sq mile).

Willeroo land system consists of undulating country on basalt, Dillinya land system of broad shallow drainage lines in the Tertiary land surface, and Ivanhoe and Legune land systems are developed on alluvium. Legune land system is formed on estuarine alluvia and the soils are more saline than in the other land systems.

(*l*) *Lowland Tall Grass Plains*

Subcoastal Plain land system comprises this pasture land. It is flat country subject to flooding each wet season, and swampy parts remain wet for much of the dry season. The pastures cannot be grazed for much of the wet season, but remain green into the dry season and provide better grazing than those of the associated upland areas.

(*m*) *Coastal Country*

Carpentaria land system which consists of saline coastal plains comprises this pasture land. Much of the country is bare mud or samphire plains but there are some areas of saline short grass which has a moderate to high carrying capacity if suitable stock water is available.

PART IX. AGRICULTURAL POTENTIAL OF THE ORD–VICTORIA AREA

By G. A. STEWART*

I. SUMMARY

The only form of agriculture in the area at present is irrigated cotton-growing on the lower Ord River, where commercial production commenced in 1962–63 and has reached approximately 14,000 acres under crop per year. A contract has recently been let to build the major storage dam on the Ord River and irrigation will then be expanded to a gross area of 178,000 acres. Some suggestions of other possible sources of water and areas of land for irrigated agriculture are made in this Part.

Evaluation of the possibilities for dryland forage and cash crops and dryland improved pasture is based largely on experimental data from Katherine, N.T., some 30 miles to the north-east of the area.

It is considered that dryland cash and forage cropping would be feasible only on loamy-surfaced, moderately to well-drained soils with more than 30 in. annual rainfall. Only minor areas of suitable land occur in the area, confined to the north-eastern margin. Their development would logically take place in association with similar lands in the Tipperary area.

For Townsville stylo improved pastures there are three important potential areas for development:

(1) Cockatoo, Angallari, Dinnabung, and Frayne land systems occurring in the vicinity of the Ord River irrigation area. The development of these lands will be greatly facilitated by the townships, roads, and other services that are or will be installed for the irrigation area.

(2) Jindara, Matheson, and Wriggley land systems, and also areas of Dinnabung and Frayne land systems adjacent to the Tipperary area in the north-east, that will be developed in association with the Tipperary area.

(3) Moyle, Litchfield, Angallari, Wingate, and Dinnabung land systems in the far north of the area, mostly within an Aboriginal reserve. Provision of suitable access to Darwin will be an essential prerequisite for their development.

II. INTRODUCTION

This part of the report is concerned primarily with an assessment of the physical suitability of land for various forms of agriculture. At present the only commercial agriculture in the area is the irrigated agriculture of stage I of the Ord River irrigation project (Plate 4, Fig. 2). For agronomic data on irrigated agriculture, the reader is

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referred to the Progress Report of Kimberley Research Station (Anon. 1968). Oliver and Hogstrom (1964, 1966) have evaluated the economic performance of the commercial farming. Davidson (1965) carried out economic appraisals at both farm and project level. Some agronomic and economic factors have changed significantly since those appraisals were made. Subsequent economic appraisals by the Western Australian and Commonwealth Governments have not been published.

At present there is no commercial dryland agriculture for cash crops and/or improved pastures of Townsville stylo in the survey area. Most of the investigations on which the following assessment is made were carried out at the CSIRO Katherine Research Station (Norman 1966) and at the Northern Territory Administration Katherine Experiment Farm (see annual reports of the Animal Industry and Agriculture Branch, Northern Territory Administration). Some investigations of dryland crops have also been made at Kimberley Research Station. Forster, Kelly, and Williams (1960) and Davidson (1965) have published economic evaluations of various potential dryland farming systems but agronomic and economic factors have since changed significantly. More recent economic evaluations by the Northern Territory Administration and the Commonwealth Government have not been published.

III. Potential Land for Dryland Agriculture

At Katherine Research Station on Tippera soils (Table 12) over the years 1957–67 the total annual rainfall has ranged from 23 to 39 in., with a mean of 30 in. Sorghum, peanuts, and Townsville stylo pastures have all given acceptable yields over these seasons. For the following assessment a mean annual rainfall of 30 in., which is approximately equivalent to an agricultural growing season of 12 wk in 80% of years and a pasture growing season of 16 wk in 80% of years, is used as a conservative estimate of the drier climatic limit for both cash cropping and improved pastures. Only the northern part of the area, approximately 25% of the area mapped, is above this limit.

It is almost certain that future research will show that Townsville stylo pastures will grow in areas of appreciably lower rainfall as the strain of Townsville stylo used at present at Katherine is a late mid-season one. Earlier maturing strains are now being multiplied for testing in lower-rainfall areas. It is possible that future investigations may also show that cash crops can be grown in lower-rainfall areas.

(a) Potential Land for Cash and Forage Crops

Table 13 summarizes crop performance on a number of soils at Katherine Research Station and the results of preliminary trials on Cockatoo sand at Kimberley Research Station. At Katherine Research Station a small number of trials indicate that Elliott soils gave yields very similar to Tippera soils, while yields on Manbulloo and Katherine soils are slightly higher. Some dryland crop trials on Cununurra clay at Kimberley Research Station have not given promising results. Thus, at our present state of knowledge, the only soils that could be recommended for cash cropping are Tippera, Elliott, and the river levee soils Manbulloo, Katherine, and Ord. The last three are of relatively small extent, mainly in Ivanhoe land system.

The land systems in which the leached loamy soils, Tippera and Elliott, are important are grouped in the Tippera tall grass plains (e.g. Plate 1, Fig. 2). Jindara and Wriggley land systems are both much more extensive in the Tipperary area (Speck *et al.* 1965) to the north-east of this survey area. Matheson land system, which appears to have similar agricultural potential to Jindara land system, also occurs only in the north-eastern corner of the area. Any agricultural development in these three land systems would obviously be associated with similar lands in the Tipperary area. Dinnabung land system is widely scattered in the northern part of the area. Although

TABLE 12

AVERAGE EXPERIMENTAL CROP AND PASTURE YIELDS* (1957/58–1966/67) ON TIPPERA SOILS AT KATHERINE RESEARCH STATION

Season	Peanuts (lb/ac in shell)	Sorghum (lb/ac grain)	Bulrush Millet (lb/ac dry matter)	Townsville Stylo (lb/ac dry matter)	Total Rainfall (in.)
1957/58	1309	1260	10,690	7450	31·54
1958/59	1089	1783	12,390	6230	35·38
1959/60	1303	2019	13,550	4830	34·35
1960/61	1455	1591	8310	4790	24·83
1961/62	1130	2399	9010	5120	20·41
1962/63	1332	3043	15,260	6520	36·38
1963/64	1745	971	7150	5730	22·93
1964/65	1186	1338	8360	5580	32·35
1965/66	1400	2674	10,880	5690	26·76
1966/67	2440	3000	18,070	5445	38·61
Average	1439	2008	11,367	5738	30·35

* M. J. T. Norman, personal communication.

TABLE 13

AVERAGE EXPERIMENTAL YIELDS* ON A NUMBER OF SOILS OF CROPS AND PASTURES AT KATHERINE UNDER REASONABLE AGRONOMIC TREATMENTS

Crop	Tippera Clay Loam	Blain Sand	Florina Sand	Cockatoo Sand (Kimberley Res. Stn)
Peanuts (lb/ac in shell)	1400 (10)†	600 (5)	400 (3)	Worth further investigation
Sorghum (lb/ac grain)	2000 (10)	Poor	Very poor	Poor
Bulrush millet (lb/ac dry matter)	11,500 (6)	7000 (3)	Very poor	Worth further investigation
Sudan grass (lb/ac dry matter)	6500 (6)	4000 (3)	Very poor	—
Cowpea (lb/ac dry matter)	4000 (6)	2000 (3)	Very poor	Worth further investigation
Townsville stylo–*Cenchrus* pasture (lb/ac dry matter)	6000 (4)	4000 (4)	1500 (4)	Worth further investigation

* M. J. T. Norman, personal communication.

† Figures in parentheses indicate number of years averaged.

gently undulating, it is mostly non-arable because of scattered low rock outcrops, mainly of dolomite. Angallari land system occurs in many small scattered areas. Approximately half of the land system is dominated by deep sandy soils that appear unsuitable for cash crops. The areas of loamy-surfaced Elliott soils appear to be liable to occasional flooding, and their development for cash cropping could not be recommended at this stage.

Small areas of Frayne land system, undulating basalt country with loamy-surfaced Frayne soils, occur in the part of the area with more than 30 in. rainfall. However, in most cases the soils are non-arable because of scattered rock outcrop and/or very stony surface soils, and/or a soil erosion hazard on sloping parts.

Thus this survey area offers little prospect for dryland cash cropping at the present state of knowledge.

(*b*) *Potential Land for Improved Pastures of Townsville Stylo*

Experience in the 30–45 in. rainfall belt around Katherine indicates that Townsville stylo will grow on a wide range of red earths, yellow earths, and lateritic podzolic soils. The average yield of Townsville stylo pastures on Tippera soil at Katherine Research Station is 5700 lb dry matter per acre (Table 12). Quantitative yield data on other soils are limited, but those data and general field observations indicate that yields are somewhat lower on sandier soils. At Kimberley Research Station, Townsville stylo appears promising on Cockatoo soils, and a wider range of soils is now being tested. Townsville stylo does not appear to be adapted to cracking clay soils, as good stands have never been observed in those soils.

It appears likely that Townsville stylo pastures will largely be established without clearing by aerial application of phosphate fertilizer and seed and by using early wet season burning of native pasture (Stocker and Sturtz 1966) and/or wet season grazing to control competition from native pastures. These methods are now being tested commercially in the Katherine–Darwin area.

Land suitable for Townsville stylo improved pastures is restricted to land systems of the high-rainfall parts of two pasture lands, the upland tall grass plains and the Tippera tall grass plains.

In the upland tall grass plains, Litchfield, Moyle, and Wingate land systems all occur in the northern higher-rainfall part of the area. At present their logical market outlet would seem to be Darwin, and their development is unlikely to take place until lands more accessible to Darwin have been developed. Cockatoo land system (Plate 2, Fig. 1) occurs mostly in the vicinity of the Ord River irrigation area, and mostly has more than 30 in. annual rainfall. It appears the obvious choice for improved pasture development in the area, and experimental and demonstration effort should mainly be concentrated on this land, of which there is a total area of approximately 1,000,000 acres. Macphee land system has a rainfall of 25–30 in. and occurs in the vicinity of the Ord River to the south of the irrigation area. Its area of more than 200,000 acres would warrant investigation of its potential for Townsville stylo improved pastures, and parts of the land system are traversed by the Ord Dam road and the Halls Creek road.

In the Tippera tall grass plains, Jindara, Wriggley, and Matheson land systems are all restricted to the north-eastern corner of the survey area, and their development will logically be associated with the development of similar lands in the adjoining Tipperary area. The largest areas of Dinnabung, Frayne, and Angallari land systems north of the 30-in. isohyet occur in the north-east, adjoining the Tipperary area, and would logically be developed in association with that area. There are also significant areas of these lands occurring in association with Cockatoo land system in the north-west which may offer scope for development in association with the Ord River irrigation area. Otherwise, these land systems occur in smaller scattered areas that do not appear attractive from the agricultural development point of view.

Because of the complex patterns of land in the areas adjoining the Ord River irrigation project, a more detailed map at scale 1 : 250,000 has been prepared and is available on request.*

IV. Potential Land for Irrigated Agriculture

The following discussion deals with medium- to large-scale irrigation possibilities. Small-scale areas (less than 5000 ac gross) have not been examined but undoubtedly many could be located when the need arises.

(*a*) *Ord River Irrigation Project*

(i) *The Project as at Present Envisaged.*—Stage I of the Ord irrigation project consists of a diversion dam at Bandicoot Bar with a storage of 80,000 ac ft, and the development of a gross area of 26,000 ac on Ivanhoe plains. The area actually under crop each year is approximately 15,000 ac, and is limited by available water supply. The main crop is cotton.

Stage II of the project as at present envisaged (Government of Western Australia, unpublished report 1967) includes:

(1) The construction of a major storage dam on the Ord River some 30 miles upstream from the present diversion dam. The dam would have a storage capacity of 3,500,000 ac ft and a safe annual offtake of 1,000,000 ac ft.

(2) The irrigation of a further 105,000 ac in Western Australia and 47,000 ac in the Northern Territory, making a total gross area of 178,000 ac. The net irrigable area on farms is expected to be 142,000 ac.

If 70% of the net farm area is cropped each year (a figure being approached by existing farmers), the total area under crop each year will be approximately 100,000 ac.

The proposed irrigation area has been defined by detailed soil surveys by the Department of Agriculture of Western Australia (S. T. Smith, unpublished data). The proposed area lies entirely within Ivanhoe land system. Nearly all of the proposed area is unit 1 of the land system—gently sloping flood-plains with Cununurra clay

* Stewart, G. A. (1969).—CSIRO Aust. Div. Land Res. tech. Memo. No. 69/10 (unpublished).

soils. On the Carlton plain part of that unit some 11,000 ac have been excluded because of moderate salt content (>0·1% NaCl within the top 6 ft) and 5000 ac because of high salt content (>0·15% in the top 2 ft).

Some of the northern parts of the stage I development have very gentle gradients, and some parts were artificially upgraded in an effort to make them more suitable for cotton which is sensitive to waterlogging and poor drainage. It is likely that low-gradient areas also occur in other parts of the potential irrigation areas.

If future agronomic research should prove that rice is a potential economic crop, the areas of flatter gradient should be admirably adapted to that crop, and the areas of moderate salt content may possibly be suitable.

Other relatively small areas of the proposed irrigation area consist of Ivanhoe land unit 4—river levees with Ord family soils. These appear to be suitable for a wide range of agricultural and horticultural crops but not for rice.

(ii) *Possibilities of Further Land for Irrigation.*—Other types of land that are worthy of consideration for expanding the irrigation area in the future are listed below. Their location can be ascertained on the land system map.

The deep red and yellow sands of Cockatoo land system appear to be above gravity command level, and their slopes are such that only relatively small areas could be commanded by moderate pump lifts. Also the soils are extremely permeable and spray irrigation would be necessary. Their most likely form of use would be for citrus and other horticultural crops or tobacco.

The loamy soils of Angallari land system are only moderately drained but may be suitable for irrigation of crops that are not extremely sensitive to waterlogging. Some parts appear to be liable to short-term shallow flooding, and this aspect would need to be examined. The sandy soils of this land system appear to be highly permeable but the subsoil drainage is only moderate to poor, and they do not appear attractive for irrigation. The largest area of potentially commandable soils appears to be east of the lower Keep River in the Northern Territory.

The large area of cracking clay and solonetz soils of Legune land system to the east of the Keep River estuary and only slightly above high-tide level may possibly be partly commandable by gravity reticulation. From very limited soil sample data the soils are of similar or slightly higher salinity than at the Coastal Plains Research Station, 40 miles east of Darwin; some are less clayey than those near the Coastal Plains Research Station and some have sandier subsoils that would possibly permit subsoil drainage and desalination. Cropping under irrigation is likely to be restricted to rice and pastures. The gross area east of the Keep estuary is approximately 100,000 ac.

(iii) *Possibilities of Further Water Supplies for Irrigation.*—In the future it may be desirable to seek other sources of water to extend irrigation development in the vicinity of the Ord project. The best possibilities are briefly described below, and their locations are shown in Figure 10.

The Western Australian Government announced (*Australian Financial Review*, October 28, 1968) the signing of an agreement with a private company, Goddard of Australia Pty. Ltd., giving approval to build dams and develop land for irrigation on the Dunham River, some 25 miles upstream from its confluence with the Ord River. The company plans to undertake the work in two stages. The first stage is a dam on Arthur Creek, a tributary of the Dunham, with a storage of 50,000 ac ft and a pilot irrigation area of 10,000 ac. Should this be economically successful, a dam will be built on the Dunham River with a storage of 500,000 ac ft and a planned irrigation area of a further 34,000 ac. The company plans to use the land for the intensive feeding of cattle and the production of grain crops for export.

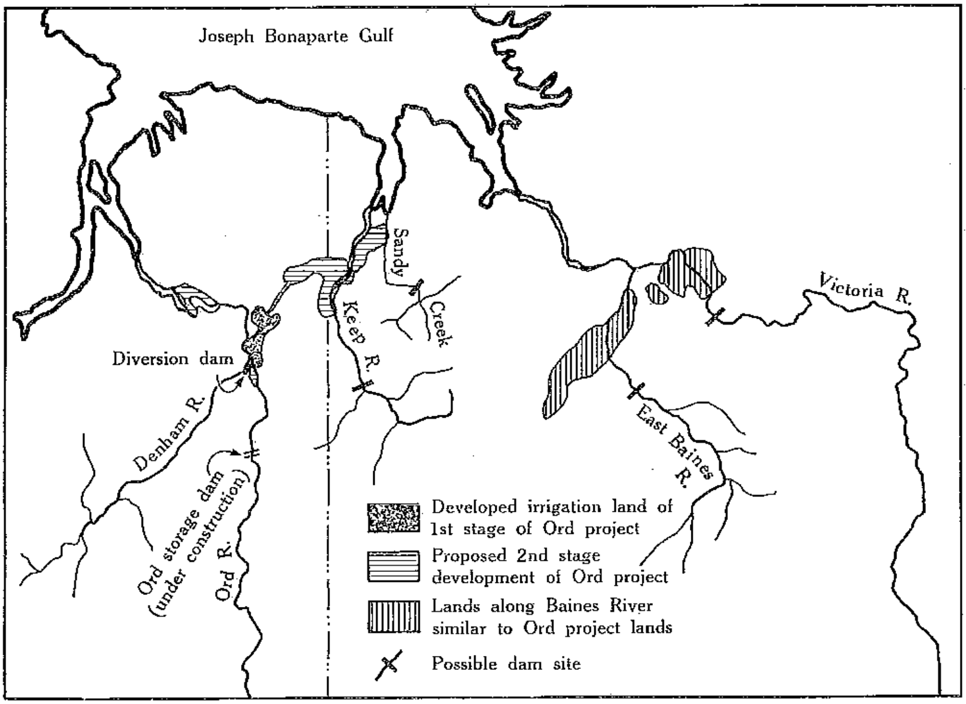

Fig. 10.—Location of the Ord River irrigation project, and some other possibilities for irrigation.

The Keep River, below its junction with Cockatoo Creek, flows through a narrow gorge which might be a suitable site for a storage dam. The catchment above that gorge is approximately 850 sq miles. If the catchment area : safe offtake ratio were the same as for the Ord dam, the safe offtake would be 48,000 ac ft. If 5 ft of water per annum was used on the area under crop, the crop area would be 9600 ac, equivalent to a gross irrigation area of 17,000 ac.

Sandy Creek has a catchment entirely of hilly sandstone and quartzite country, and flows through a narrow gorge just before entering its flood-plain area of Angallari land system. Its catchment above the gorge is approximately 200 sq miles. If, because of higher rainfall and very rugged catchment, its catchment area : safe offtake ratio was twice that of the Ord dam, its safe offtake would be 22,000 ac ft. Using the same assumptions as under Keep River, this would be sufficient for a gross irrigable area of approximately 8000 ac. From reconnaissance data, this could easily be found in the downstream area of Angallari land system.

Very little is known of the ground-water resources of the lower Ord–Keep plains. Because of their apparent high permeability, the sandy soils of Cockatoo land system and the sandy parts of Angallari land system may have the best quality ground water. The possibility of irrigating parts of these lands by direct pumping of ground water for spray irrigation is worthy of investigation.

To the west of the Ord River the Penticost and Salmon Rivers both have much larger catchments than those described above, but there are no significant areas of land suitable for irrigation that could readily be commanded from those rivers.

(*b*) *Other Large Potential Irrigation Areas*

(i) *Lower Daly River*.—Investigations by the Water Resources Branch of the Northern Territory Administration (unpublished data) have shown that the lower Daly River is one of the largest water resources in the north. Its minimum recorded dry season flow is 280 cusec (Anon. 1967). Soil and topographic surveys have been initiated by the Northern Territory Administration. The major areas likely to be suitable for irrigation are the Wildman soils of the Subcoastal Plain land system. The potential of these soils appears to be limited to rice and pastures, and these forms of production are being investigated at Coastal Plains Research Station and Beatrice Hill Experiment Station on the subcoastal plains of the Adelaide River, N.T. The lower Daly River is the northern boundary of this survey area. Large areas of Wildman soils in the Subcoastal Plain land system also occur to the north of the lower Daly River.

(ii) *The Baines–Angallari Valley*.—This valley contains large areas of Ivanhoe land system similar to the potential irrigation areas of the Ord River irrigation project. Excluding the braided channel areas of the West Baines River, the approximate areas of gently sloping Cununurra family soils are:

(*a*) north-east of the lower Victoria River—35,000 ac;

(*b*) between Alpha Creek and the lower Victoria River—40,000 ac;

(*c*) south-east of the Baines River and south-west of Alpha Creek—120,000 ac.

There are also large adjacent areas of Angallari land system that may also be suitable for irrigation.

The potential sources of water supply appear to be the Victoria and/or East Baines Rivers. The Victoria River is still strongly tidal where it transects the valley. Immediately upstream of the valley the Victoria flows through a narrow valley between high hills, that might be a suitable dam site. The catchment area at this site is approximately 23,000 sq miles. If that is not suitable, a suitable dam site might be found further upstream and a diversion dam built at the lower site. There are very few data on which to assess the possibility of gravity reticulation of water to the potentially irrigable land, particularly the land further upstream along the West Baines River. The East Baines River flows through a narrow gorge a short distance upstream from its flood-plain tract, which could possibly provide a suitable dam site. The catchment area above the gorge is only approximately 900 sq miles. This is of similar size to the Keep River catchment, although more hilly in topography. Thus it might be expected to provide irrigation water for a gross area of approximately 20,000 acres.

V. General Conclusions

It appears that there are worth-while prospects of increasing the area of land irrigable from the Ord River project. The first step in assessing this possibility should be detailed topographic and soil surveys, with initial emphasis on Angallari and Legune land systems as these offer the best prospects for significant increases in irrigation. In both these land systems attention should also be given to the assessment of flooding and the feasibility of its control.

Because of the large dry-season flow, further investigations of the lower Daly River appear warranted.

The other possibilities discussed should only be considered as long-term prospects. Preliminary investigations of dam sites and commandability should be undertaken in order that further gauging stations can be installed, and so that alternative forms of land use that might be developed in the near future do not prejudice the eventual development of irrigation. As a potential example of the latter, if the narrow valley on the Victoria River immediately upstream from the Baines–Angallari valley is a potential site for a storage or diversion dam, it would probably be desirable to redirect the development of the present site of Timber Creek because of its likely inundation in such a dam. A suitable alternative might be the area of Cockatoo land system some 10 miles towards the Western Australian border. This site might also be a suitable location for a township if irrigation development of the Baines–Angallari valley were undertaken.

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Fig. 1.—Rugged hilly country with much rock outcrop and shallow stony soils covers approximately 45% of the area.

Fig. 2.—Gently sloping loamy red and yellow earth soils in the higher-rainfall parts carry northern box–bloodwood woodland over Tippera tall grass. The small areas of this type of country with an annual rainfall exceeding 30 in. are suitable for cash cropping or improved pastures of Townsville stylo.

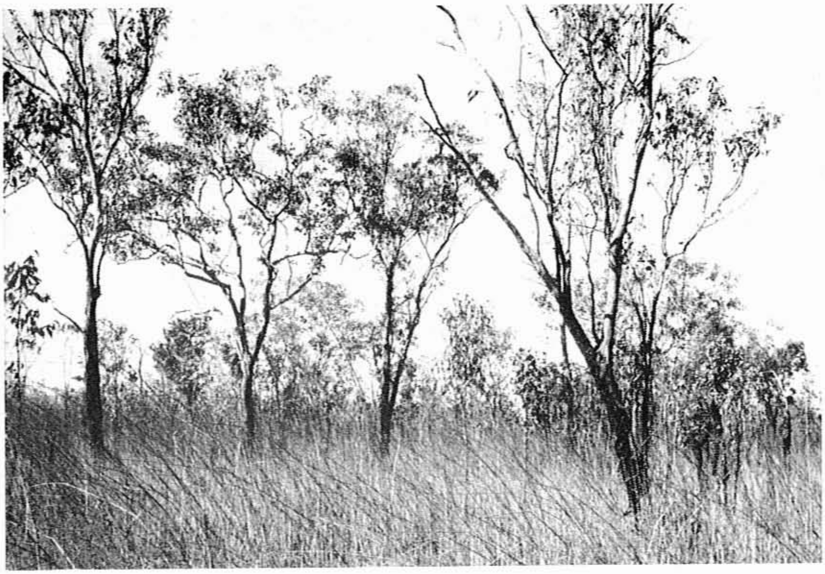

Fig. 1.—Gently sloping deep sandy soils have stringybark–bloodwood woodlands over upland tall grass. Areas of this land with annual rainfall exceeding 30 in. appear suitable for Townsville stylo improved pastures.

Fig. 2.—Gently sloping deep sandy soils with soft spinifex (*Triodia pungens*) under desert sparse low woodland in the 15–20-in. rainfall zone. The carrying capacity of these natural pastures is low.

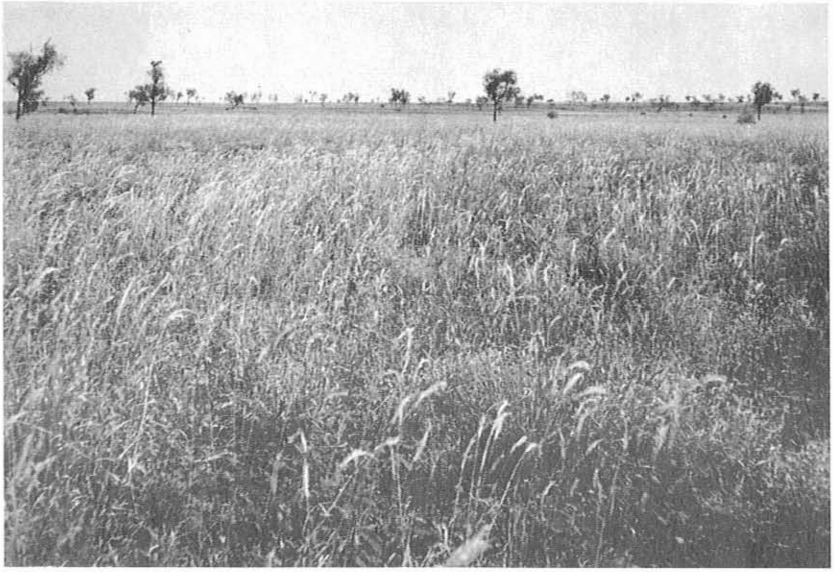

Fig. 1.—Mitchell grass and other mid-height grasses occurring on gently undulating basalt country with cracking clay soils is the best cattle-carrying pasture in the area. This pasture type is confined to areas with less than 27 in. annual rainfall.

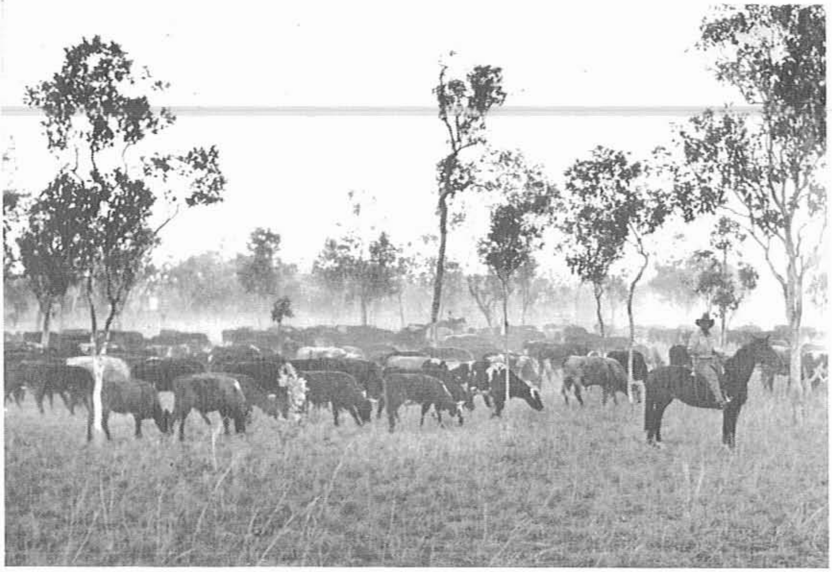

Fig. 2.—Beef-cattle raising on natural pastures is the most important and widespread industry in the area. The individual properties are large and the efficiency of the industry is generally low.

Fig. 1.—Halls Creek township was originally established as a gold-mining centre. Only minor mining takes place at present, and Halls Creek now acts as a service centre for the cattle industry.

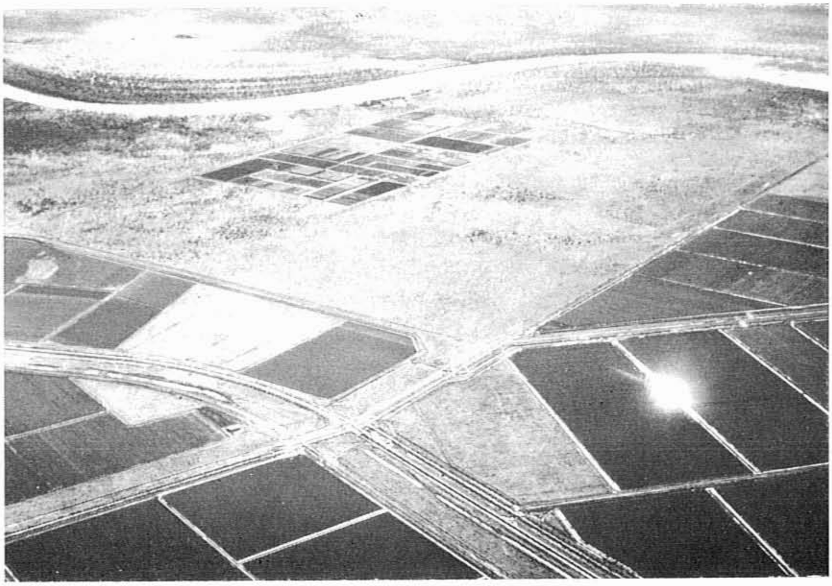

Fig. 2.—Following a period of agricultural research at Kimberley Research Station (in background), irrigated agriculture was commenced in 1962, with water derived from a small dam on the Ord River at Kununurra. Some 15,000 acres of crop, almost entirely cotton, are grown each year. Work has now commenced on a large upstream dam that will provide water for 178,000 acres of land.