THE WESTERN AUSTRALIAN
NATURALIST

Vol. 16 April 30, 1986 Nos. 5-7

A BOTANICAL SURVEY OF BUNGLE BUNGLE AND OSMOND RANGE, SOUTH-EASTERN KIMBERLEY, WESTERN AUSTRALIA

By STEPHEN J. FORBES, National Herbarium of Victoria, Birdwood Avenue, South Yarra, Victoria 3141

and

KEVIN F. KENNEALLY, Western Australian Herbarium, George Street, South Perth, Western Australia 6151

ABSTRACT

A preliminary botanical survey of Bungle Bungle and Osmond Range in the south-eastern Kimberley Division of Western Australia was undertaken in 1984. Descriptions of 18 vegetation types and an annotated list of 403 plant species are presented. Previous studies of the physical environment are reviewed. A brief history of land use and botanical exploration is presented. Conservation status and botanical significance of vegetation types and plant species are discussed.

CONTENTS

INTRODUCTION

A botanical survey of a previously poorly known and apparently uncollected region of the south-eastern Kimberley Division of Western Australia was undertaken in May and July 1984, during the 'dry' season. Descriptions of vegetation types and an annotated list of 403 species supported by voucher collections are included in this paper. A complete set of voucher specimens is shared between the Western Australian Herbarium and the National Herbarium of Victoria although each collection is close to complete. Duplicates were distributed to specialists in particular taxa.

LOCALITY

The study area is shown in Map 1. The area is located around the abandoned Bungle Bungle Outcamp (latitude 17°21'S, longitude 128°21'E) and lies approximately 160 km S of Kununurra and 120 km NE of Halls Creek, the two nearest towns. The area is within the Shire of Halls Creek and is 50 km W of the Northern Territory border.

Most of the study area lies within the Ord River Station, managed by the Western Australian Department of Agriculture as a reserve for regeneration of eroded areas in the Ord River catchment area. Osmond Valley, Texas Downs and Mabel Downs are privately managed pastoral leases in the north of the study area.

NARRATIVE

The spectacular geomorphology of the sandstone ruiniform towers (Fig. 1) and steep cliffs (Fig. 2) of the Bungle Bungle massif first attracted media attention in late 1982 and 1983. The resulting influx of tourists prompted detailed consideration of management requirements for the region by the Western Australian Government (Bungle Bungle Working Group 1984). The present study was undertaken to contribute botanical information to the planning process.

The study reported here is based on field work undertaken during the 1984 dry season. An initial camp was made from May 13-16 at Winnama Spring. The party at this stage comprised three botanists, S.J. Forbes (National Herbarium of Victoria), J.H. Willis (formerly National Herbarium of Victoria) and E.A. Chesterfield (State Forests and Lands Service, Victoria), assisted by S.P. Lloyd and P. Woodward. Collections and observations were made on foot in the Winnama Gorge area and by vehicle along the access road south to Palms Yard and along its continuation as a mineral exploration track as far east as Wulwuldji, an area then in use as a geologist's camp by Samim Australia Pty. Ltd. Collections of Forbes (nos. 1974-2037), Willis (72 unnumbered) and Chesterfield (nos. 186-238) were made during this initial camp.

The second phase of field work from July 4-17 began with the charter of a fixed wing aircraft at Turkey Creek to fly over the study area. The first few days of this phase were coincidental with an inspection of the region by the Western Australian Environmental Protection Authority Bungle Bungle Working Group. The party for this stage comprised Forbes and two additional botanists K.F. Kenneally (Western Australian Herbarium) (assisted by D.J. Choules Edinger and P.J. Spencer) and N.H. Scarlett (La Trobe University). In addition a photographer, C.J. Totterdell (CSIRO), two soil conservationists, A. Mitchell and W.A. Papst (Soil Conservation Authority, Victoria) and an anthropologist D.B. Rose (Australian Institute of Aboriginal Studies) were with the party for various periods. Two vehicles belonging to the party were used for access through Palms Yard and Wulwuldji. Scarlett and Rose worked largely independently on ethnobotanical studies with Gidja people from the Warmun Community at Turkey Creek in a third vehicle belonging to R. Wallaby from July 7 onwards.

Figure 1. Arrays of sandstone towers (ruiniform relief), here seen in the north eastern area of the massif, have come to be regarded as the characteristic landscape feature of the Bungle Bungle massif. Photo KFK.

Figure 2. On its western side the Bungle Bungle massif is bounded by cliffs that rise abruptly from the surrounding lowlands. Photo KFK.

Camps were made at Dutbu (July 5), on the access track at the first crossing of Red Rock Creek (July 6), at Bellburn Creek west of the Bungle Bungle massif (July 7) and subsequent camps on Red Rock Creek east of the Bungle Bungle Outcamp. An overnight camp was also made by Forbes and Scarlett at Blue Holes (July 13) on the Ord River.

Collections and observations were made by vehicle and on foot. A Bell Jetranger helicopter allowed Kenneally and Forbes access to Piccaninny Gorge and the summit of the Bungle Bungle massif on July 12. Collections of Forbes (nos. 2516-2693) and all those of Kenneally (nos. 9184-9301) and Scarlett (nos. 84-290 — 84-388) were made during this period. Scarlett's ethnobotanical studies are reported elsewhere (Scarlett unpub. & in prep.).

Additional collections made at the end of the wet season between 3 & 10 April 1985 were provided by Marion I. Blackwell and Arthur S. Weston.

HISTORY

The country surrounding the upper reaches of the Ord River remained virtually unexplored by Europeans until Alexander Forrest's expedition from the De Grey River to Port Darwin in 1879. Forrest and another member of his party, James Carey, made some botanical collections and "although hardly any new species were discovered, (they) seemed still of sufficient interest . . . as the localities for every kind of plant were accurately recorded, and . . . new data concerning the natural spread of many of the rarer species became available." (Mueller 1880).

The specimens were forwarded to Mueller who published a catalogue of plants from the expedition (Mueller op. cit.). Forrest's route passes through the southernmost boundary of the study area along the Ord River; however Mueller's locality 'Ord River' is generalised to include the route as far north as the Negri River. The specimens from this locality (Appendix 1) are few and include no type material.

Mueller's catalogue incorporates some of his own collections and observations made when he accompanied Augustus Gregory's exploration of the Victoria River and Sturt Creek in 1855-56 during the North Australian Expedition. Although these collections are east and south of the study area (see Cumpston 1972) the specimens constitute the first from the south-eastern Kimberley and are therefore of historical interest. A number of types of species collected within the study area are included (Appendix 2). Unfortunately many of the collections were destroyed en route from Timor to Sydney.

A complete list of type material from Sturt Creek has been compiled from Bentham (1863-1878) by J.H. Willis (Appendix 3). Many of these species may reasonably be expected to occur within the study area; their absence from Mueller's published account (Mueller op. cit.) is apparently a result of his including only 'data from . . . unpublished diaries' rather than from specimens, many of which would have been on loan to Bentham at Kew. A complete list of type material collected by Mueller from the Fitzmaurice River, Victoria River, Wickham River, Depot Creek, Depot Pool and Hookers Creek is not available but could be compiled from Bentham (op. cit.) and papers published by Mueller on his return (e.g. Mueller 1859 a & b).

In 1882 John Pentacost, a surveyor employed by the Duracks, explored west of the Ord River (Durack 1983) and in 1883 J.S. Brooking and H.F. Johnston, accompanied by E.T. Hardman, a geologist, began a survey of the Kimberley by triangulation. At the request of Alex. Forrest the surveyors collected plant specimens which were forwarded to Mueller (Johnston 1962); however none of this material is known with certainty to have come from the study area. A number of specimens collected by Johnston have been located at the National Herbarium of Victoria (MEL), including the type material of *Triumfetta johnstonii* F.Muell. (MEL 1530388), named after

Johnston by Mueller, and a specimen of the Boab, *Adansonia gregorii* F.Muell. (MEL 1530226-27). The collections are dated 1884 and the localities are no more precise than 'near the Ord River'.

As a result of reports from Forrest's expedition, pastoral development in the south-eastern Kimberley was rapid. In 1883 Nat Buchanan took 4,000 head of cattle into the Kimberley to stock Ord River Station for the Victorian partnership of William Osmand (Figure 3), a Stawell mine-owner, and Joseph Panton (Figure 4), a Melbourne magistrate, thus being first with cattle in the Kimberley (Durack 1983). (The alternative spelling Osmond is occasionally used and Osmand may have been indifferent on this point. Nevertheless his death is registered as Osmand and an early map of the region (Young 1886) uses this spelling for the Osmand Range and Osmand Creek.) During the 'dry' the Ord would provide no barrier to stock and the small but attractive pastures of the Antrim land system around Bellburn Creek, Osmond Creek and Red Rock Creek would have led stock and stockmen into the study area soon after. Osmand and Panton travelled to the Kimberley on Osmand's steam-yacht 'Cushie Doo' in 1885. Panton was acquainted with Mueller apparently through the Royal Geographical Society of Australasia (a sketch of Mueller by Panton is included as Figure 5). Although Panton collected specimens for Mueller in the West Kimberley (Panton 1885) circumstances contrived to prevent his landing in the East Kimberley (Panton unpub.) and he returned to Melbourne without seeing Ord River Station. A new *Gardenia* species was named by Mueller (1887) after Panton (from Panton's collections at Lagrange Bay in the West Kimberley) but never validly published.

Figure 3. W.H.S. Osmand (1824-1901), partner in Ord River Station. (Reproduced with permission from The Library of the Parliament of Victoria).

Figure 4. J.A. Panton (1831-1913), partner in Ord River Station and botanical collector. (Reproduced with permission from La Trobe Collection, State Library of Victoria).

After Osmand's death in 1901, Perth land magnate Samuel Copley purchased Ord River Station. By 1906 it is estimated that Ord River carried between 80,000 and 100,000 head of cattle (Durack 1983). At this stage smaller leases in the northern Bungles were established and often stocked by 'shaking' (a polite term for stealing) Ord River cattle. In 1914 Ord River Station was sold to Vesteys which (through various subsidiaries) consolidated the northern leases (including Bungle Bungle Station) into Ord River Station by 1948. In 1967 the lease was resumed by the Western Australian Government in order to rehabilitate severely degraded land systems. Osmond Valley, Texas Downs and Mabel Downs are the only remaining private pastoral leases in the study area.

Unfortunately managers of Ord River Station (for absentee leaseholders) and surrounding leases seem to have had little interest in plant collecting and neither the leaseholders nor early managers such as Bob Button or Charlie Young appear to have forwarded specimens to herbaria. In contrast material collected by leaseholders downstream on the Ord River including F. Connor, K.M. and M.P. Durack figure prominently in early Kimberley collections (see Gardner 1952).

The redoubtable Government Botanist, C.A. Gardner, made significant collections for the W.A. Herbarium in the east Kimberley in 1944 chiefly along the lower Ord River. Contemporary collections have been made during rangeland surveys and regeneration trials by the Western Australian Department of Agriculture. Chris Done of the Department of Conservation

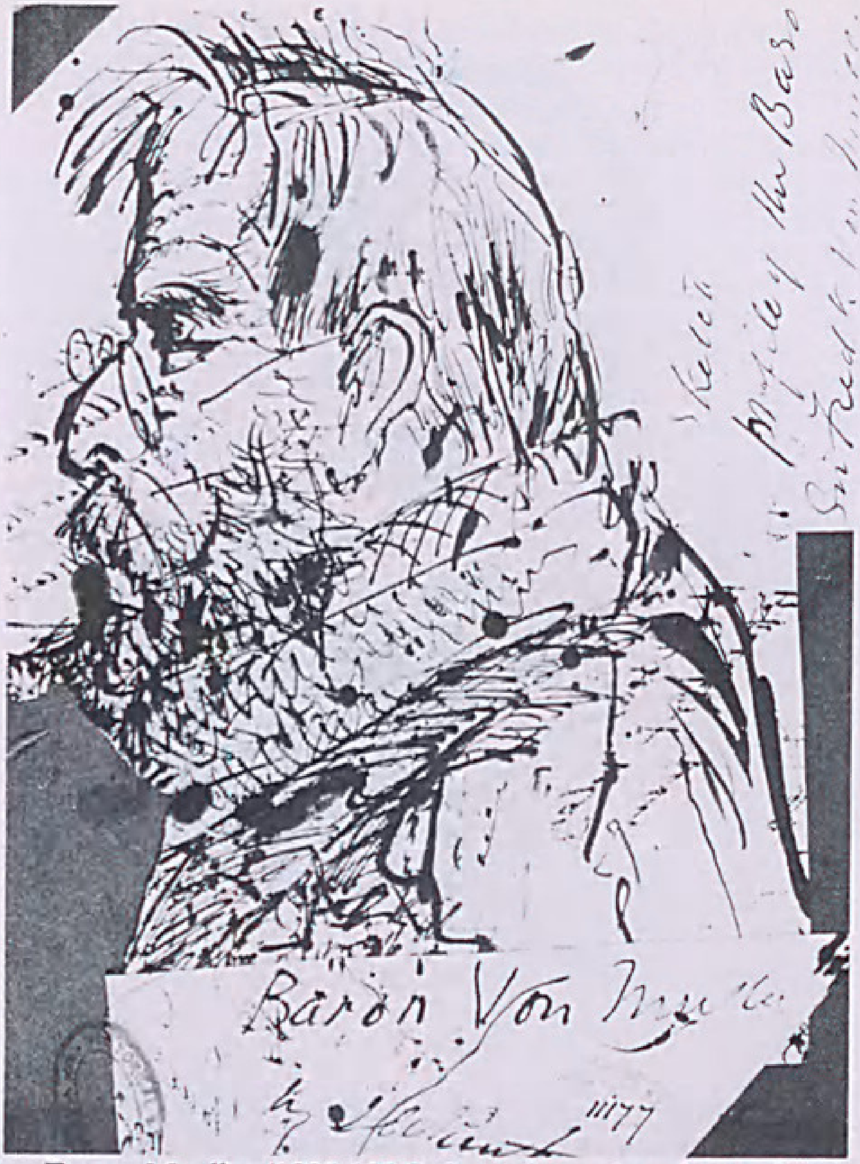


Figure 5. F. von Mueller (1825-1896), botanist and explorer, drawn by J.A. Panton. (Reproduced with permission from the Royal Historical Society of Victoria).

and Land Management and freelance botanist Arthur S. Weston have also contributed specimens to the W.A. Herbarium.

The availability of further information regarding collections in the region will be facilitated by the current programme of computerising herbarium records.

CLIMATE

A description of climate of the study area may be found in Slatyer (1970) and valuable summaries in Beard (1979) and Bungle Bungle Working Group (1984). The study area may be described as having a dry, monsoonal climate. The mean annual rainfall for the nearest station, Turkey Creek (40 km to the north-west), is 681 mm, which is virtually confined to the 'wet' season from December-March. The mean may be misleading, as the region has extreme seasonal variability in annual rainfall. Rainfall is confined to relatively few events, reflected in an extreme 24 hour rainfall of 215 mm (at Halls Creek). Monthly mean maximum temperature reaches a peak of 39.6°C in November and the lowest monthly mean minimum is 12.3° during July. Sub-zero ground temperatures were experienced by the party on July 6 at Red Rock Creek. Monthly mean relative humidity reaches a peak of 40% during the 'wet' and drops to 17% during the 'dry'.

GEOLOGY

The study area has been geologically mapped at 1:250,000 scale by Dow and Gemuts (1967) whose mapsheet and explanatory booklet should be referred to for details of geology. A useful summary of the geology of the Kimberley based on Memoir No. 2 of the Geological Survey of Western Australia (1975) may be found in Beard (1979), while details pertinent to the study area are included in the report of the Bungle Bungle Working Group (1984). Traves et al. (1970) also provide a valuable background for the geology of the Ord-Victoria area. The following notes are drawn from the above sources.

The south-eastern Kimberley is divided into three major geological units, namely the Halls Creek Province surrounding the Halls Creek Mobile Zone, the Ord Basin (represented in the study area by the Hardman Sub-Basin) and the Victoria River Basin. The study area is composed of areas of each of these three units.

The oldest rocks exposed in the study area occur in the Halls Creek Province (the western margin of the study area) and are formed from Archaean Halls Creek Group sediments. Some evidence suggests these sediments may have been laid down over the entire east Kimberley. Subsequent folding, metamorphism and basic intrusions followed into the Lower Proterozoic. Major activity characterised the Halls Creek Mobile Zone and there is evidence that during the Adelaidean the zone formed a glaciated range. The Mobile Zone probably controlled sedimentation to the east and west.

The later Victoria River Basin sediments are comprised of Proterozoic sandstones and dolomites containing stromatolites. Such deposits characterise the Osmond Range.

During the Lower Cambrian the extensive outpouring of basalts known as the Antrim Plateau Volcanics covered most of the study area. A few relict outcroppings are exposed north and west of the Bungle Bungle massif.

Marine transgressions followed during the Lower Palaeozoic. The Hardman Sub-Basin was formed east of the Halls Creek Province and south of the present Osmond Range as a result of upward drag along faults in these regions. The Sub-Basin accumulated Negri Group sediments of hard crystalline limestones and soft shales now exposed as Headley limestones and Nelson shales.

Following uplift and erosion the Elder sandstones were deposited during the Devonian and are presently exposed as the Bungle Bungle massif and Dixon Range. Erosion of these sandstones has produced the plains of the Buchanan Land System.

SOILS

Soils within the study area are principally determined by geology. The most extensive are lithosols, characteristic of rocky slopes and uplands. These soils are undifferentiated, containing large amounts of rock fragments and displaying little pedological development. A varied relief usually confines such soils to scattered pockets and fissures. The alluvial soils constitute a second undifferentiated group confined to levees, terraces and floodplains of major watercourses. Alluvial soils are substantially unaffected by weathering, and must, therefore be confined to relatively recent deposits. The parent material defines the nature of both groups of undifferentiated soils.

Cracking clay soils are developed on poorly drained calcareous and basic igneous rocks or alluvium and colluvium derived from these rocks. Although generally referred to as 'black soil plains' such clays are typically grey or brown. The soils are alkaline, crack deeply in the dry season and are self-mulching. Leached gradational soils are found as red and yellow earths developed on the sandy erosion plains of the Buchanan Land System surrounding the Bungle Bungle massif. These soils are massive with weak profile differentiation.

A useful description and classification for soils within the study area may be found in Stewart (1970a).

GEOMORPHOLOGY AND LAND SYSTEMS

For details of geomorphology and land systems the reader is referred to CSIRO Land Research Series report for the Ord-Victoria area (Paterson 1970; Stewart et al. 1970b), the Western Australian Department of Agriculture report for Ord River Station (de Salis 1982) and the Bungle Bungle Working Group Draft Report (1984).

A summary of the land systems considered in the present study is adapted from the Bungle Bungle Working Group Draft Report (op. cit.) to assist interpretation of the vegetation descriptions.

Antrim Land System

Land units — Upland and lowland land units.

Lòcation — The Antrim Land System is situated in the main to the south of the study area. However it is present as a narrow strip to the west and north of the Bungle Bungle massif where it marks the edge of the Hardman Sedimentary Basin.

Geology — Confined to Antrim Plateau Volcanics principally basalts of Lower Cambrian age.

Geomorphology — Within the study area the land system consists of rough stony hills, and associated narrow outwash plains (respectively the upland and lowland land units).

Soils — Lithosols in uplands, juvenile cracking clays on the outward plains.

Condition — Upland areas stable, lowland unit severely degraded with extensive sheet and gully erosion. Donkeys, camels and feral cattle common.

Buchanan Land System

Land units — Uplands, sandplain, frontage plain.

Location — Forms much of the core of the study area in association with the Elder Land System (below).

Geology — Derived from the underlying Elder Sandstone.

Geomorphology — A structural bench forming extensive undulating sandplains.

Soils — Deep siliceous red and yellow sands and red and yellow earths and on the narrow frontage plains, fine white sands.

Condition — All units are in good condition with no erosion. They are usually distant from water, generally unpalatable to stock and have thus attracted little grazing pressure. Sandy soils break down under vehicle usage.

Dockrell Land System

Land unit — Not subdivided into land units.

Location — The Dockrell Land System is located along the western boundary of the study area running parallel to the Halls Creek Mobile Zone.

Geology — Sedimentary and metamorphics of the Archean period predominantly sub-greywacke, phyllite and conglomerate rocks.

Geomorphology — Complex folded hills and ridges.

Soils — Sparse gravelly lithosols.

Condition — Inherently stable land with vegetation largely unpalatable to stock, has suffered little grazing pressure and is in excellent condition.

Elder Land System

Land units — Uplands, cuestas and cuesta backslopes, lower slopes.

Location — An extensive land system which includes the Bungle Bungle massif.

Geology — Confined to Elder Sandstones and sandplains derived from this parent rock.

Geomorphology — Structural plateau (Bungle Bungle) and cuestas.

Soils — Exposed rock to sandy lithosols on the upland and cuesta units, sandy to friable calcareous soils on the lower footslopes.

Condition — Uplands and cuesta land units, show no degradation or erosion. They attract little grazing pressure as the vegetation is unpalatable and the land often inaccessible to stock and distant from water. Lower slopes land unit, fair condition with some gutters and sheet erosion on the calcareous soils. Evidence of fairly heavy grazing on this unit.

Wickham Land System

Land units — not subdivided into land units.

Location — The Wickham Land System comprises the Osmond Range, located along the northern and north western boundaries of the study area and extending beyond the study area in the west to Halls Creek Mobile Zone.

Geology — Formed on shales, siltstones, sandstone, conglomerates and dolomites of the Proterozoic period. It forms the geographic barrier in the northern and north western edges of the Hardman Sedimentary Basin.

Geomorphology — Strike ridges and cuestas formed on a faulted anticline with intense drainage patterns and rugged inaccessible terrain.

Soils — Stony lithosols between rock sheets, boulders and outcrops, duplex soils on mid and lower slopes and some development of dark clay loams in major valley bottoms.

Condition — The upland areas are inherently stable and inaccessible to stock and are in excellent condition. Some of the broader valleys in Osmond Valley pastoral lease show evidence of localised sheet and gully erosion but are largely in good condition. Donkeys and cattle are common in valley areas.

PREVIOUS VEGETATION STUDIES

A vegetation map and explanatory notes for the Kimberley have been prepared by Beard (1979) and a land systems report and map published in the CSIRO Land Research Series for the Ord-Victoria region by Stewart et al. (1970). Beard's report provides an excellent overview of Kimberley vegetation. Both maps are at a scale of 1:1,000,000 and have relied largely on photo interpretation with limited field observations and specimen vouchers. This has resulted in certain errors of detail which have become apparent as a result of our own work; for example both erroneously report *Eucalyptus brevifolia* as dominant on the Bungle Bungle plateau and Osmond Range, where in fact the dominant species are *E. cliftoniana* and *E. collina* respectively. *Eucalyptus collina*, the dominant species of sandplain surrounding the Bungle Bungle massif is incorrectly mapped as *E. pruinosa* by Stewart et al. and as *E. tectifica* and *E. terminalis* by Beard.

The broad scale of these studies has likewise precluded the inclusion of restricted vegetation types such as most of those in the riparian complex.

Figure 6. Bed of Red Rock Creek looking east towards Red Rock. The creek bank is fringed with a narrow stand of *Eucalyptus camaldulensis* (white-barked) and *Terminalia platyphylla* (dense canopy) to left of Red Rock. Photo KFK.

VEGETATION DESCRIPTIONS OF BUNGLE BUNGLE, OSMOND RANGE AND WINNAMA GORGE

The following account of vegetation in the study area is based on notes prepared in the field from aerial and ground reconnaissance. The structure (based on Specht et al. 1974) and physiognomically dominant species were noted according to topography, soils and geology to establish homogeneous vegetation types. This essentially subjective approach is suitable for primary survey, however additional vegetation types and some refinement of those already noted could be expected to result from further fieldwork, especially during the wet season. The term 'spinifex' refers to hummock grasses of the genera *Triodia* and/or *Plectrachne*. Preparation of a vegetation map based on field checking by helicopter of sites chosen from air-photo interpretation would be valuable.

1. **RIPARIAN COMPLEX** (Figures 6-14)

1.1 **Ephemeral streams on plains and broad valleys** (Figure 6)

An open forest dominated by *Lophostemon grandiflorus* subsp. *riparius* characterises ephemeral stream courses on plains and broad valleys. Such forest is restricted to a narrow fringe, rarely extending beyond a single canopy on each bank. Major streamcourses, such as Red Rock Creek, are distinguished by the presence of *Eucalyptus camaldulensis* and *Terminalia platyphylla*. Occasional smaller trees including *Ficus coronulata*, *Nauclea orientalis*, *Vitex glabrata* and *Canthium attenuatum* complete the overstorey.

The understorey is dominated by tussock grasses, especially *Arundinella nepalensis, Coelorhachis rottboellioides* and *Eulalia fulva*.

The stream-bed may be scoured quite bare, although tussocks of *Cyperus vaginatus* are common, and in major streamcourses *Terminalia bursarina* may form a low open woodland. The margins of drying pools support ephemerals including *Ludwigia* spp., *Rotala* spp., *Eriocaulon* spp. and grasses well into the dry season.

This community is typical of watercourses in the Antrim, Dockrell and Wickham Land Systems on varied geology. Availability of water and the presence of some alluvium are the prime determinants of the vegetation.

1.2 **Permanent and semi-permanent streams of Osmond Valley and surrounds.** (Figures 7 & 8)

A complex of permanent and semi-permanent streams occurs along the northern fringe of the Osmond Plateau. A broad band of open forest, commonly extending beyond a single canopy fringe characterises such streams on the plains and broad valleys. A number of tree species not found along ephemeral streamcourses are dominant, especially *Melaleuca leucadendra* and *Sesbania formosa* which form an overstorey to *Pandanus integer*. The groundlayer is composed of partially submerged swards of *Colocasia esculenta* and *Cyclosorus interruptus*. Rampant tangles of the creeper *Passiflora foetida* may occur on the margins of this community.

The lush appearance of this community is in vivid contrast to the surrounding sandstone hills which support a dry tree steppe (low open woodland) of 'spinifex' and *Eucalyptus brevifolia*. (see 6.1)

The community is restricted to the Wickham Land System and occurs on a rich grey-black humus and alluvium.

1.3 **Ord River at Blue Holes** (Figure 9)

The Ord River around Blue Holes is described as a semi-permanent river. Blue Holes is a series of permanent pools, now greatly reduced by silting (R. Wallaby pers. comm.). A riparian closed forest dominated by *Melaleuca*

Figure 7. Creek bed in Osmond Valley, dominated by the screw-pine *Pandanus integer* with a dense understorey of *Colocasia esculenta* (taro) and the fern *Cyclosorus interruptus*. Photo KFK.

Figure 8. Dense stands of *Melaleuca leucadendra* (cadjeput) are common on broad alluvial stream braids. Photo KFK.

Figure 9. Ord River at Blue Holes bordered by riparian closed forest dominated by *Melaleuca leucadendra* and *Eucalyptus camaldulensis*. Photo N.H.Scarlett.

leucadendra, Eucalyptus camaldulensis, Ficus coronulata, F. racemosa and *Terminalia platyphylla* forms stands on alluvium adjacent to the river. A formerly extensive fringe of *Phragmites karka* and *Pandanus spiralis* has been largely destroyed by floods (R. Wallaby, pers. comm.). *Terminalia bursarina* forms a low open woodland on strands in the river course. The only record of *Syzygium eucalyptoides* for the study area is from sandbanks at this site.

The site is in the Antrim Land System.

1.4 **Sheltered gullies of streams in Osmond Valley and surrounds** (Figures 10 & 11)

Permanent and semi-permanent streams sheltered by deeply incised gullies support closed forest. *Carallia brachiata, Ficus coronulata, F. racemosa* and *Euodia elleryana* are the dominant tree species. *Nauclea orientalis, Syzygium angophoroides* and *Timonius timon* are locally co-dominant and *Mallotus nesophilus* is occasionally sub-dominant. The understorey is poorly developed with scattered shrubs of *Zizyphus oenopilia* and *Citriobatus spinescens* and the herb *Coleus scutellarioides*, sporadic on streambanks. The moist sheltered sites support a ferny understorey including *Lindsaea ensifolia, Blechnum orientale* and *Nephrolepis hirsutula*. The climbing fern *Lygodium microphyllum* is also present but epiphytes are absent. Sheltered rock walls support bryophytes and a rare fern ally, *Psilotum nudum*.

The occurrence of such well developed closed forest has not previously been reported for the S.E. Kimberley and represents the extreme inland penetration of such forest for Western Australia. Narrow fringing riparian communities with similar species composition have been recorded from around pools in Flying Fox, Smoke and Limestone Creeks in the East Kimberley (Dames & Moore, 1982). This riparian community is of special biogeographic and botanical interest.

The community is restricted to the Wickham Land System and occurs on black alluvium.

1.5 **Ephemeral streams on the Bungle Bungle plateau** (Figure 12)

All streams on the plateau are ephemeral, although permanent water is found in rockholes in streambeds. Streams incise sandstone gullies, commonly to about 10 m, which offer niches not available on the remainder of the plateau. Accordingly, the majority of species noted for the plateau are from stream surrounds.

The overstorey is a low open forest characterised by *Eucalyptus aspera* and *E. collina* which, on the plateau, are restricted to such sites. *Eucalyptus herbertiana* is only recorded for the study area in this community. The understorey is composed of shrubby thickets of *Acacia* spp. and *Jacksonia thesioides. Distichostemon hispidulus* and *Vitex glabrata* are less common. Sandy pockets adjacent to the streambed and on gully walls are colonised by sedges, *Cyperus* spp. and daisies, *Blumea* spp. and *Pterocaulon* spp. Rock faces support *Ficus leucotricha* and *F. platypoda* affin. var. *cordata* and *Stemodia viscosa*. The ferns *Cheilanthes brownii* and *Cheilanthes* sp. (SJF 2627) occur in associated crevices.

The community is established on sandstones and lithosols of the Elder Land System.

1.6 **Ephemeral streams draining scree and boulder slopes and gorges of the Bungle Bungle massif** (Figure 13)

Permanent water is absent below the plateau apart from a few plunge pools. Streams are characterised by deep gorges, although with broader valleys than those of the chasms (see 1.7). Low open forest fringing the stream is characterised by *Eucalyptus aspera* and *E. collina. Lophostemon grandiflorus* subsp. *riparius* is restricted to larger streams including Piccaninny Creek.

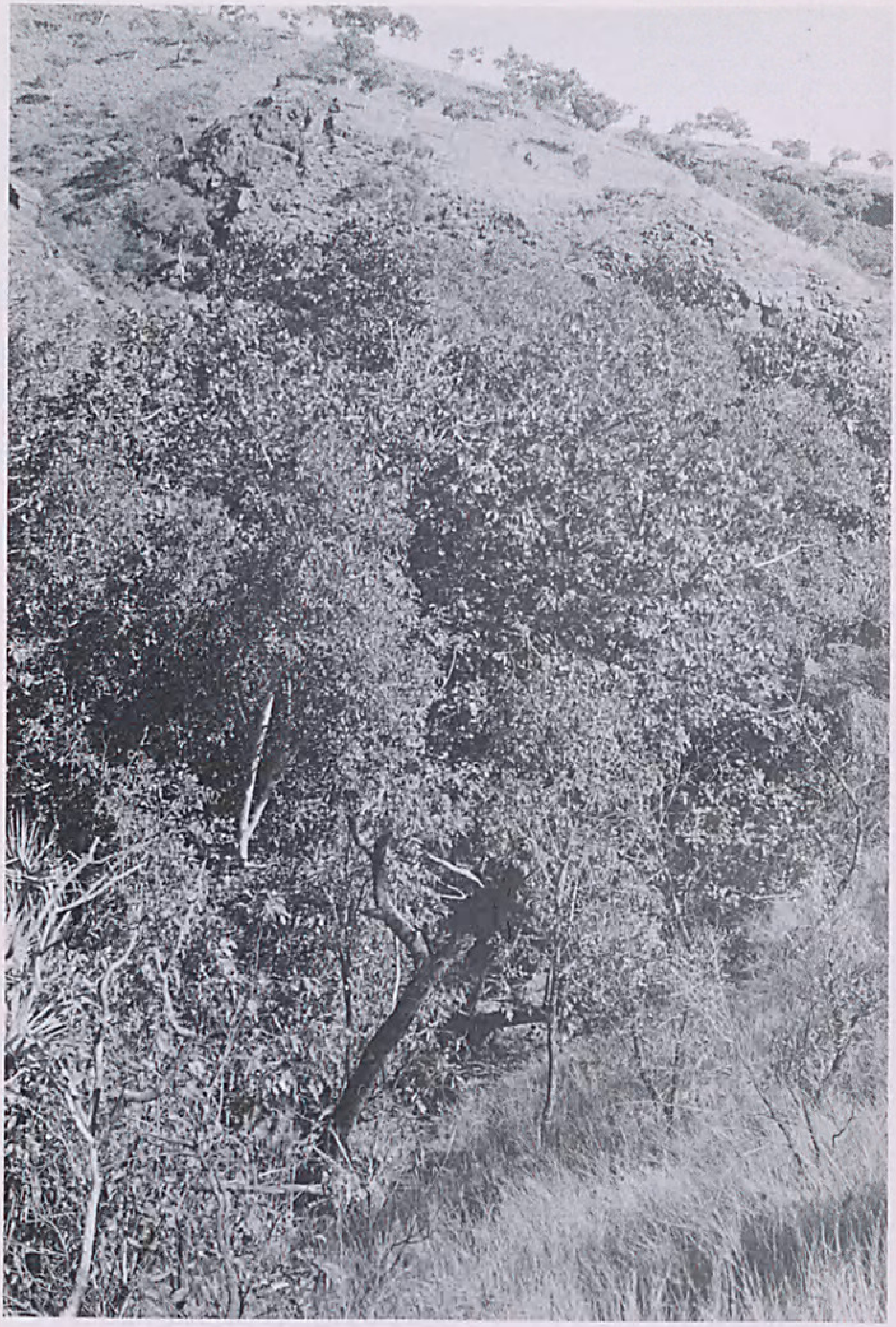


Figure 10. Sheltered gully in Osmond Valley near Wulwuldji dominated by a riparian closed forest. Note that the adjacent gully slopes are dominated by a low open woodland of *Eucalyptus brevifolia*. Photo KFK.

Figure 11. Close forest in Osmond Valley near Wulwuldji. Note the buttressed tree of *Syzygium angophoroides* and the screw-pine *Pandanus integer*. Note the narrow course of the running creek at this time of year (July 1984). Photo C.J. Totterdell.

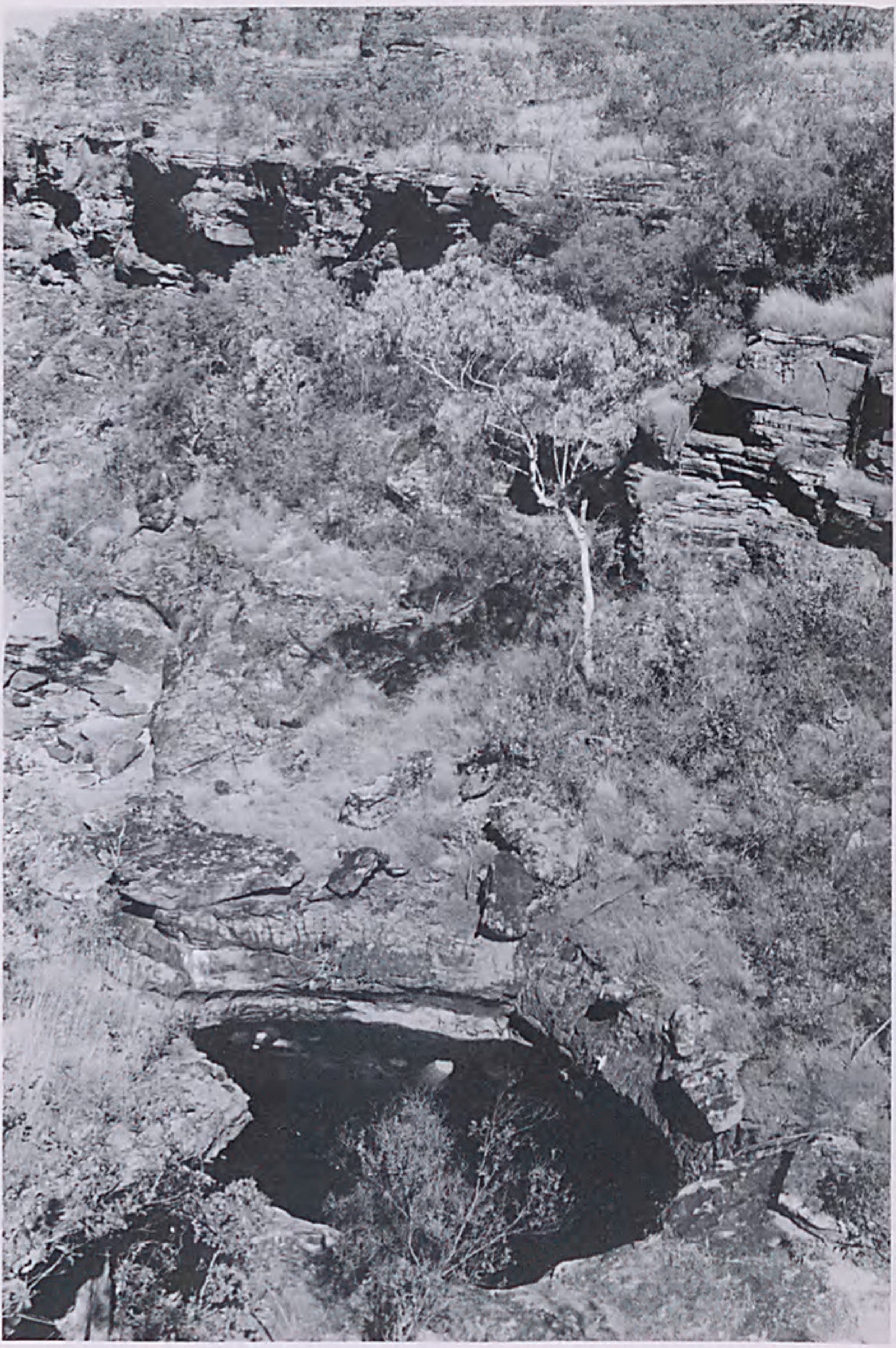


Figure 12. Incised streambed on Bungle Bungle plateau showing semi-permanent rock pool (July 1984). Photo KFK.

The understorey is composed of shrubby thickets of *Acacia* spp., *Jacksonia thesioides* and *Templetonia hookeri*. The palm *Livistona* sp. 'Victoria River', *Myoporum acuminatum* and *Dodonaea viscosa* subsp. *mucronata* are common in rocky tracts. Sandbanks support *Clerodendrum tomentosum* and *C. floribundum* and fine examples of *Leptospermum parviflorum* a new record for Western Australia. 'Spinifex' is usually present as a ground layer in all situations.

The streambed is composed of white pebbles derived from surrounding conglomerates and is typically bare of vegetation. The community is placed in the Elder Land System.

1.7 **Chasms and cliffs** (Figure 14)

The narrow floors of chasms may support a weakly developed low closed forest. The absence of permanent water, other than in plunge pools, precludes closed forest as described from sheltered gullies of streams in Osmond Valley and surrounds (see 1.4).

The dominant trees are *Mallotus nesophilus, Celtis philippinensis, Ficus virens* and *Alstonia actinophylla*. The understorey is dominated by *Bridelia tomentosa* var. *glabrifolia*, a 2-3 m shrub with rampant, arching canes. *Livistona* sp. 'Victoria River' is a handsome palm associated with this community in rock crevices and at cliff bases, but is more conspicuous on adjacent rock walls. The palm appears to be restricted to the western massif. Another species of the rock walls *Pandorea* affin. *doratoxylon*, a twiner or semi-shrub, is most conspicuous on the cliff faces of Piccaninny Gorge. Two other creepers, *Marsdenia velutina* and *Stephania japonica*, are common on the chasm floors.

Sheltered seepage areas support *Stemodia viscosa*, etiolated plants of *Leptospermum parviflorum* and the ferns *Dicranopteris linearis, Lygodium microphyllum* and *Taenitis pinnata*.

The chasms may be 100 m deep and less than 10 m wide with an extensive catchment. As a result, scour on the sandstone and conglomerate chasm floor precludes significant humus accumulation in most sites and soils are largely sands and lithosols. The community is part of the Elder Land System.

2. **STREAM LEVEE AND TERRACE COMPLEX** (Figures 15-17)

2.1 **Low-lying plains adjacent to semi-permanent streams of the Osmond Valley** (Figure 15)

Depressions and flats adjacent to semi-permanent streams of the Osmond Valley support a low open woodland of *Eucalyptus ptychocarpa*, a species entirely confined to such sites within the study area. The understorey is typically a grassy sward, and often dominated by *Heteropogon contortus*, an indicator of disturbance, probably a result of grazing and frequent burning (Groves and Williams 1981). *Pandanus* spp. commonly occur as a small tree layer.

The community is developed on alluvium in the Wickham Land System.

2.2 **Stream frontage** (Figures 16 & 17)

The levees of watercourses support woodland dominated by *Eucalyptus confertiflora* and *E. papuana*. The typical narrow-leaved form of the latter is abundant adjacent to streams on deep alluvial soils, and a broad-leaved form, *Eucalyptus* sp. affin. *papuana* reminiscent of *E. grandifolia* occurs on the levee proper. A smaller tree layer is dominated by *Buchanania obovata* and *Lysiphyllum cunninghamii*. *Acacia plectocarpa* is localised in outwash areas. A sparse shrub layer is characterised by *Acacia holosericea* and *Carissa lanceolata*. The ground layer is a grassy sward dominated by *Heteropogon*

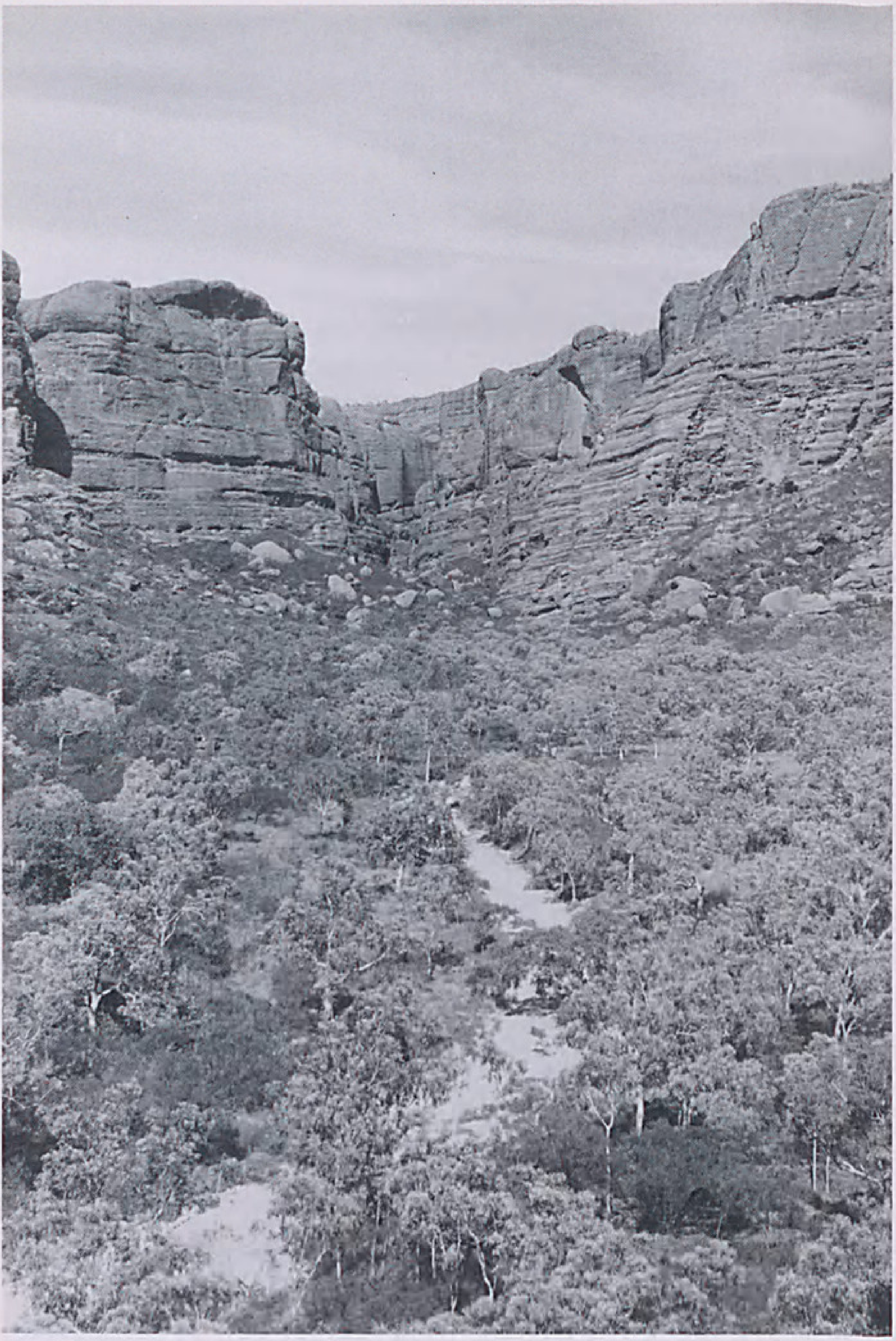


Figure 13. Broad pebbly streambeds derived from surrounding conglomerates drain the Bungle Bungle massif. The dominant eucalypt is *Eucalyptus collina* and *E. aspera* is restricted to the stream bank. Photo KFK.

Figure 14. Cliff-face in Piccaninny Gorge with *Livistona* sp. 'Victoria River' growing in fissures of massive sandstone. Photo KFK.

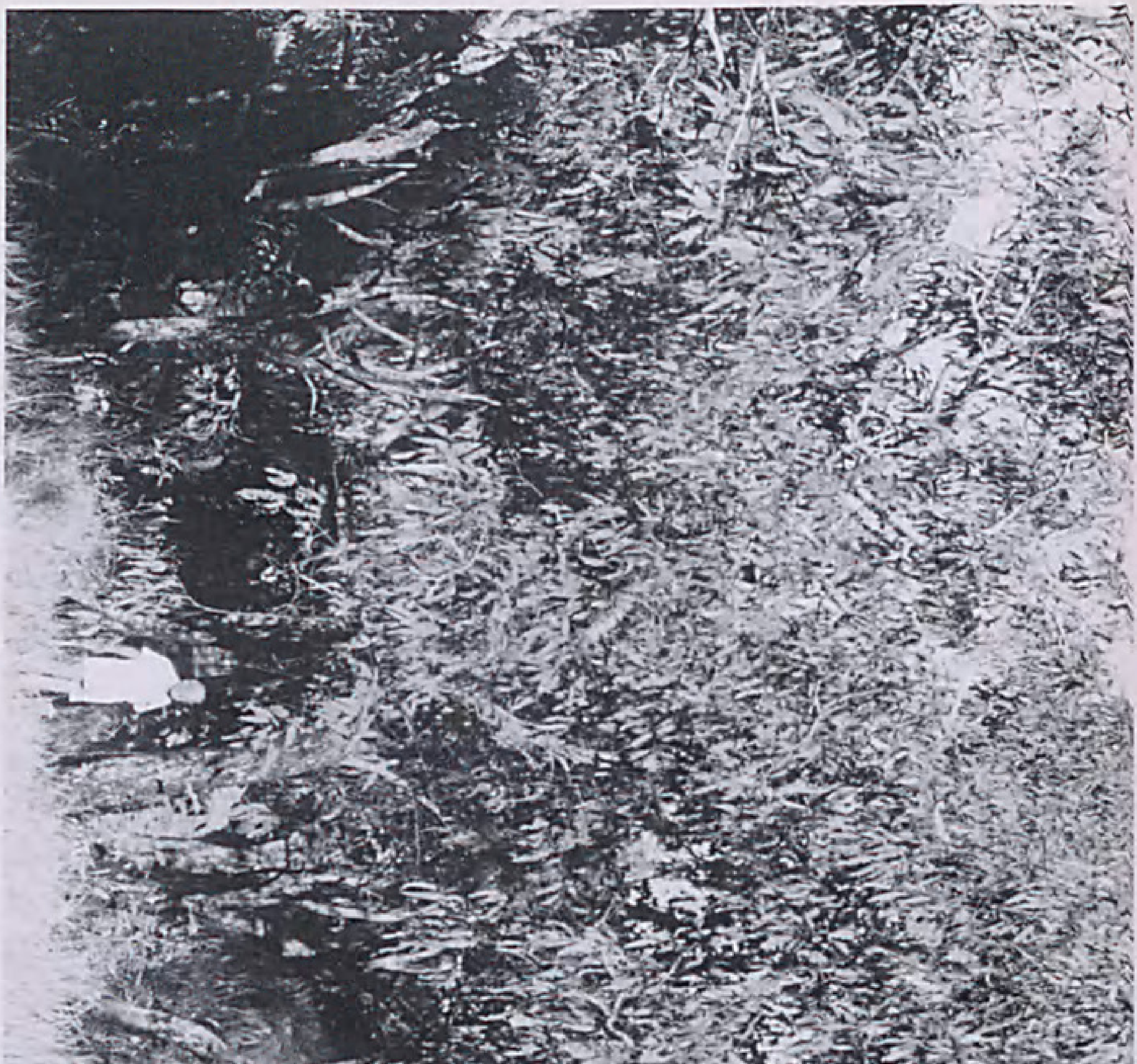


Figure 15. Depression adjacent to stream in Osmond Valley dominated by *Eucalyptus ptychocarpa*. Photo SJF.

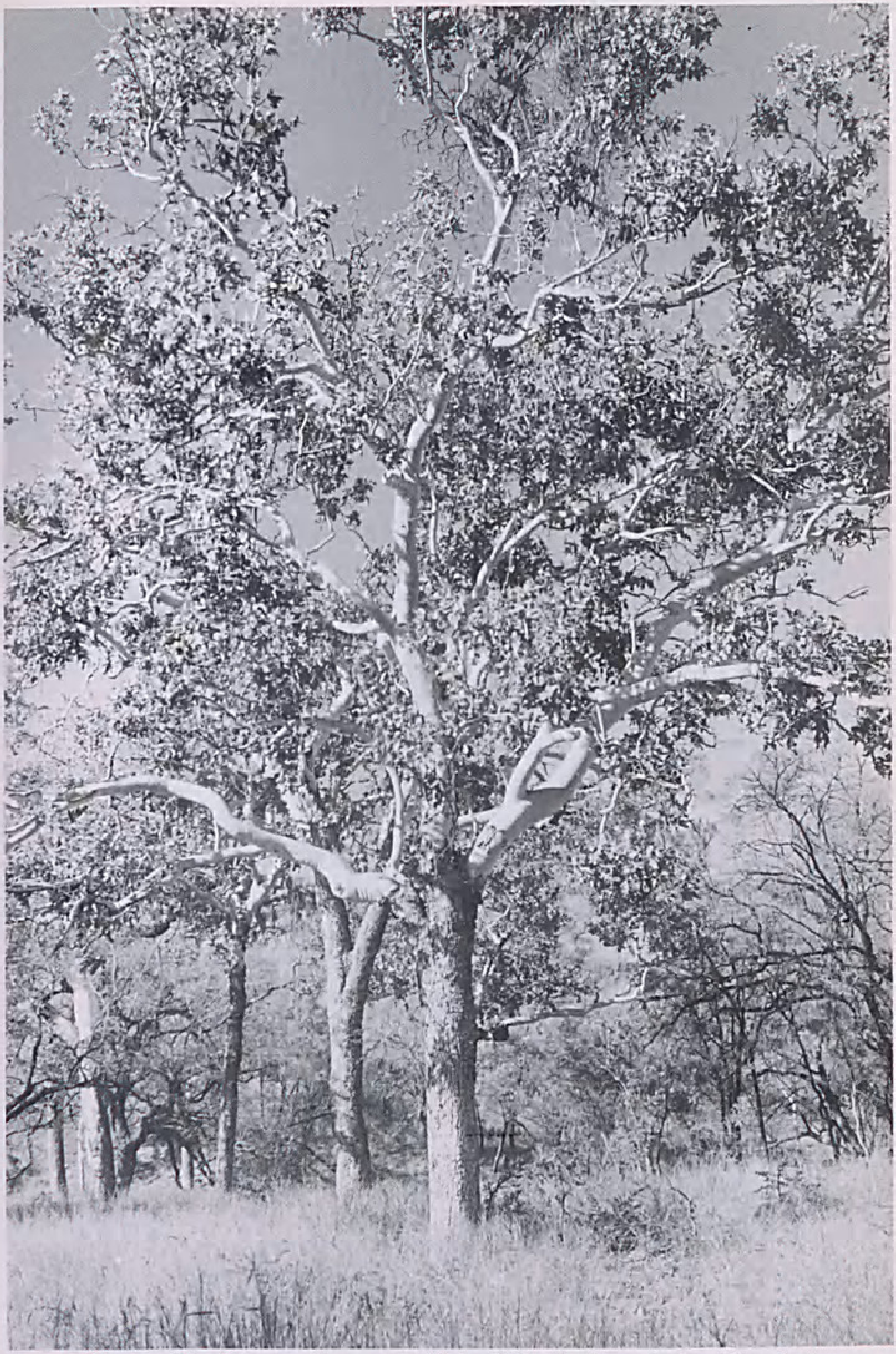


Figure 16. Stream levee at Wulwuldji dominated by *Eucalyptus confertiflora*. Note sparse canopy of *Lysiphyllum cunninghamii* in background. Photo KFK.

Figure 17. Stream levee adjacent to Red Rock Creek near Bungle Bungle Outcamp dominated by *Eucalyptus papuana* on deep alluvial soils. Photo KFK.

contortus, Sehima nervosum and *Eulalia fulva*. The former is an indicator of disturbance (see 2.1). Small shrubs such as *Crotalaria novae-hollandiae, C. verrucosa* and *Tephrosia rosea* and herbs, *Euphorbia* spp. and *Pterocaulon* spp. colonise scalds where cover has been removed. *Adansonia gregorii* is uncommon in the study area but is a distinctive feature of this community when it occurs.

Soils are dependent on surrounding geology, typically alluvial silts and sands. In the Wickham Land System sandstones predominate whilst the Antrim Land System is predominantly basalt and is severely degraded.

3. LOWLAND PLAINS (Figures 18-21)

3.1 Interfluves and undulating plains (Figure 18)

An open woodland dominated by *Eucalyptus dichromophloia* or *E. terminalis* is common on interfluves, undulating plains and lower slopes. Scattered small trees, principally *Lysiphyllum cunninghamii* and *Hakea arborescens* and shrubs, principally *Carissa lanceolata* form the middle layer. The groundstorey is generally grassy with *Aristida* spp., *Cymbopogon bombycinus* and 'spinifex' being abundant. Shallow, skeletal soils are formed from a wide range of parent materials. *Eucalyptus dichromophloia* is considered typical of acid rocks, and *E. terminalis* typical of basic rocks in this region (Perry 1970, Aldrick et al. 1978).

This community is found in the Antrim, Dockrell and Wickham Land Systems.

3.2 Sand plains surrounding Bungle Bungle massif (Figure 19)

The Bungle Bungle massif is surrounded by an uneven woodland fringe, developed on sands derived from the massif forming massive red and yellow earths. The silver-blue shoots of the dominant *Eucalyptus collina* readily distinguish this fringe from adjoining communities. The density of *E. collina* indicates the catchment value of the massif. Shrubs and small trees include *Dolichandrone heterophylla, Grevillea miniata, G. pyramidalis* and *Grevillea* sp. affin. *wickhamii. Acacia* scrubs, dominated by *A. lysiphloia, A. tumida* and *A. stipuligera* occur in some areas. An Aboriginal informant (R. Wallaby pers. comm.) observes that these scrubs are the relatively recent results of lack of firing. However, they may eventually be excluded by an absence of fire. 'Spinifex', including *Plectrachne pungens* dominates the understorey.

The community is developed on the Buchanan Land System.

3.3 Black soil plains (Figure 20)

Black soil plains are limited to narrow bands west and north of the massif, within the study area. The plains are now grossly degraded with extensive sheet and gully erosion and only minimal groundcover. *Parkinsonia aculeata, Acacia farnesiana* and *Calotropis procera* occur in thickets around the Outcamp. These species are all considered invasive of over-trampled areas, although only the latter two are found away from the Outcamp. Scattered shrubs of *Cassia venusta* characterise the shrub layer, with *Aerva javanica* occasional on the most degraded sites. The ground layer, where present, is dominated by *Cenchrus* spp. All of the above species are colonisers.

In an undisturbed state the black soil plains are grasslands with scattered emergent trees, particularly *Terminalia arostrata, T. volucris* and *Lysiphyllum cunninghamii*. Perennial grasses including *Astrebla* spp., *Dichanthium* spp., *Chrysopogon fallax* and *Themeda australis* are now virtually absent in the study area (de Salis 1982).

These grey and brown cracking clays are derived from basalts and limestones and are included in the Antrim Land System.

Figure 18. Open woodland dominated by *Eucalyptus dichromophloia* south of Bungle Bungle Outcamp on Tickalara Track looking towards Bungle Bungle massif. Photo KFK.

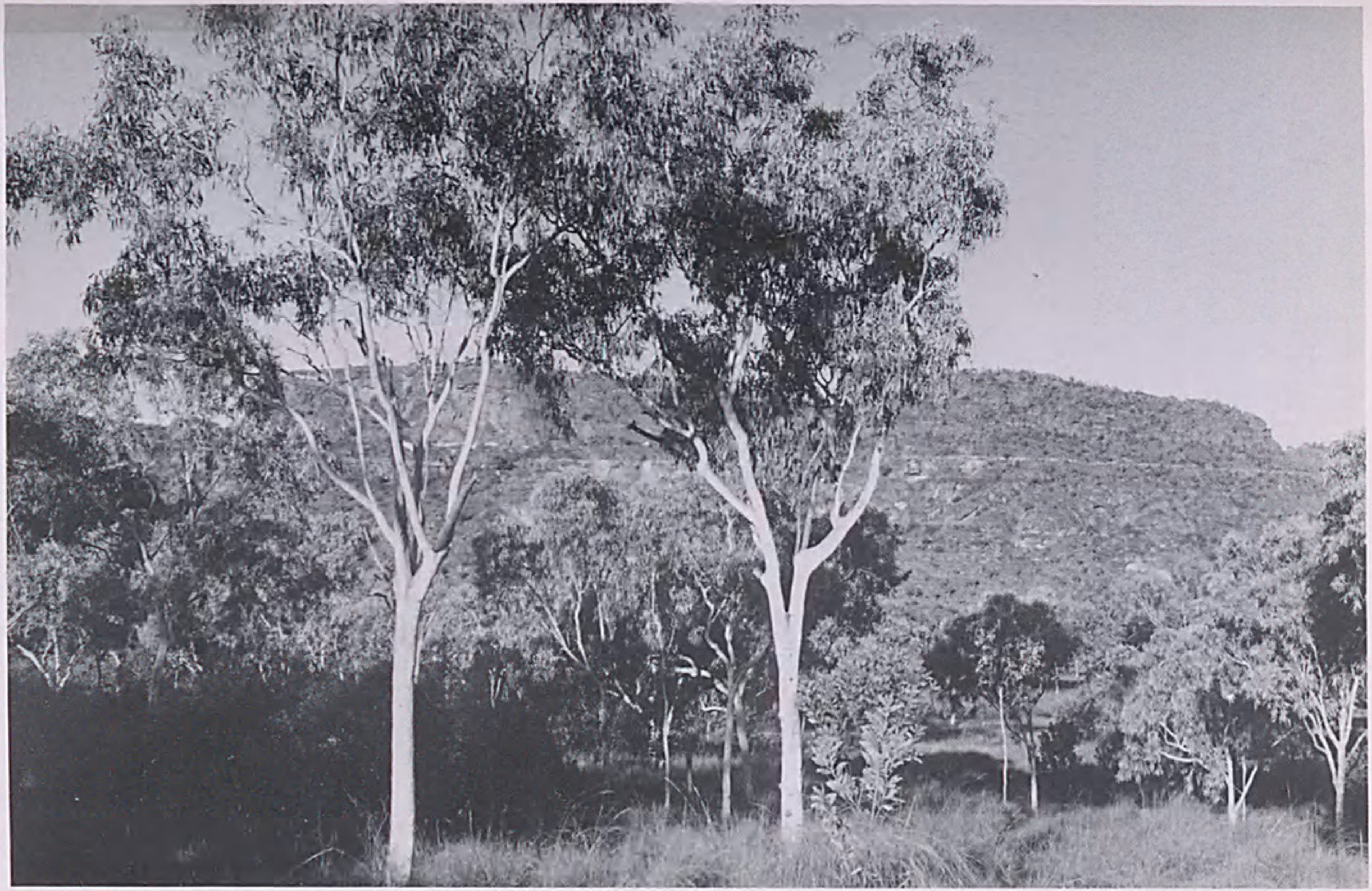


Figure 19. Woodland on sandplain adjacent to Bungle Bungle massif north-east of Blue Holes. *Eucalyptus collina* is dominant to an understorey of *Acacia stipuligera* and *Plectrachne pungens*. Photo KFK.

Figure 20. Black soil plain looking south toward Bungle Bungle massif and Mindjiyurrdji. The plain is virtually treeless. Photo SJF.

3.4 **Calcareous red earths** (Figure 21)

A low woodland dominated by *Eucalyptus pruinosa, Eucalyptus* affin. *pruinosa* and *E. terminalis* was recorded in a number of areas but was not observed to be extensive.

A sparse understorey of 'spinifex', *Acacia, Carissa lanceolata* and *Gossypium australe* were common features.

The community may formerly have been more abundant on the scalds around Bellburn Creek and Red Rock Creek where a degraded sub-climax dominated by 'spinifex' and *Aerva javanica* is now dominant.

The community is included in the Antrim and Wickham Land Systems.

4. HILLS AND SLOPES (Figures 22-24)

4.1 **Rocky slopes** (Figure 22)

A low open woodland of *Eucalyptus brevifolia* and occasionally *E. dichromophloia* occurs on sandstone and shale slopes over much of the study area, excluding the Bungle Bungle massif.

'Spinifex' is the dominant groundcover. Stable slopes, such as in the Osmond Creek catchment are relatively species rich.

Common small trees include *Cochlospermum fraseri, Brachychiton viscidulus, Terminalia carpentariae* and *T. canescens. Calytrix exstipulata* is characteristic of rocky declivities. Exposed stony slopes are usually characterised by a leguminous scrub of *Acacia lycopodifolia, A. cowleana, A. retivenia, Atylosia reticulata* or *Tephrosia virens.* Areas of this community above Red Rock Creek near the Bungle Bungle Outcamp were burnt early in the dry season 1984. The fire ecology of this community may explain much of the variation observed in the field. It occurs on Antrim, Dockrell and Wickham Land Systems.

4.2 **Scree and boulder slopes of Bungle Bungle massif** (Figure 23)

The escarpment of the massif is surrounded by a narrow band of boulder and scree which carries a low open woodland dominated by *Eucalyptus cliftoniana. Eucalyptus brachyandra* is an occasional sub-dominant. Shrubs include *Calytrix exstipulata, Grevillea miniata, Grevillea* sp. affin. *wickhamii, Grevillea psilantha, Persoonia falcata, Gardenia pyriformis* and a *Comesperma* species (KFK 9242, 9247; SJF 2579). *Ficus* spp. are common on rock surfaces. The groundlayer is dominated by *Cymbopogon procerus* and 'spinifex'. The higher effective rainfall surrounding the massif and the unconsolidated substrate apparently differentiates this community from 4.1.

The community is included in the Elder Land System.

4.3 **Limestone outcrops** (Figure 24)

A number of shrubs and small trees commonly occur together on limestone outcrops. Although typically scattered on favourable sites, thickets of low closed forest are formed. *Celtis philippinensis, Ficus opposita, Premna acuminata, Clerodendrum tomentosum* and *Vitex glabrata* are dominant. *Dodonaea polyzyga* and *Opilia amentacea* are occasional shrubs and *Operculina brownii* a common trailer.

The outcrops in the northern and western Bungle Bungle are in the Antrim Land System.

Figure 21. Sheet and gully erosion are characteristic of red soil plains south and east of the Bungle Bungle massif. These degraded areas are mostly devoid of vegetation, however stands of *Eucalyptus pruinosa, E.* affin. *pruinosa* and *E. terminalis* occur. Photo KFK.

Figure 22. Rocky hillside dominated by spinifex and scattered trees of *Eucalyptus brevifolia* near Wulwuldji. Photo KFK.

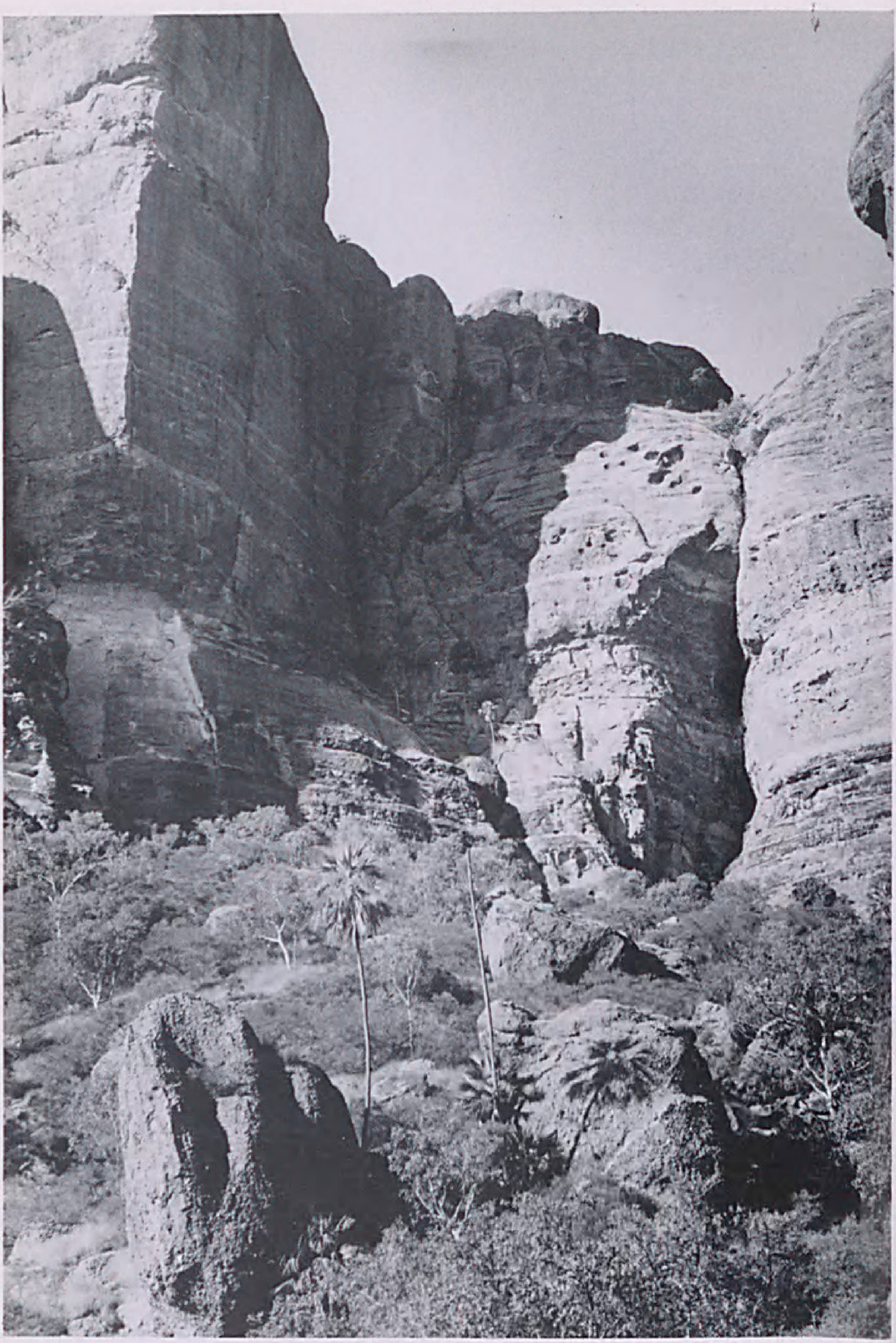


Figure 23. Boulder and scree slope below Bungle Bungle massif south-east of Bungle Bungle Outcamp. Photo KFK.

Figure 24. Low closed forest thicket on limestone outcrop near Bungle Bungle Outcamp. Photo KFK.

Figure 25. Sandstone pavement on Bungle Bungle plateau with scattered *Eucalyptus cliftoniana* with *Acacia* spp. and *Grevillea* spp. Photo KFK.

5. **PLATEAUS** (Figure 25)

5.1 **Bungle Bungle plateau** (Figure 25)

The plateau carries a rather depauperate low open woodland dominated by *Eucalyptus cliftoniana* and scattered stands of *E. collina* with a sparse shrub layer of *Grevillea refracta, Grevillea* sp. affin. *wickhamii, Acacia acradenia, A. eriopoda* and *A. retivenia. Petalostylis cassioides* is an uncommon associate. The lichen *Microthelia aterrima* is a conspicuous epiphyte over extensive areas of otherwise bare rock.

The community is developed on weak sandstone lithosols included in the Elder Land System.

5.2 **Osmond plateau and surrounds**

A low open woodland dominated by *Eucalyptus collina* with a 'spinifex' understorey is the most widespread association on the plateau. The only record of *E. cupularis* within the study area is from this community. Pockets of closed riparian forest surrounding areas of hot springs along Osmond Creek are reported from the plateau (A.S. Weston pers. comm.). No collections were made from the Osmond plateau, which is included in the Wickham Land System. The community is developed on sandstone and quartzite lithosols.

BOTANICAL SIGNIFICANCE

These notes consider the botanical significance of restricted plant communities and species only and do not take account of the overall conservation status of more widespread plant communities for which the reader is referred to Specht (1974), Beard (1979) and Beadle (1981).

The absence of major reserves in the region suggests that even the widespread plant communities may require reservation; further studies are required to assess conservation status.

The complex of permanent and semi-permanent streams in the Osmond Valley supports closed forest of regional significance. The area is the most south-easterly extension of such forest reported in Western Australia. Sheltered, well-drained sites are dominated by trees such as *Syzygium angophoroides, Ficus racemosa, Carallia brachiata* and *Euodia elleryana*. The latter has only been reported twice previously for Western Australia. Poorly drained sites are dominated by trees such as *Sesbania grandiflora, Timonius timon* and venerable specimens of *Melaleuca leucadendra* over swards of *Cyclosorus interruptus* and *Colocasia esculenta. Pandanus* species characterise some areas. A sedge previously unrecorded for Western Australia, *Cyperus eleusinoides*, was collected from one such site. All of the above species (and many others) are virtually confined to the closed forest. The juxtaposition of this vegetation with the surrounding dry tree steppe (low open woodland) is of high educational value. *Colocasia esculenta* (Taro) is confined to a few localities in the Kimberley but is a widespread economic species grown as a rootcrop throughout the humid tropics. The population was formerly utilised by aborigines (Scarlett unpub.) who ate the large central starchy corms. As an isolated population, it is considered a valuable genetic resource. Material from this population has been successfully cultivated at the Royal Botanic Gardens, Melbourne.

A stand of riparian closed forest at Blue Holes on the Ord River is also significant although floristically depauperate compared with the Osmond Valley. The presence of *Syzygium eucalyptoides* and *Phragmites karka* is noteworthy as these species have not been recorded elsewhere in the study area.

Winnama Gorge, north of Palms Yard and outside the Osmond Valley catchment, supports vegetation of regional significance including the best developed closed forest stand in the study area. Although the dominant species are shared with the Osmond Valley, the ground flora of the sheltered gorge tract contains many additional species. Ferns are abundant, including the only records for the south-eastern Kimberley of *Blechnum orientale*, *Lindsaea ensifolia* and *Nephrolepis hirsutula*. *Psilotum nudum* is a rare though widely distributed fern ally occurring on the gorge walls. A new sedge record for Western Australia, *Cyperus polystachyos*, was collected from the gorge floor.

Winnama Gorge is a restricted, sensitive and extremely vulnerable site requiring considerate future management. The site is unsuitable for camping for this reason.

The vegetation surrounding the sheltered gorge tract is equally significant. The dry tree steppe (low open woodland) supports the second known populations of an undescribed *Hibiscus* species 'Middle Springs', an undescribed *Josephinia* species and the first Western Australian collections of an undescribed *Blumea* (previously recorded from the Northern Territory). Unusual Euphorbiaceae represented include *Chamaesyce* affin. *micradenia*, *Euphorbia* affin. *tannensis* and *Petalostigma nummularium*.

The Bungle Bungle massif is of national significance. Although it generally supports a rather depauperate vegetation, a number of rare or restricted species, new records for Western Australia, elements of biogeographic significance and undescribed species are reported here. *Livistona* species 'Victoria River', an undescribed palm, characteristic of the massif is considered a restricted species of horticultural potential. *Grevillea psilantha* is a showy shrub first collected during this survey. The first collection of *Blumea pungens*, other than the type, was made in the associated gorge tract. New records for Western Australia include the fern *Taenitis pinnata*, the moss *Uleobryum peruvianum*, the scrambler *Stephania japonica*, the shrub *Jacksonia odontoclada*, the shrub *Comesperma* sp. (KFK 9242, 9247; SJF 2579) and the tree *Leptospermum parviflorum*.

CONSERVATION

Sheltered habitats, in the permanently moist chasms and gorges of the Bungle Bungle, are of high conservation significance. These areas are restricted in their occurrence within the region and have provided refugia for species during drought and climatic variation. As access to the Bungle Bungle massif at present is through gorges (such as Piccaninny Gorge) tourist pressure is concentrated on these sensitive and vulnerable areas.

The sand plain surrounding the Bungle Bungle forms part of the Ord River Regeneration Reserve and is severely degraded due to a past history of overgrazing combined with the present impact of feral cattle, donkeys and camels. The reserve was set aside in 1967 for regeneration of eroded areas and control of siltation in Lake Argyle. Uncontrolled access of vehicles to the Regeneration Reserve will exacerbate erosional problems and facilitate the spread of alien plant species. Erosion can result from structural damage to soils and from destruction of soil microflora. Soil microflora (fungi, algae and lichens) commonly form fragile, self-mulching crusts which bind soil and fix nutrients. Aboriginal informants (e.g. R. Wallaby pers. comm.) have observed that *Heteropogon contortus* is favoured by burning and other disturbance and has increased its occurrence throughout the sandplain (see e.g. Groves and Williams 1981). Additionally the introduced species *Calotropis procera* and *Parkinsonia aculeata* occur near the Bungle Bungle Outcamp and could be spread by vehicles throughout the area.

The absence of detailed biological surveys of the region makes accurate assessment of the conservation significance of species collected or habitats recorded in the study area impossible. Further surveys of the East Kimberley are required.

ACKNOWLEDGEMENTS

The authors are indebted to all members of the expedition for their assistance in the collection of specimens and in making available information from their field notes. Without their willing support both in the field and on return little would have been accomplished.

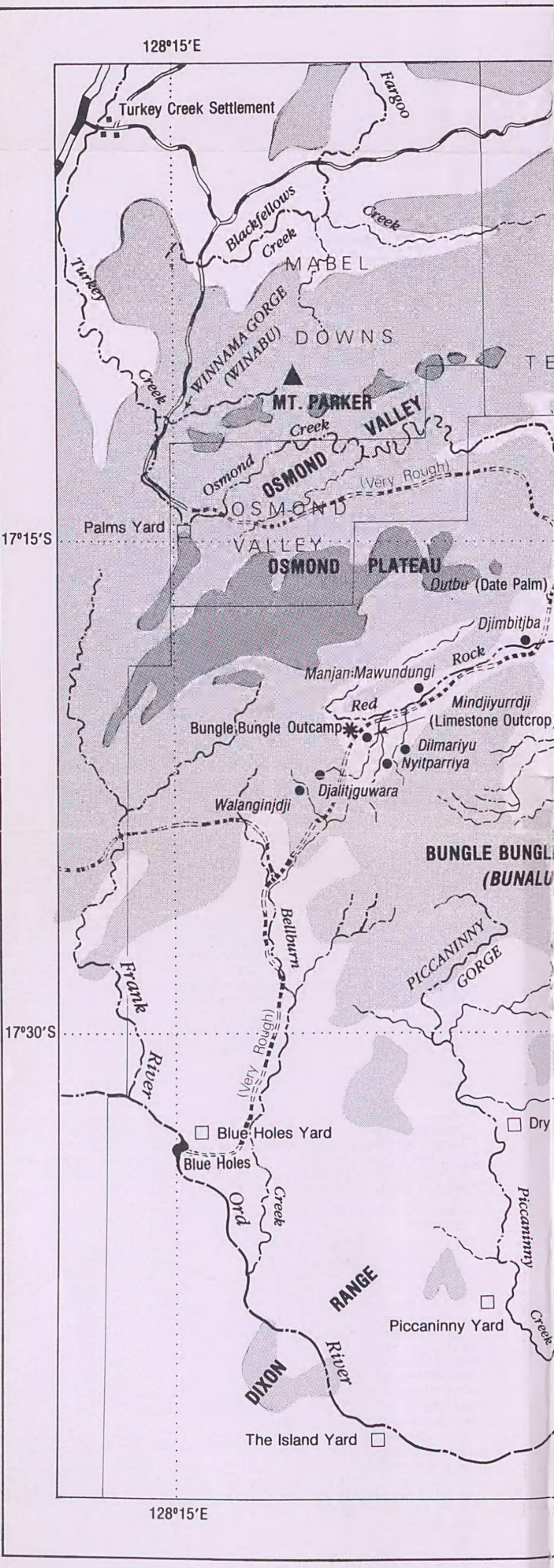
Work within the study area was facilitated by assistance from leaseholders and traditional owners. Jack Green (Osmond Valley Station), Samim Australia Pty. Ltd. (mining and exploration leaseholder, Osmond Range), Western Australian Department of Agriculture officers (for Ord River Station) and the Warmun Aboriginal Community (especially Raymond Wallaby) all assisted the study. In particular Raymond Wallaby's detailed knowledge of access and plant distribution allowed efficient use of available time.

The field work of S.J. Forbes was funded, in part, by a grant from the Australian Heritage Commission with support from ARB Vehicle Accessories, BHP Petroleum Pty. Ltd. and Ansett Airlines of Australia all of whom are gratefully acknowledged.

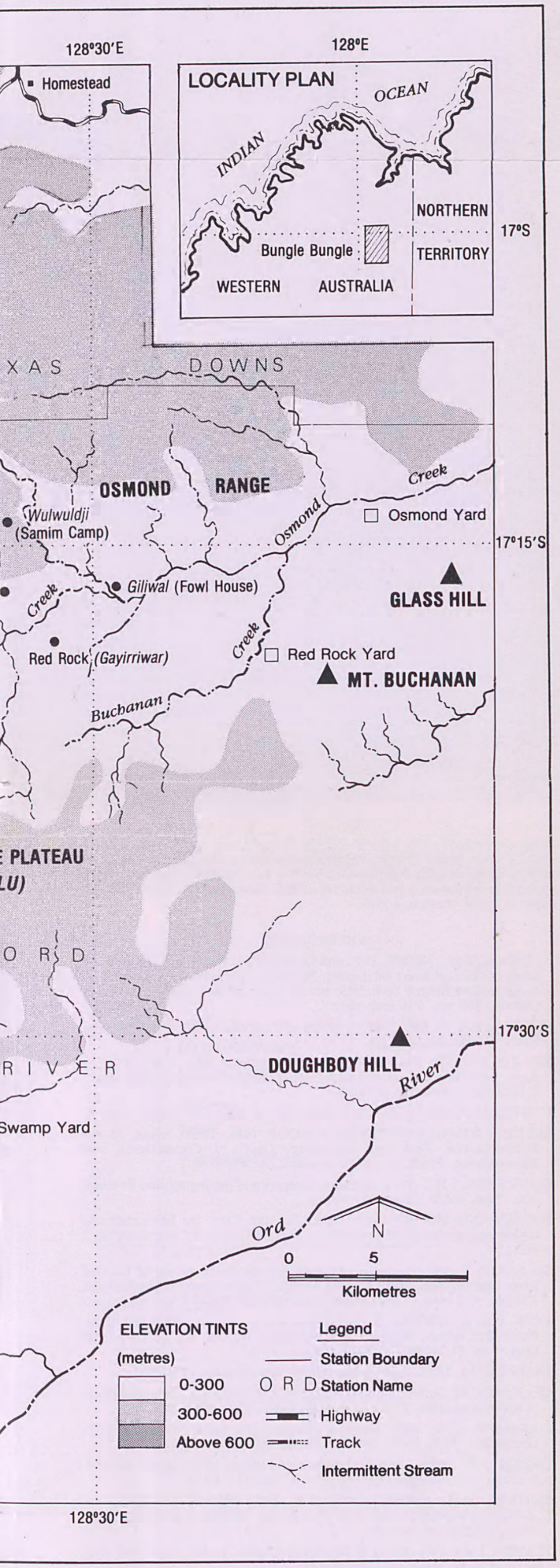
Whilst in the Kimberley, Chris Done (Western Australian Forests Department) provided invaluable assistance with all aspects of fieldwork. Allan Tegg (Warmun Aboriginal Community), Arthur Weston and David Pratchett (Western Australian Department of Agriculture) provided valuable information regarding access to the study area. Marion Blackwell and Arthur Weston kindly made available additional plant collections.

Assistance with identification of specimens was provided by the following botanists:

H.I. Aston (MEL) — Aquatics
R.M. Barker (AD) — Acanthaceae
W.R. Barker (AD) — *Josephinia*
B.A. Barlow (CANB) — *Melaleuca*, Loranthaceae
M.I.H. Brooker (FRI) — *Eucalyptus*
P. Buchanan (DSIR, Auckland, N.Z.) — Fungi
R.C. Carolin (SYD) — Goodeniaceae
D.G. Catcheside — Bryophyta
W.L. Chew (NSW) — *Ficus*
R.J. Chinnock (AD) — Pteridophyta
B.J. Conn (MEL) — *Mitrasacme*, Lamiaceae
L. Craven (CANB) — *Hibiscus, Heliotropium*
M.D. Crisp (CBG) — Papilionaceae
C.R. Dunlop (DNA) — Asteraceae, general
R.B. Filson (MEL) — Lichens
P.S. Green (K) — *Jasminum*
G.P. Guymer (BRI) — *Brachychiton*
R.N. Hilton (UWA) — Fungi
D.L. Jones — *Taenitis*
M. Lazarides (CANB) — Poaceae
B.R. Maslin (PERTH) — *Acacia*
D.J. McGillivray (NSW) — *Grevillea*
L. Pedley (BRI) — *Tephrosia*
C. Puttock (UNSW) — *Gardenia*
J.H. Ross (MEL) — Caesalpiniaceae, Papilionaceae
G.A.M. Scott (MONU) — Hepaticae
B.C. Stone (PH) — *Pandanus*
I.G. Stone — Bryophyta
J. Thompson (NSW) — *Leptospermum*
J.G. West (CANB) — *Dodonaea*
P. Weston (NSW) — *Boronia, Persoonia*
J.H. Willis — Fungi
K.L. Wilson (NSW) — Cyperaceae



Map 1. The Study Area — Bungle Bungle and environs, south-eastern Kimberley, Wester
maps and from Gidja informants, especially R. Wallaby. (Prepared by G. Dunnett, U



n Australia, showing main features and collecting localities. Names are from topographic
per Yarra and Dandenong Valley Authority, Melbourne).