

Vegetation on rocky outcrops and ranges in central and south-western New South Wales

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Abstract

Norris, E.H. & Thomas, J.* (*National Herbarium of New South Wales, Royal Botanic Gardens, Sydney, NSW, Australia* 2000) 1991. *Vegetation on rocky outcrops and ranges in central and south-western New South Wales*. *Cunninghamia* 2(3): 411–441. The natural vegetation of rocky outcrops and ranges in the Lake Cargelligo, Griffith and Berrigan district (33°19'S 146°22'E to 35°40'S 145°49'E) is described (Central Western Slopes, South Western Slopes and South Western Plains botanical subdivisions). Nineteen sites were sampled on different geological types: sandstone, granite, slate and rhyolite. Vegetation in general is eucalypt woodland with a mixed shrubby to herbaceous understorey. Plant communities relate to geological type. A list of 338 species (283 native, 55 exotic) is provided. Isolation of the vegetation as a result of clearing for agriculture, and the disturbance of many of these sites by feral animals, grazing and quarrying are important factors to consider for future conservation and management.

Introduction

Low ranges and isolated rocky outcrops representing the boundary between outcropping Palaeozoic bedrock and the Tertiary/Quaternary alluvial plains flank the eastern edge of the South Western Plains of New South Wales. Being less accessible and having generally poorer soils, these outcrops often retain the only natural vegetation in a landscape substantially modified by agricultural use. Some are conserved as National Parks or Nature Reserves, whilst others, such as Mount Galore, are under the control of local Shire Councils. Others are subject to varying degrees of grazing and other land use.

Little information is available on the vegetation of these outcrops, especially the smaller ones (NSW National Parks & Wildlife Service, Forestry Commission of NSW and the Soil Conservation Service of NSW pers. comm.). This study examines rocky outcrops and ranges between the towns of Lake Cargelligo in the north and Corowa in the south (300 km apart), and between Ardlethan in the east and Jerilderie to the west (110 km apart) (Figure 1). These include the Cocoparra, Lachlan and McPhersons Ranges, Boat Hill and Mount Boomanoomana. Also included were the Keginni Range north of Roto, and Manfred Range south of Darnick. An initial account of the vegetation of these rocky areas and their potential conservation significance is provided.

Geology and soils

The rocky outcrops within the study area comprise Palaeozoic geosynclinal sediments within the Lachlan Geosyncline, a marine trough forming part of the Central and Southern Highland Fold Belt (Packham 1969; Butler et al. 1973)). Part of the Lachlan Geosyncline is characterized by a wide belt of Ordovician sedimentary and

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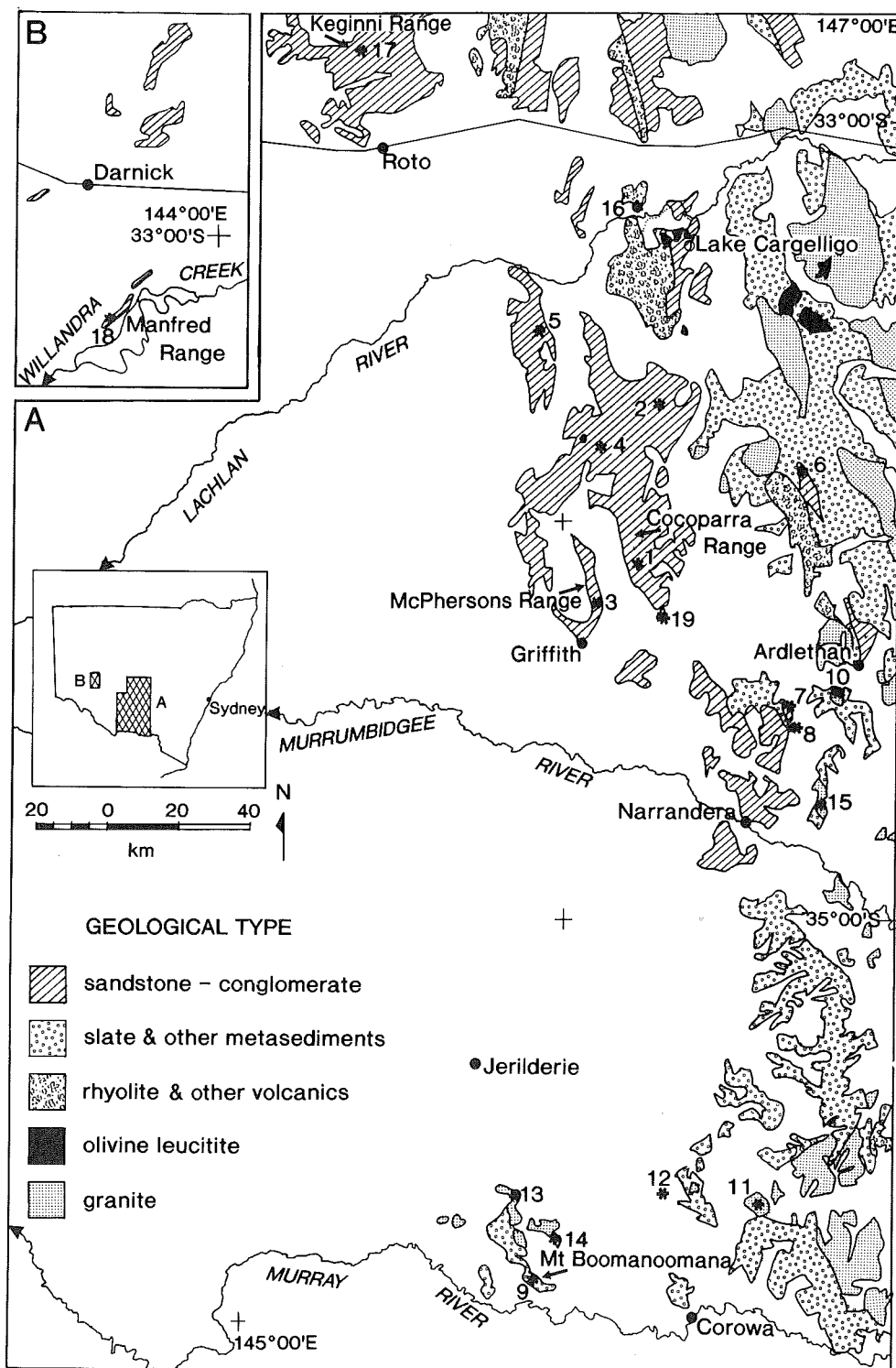


Figure 1. Map showing the study area and the main geological types (modified from Geological Survey of New South Wales (1972)). Numbers refer to sites. Major towns and rivers are also shown.

metamorphic rocks and granite masses (the Wagga Metamorphic Belt), with the western flank comprising a large area of Upper Devonian quartz sandstones of the Cocoparra Group. Some minor occurrences of possible Silurian sediments and volcanics can be found within its boundaries (Packham 1969). Hills north and west of Lake Cargelligo are formed on quartz-feldspar porphyries and rhyolites. Sandstones of the Mulga Downs Group outcrop in the northern and western section of the study area and include the Keginni and Manfred Ranges respectively (Geological Survey of New South Wales various dates 1971, 1968) (Figure 1, Table 1).

Skeletal soils or lithosols occur where rock is near the surface. These comprise shallow sands, loams and clay loams and are always stony or gravelly due to the presence of fragmented rock material showing some degree of weathering. (Stace et al 1968). Sandstone lithosols are found at sites in the Manfred, Keginni and Cocoparra Ranges, at Mount Bunganbil, Mount Wammera and sections of Jimberoo Creek State Forest.

Deeper soils derived from sandstones, mapped as massive, neutral red earths (Soil Conservation Service 1986), occur on slopes in Cocoparra National Park, the Lachlan and McPhersons Ranges and Jimberoo Creek State Forest. These soils are mainly sandy in texture, red-brown to brown in colour with a weak profile differentiation gradually increasing in clay content with depth (Stace et al 1968).

Surface weathering of granite usually produces a shallow sandy loam. Such soils can be found at sites including Berrigan, Grong Grong and parts of Mount Goombargana. Granite-derived soils at sites influenced by slope tend to have a contrasting profile with the A-horizon being a loamy sand to sandy loam 20–30 mm thick overlying a very sandy clay. Such profiles occur at several sites including Mount Goombargana, Bald Hill Tank and The Boat Hill.

Geomorphology

The landscape is characterised by depositional sand and flood plains surrounded by a margin of low relief erosional landforms rising 30 to 300 m above the adjacent plains (Palfreyman 1984). Erosion has resulted in valley incision with narrow alluvial valleys within the ranges and bands of alluvial and colluvial material around the footslopes. The long continued action of streams is evident by the depth of alluvium accumulated on the plains to the west (Butler et al 1973).

Vegetation

Prior to European settlement, the vegetation of the region was a mosaic of open-forest, mallee and *Acacia pendula* shrublands on the plains country, whilst the outcrops and ranges carried forests and woodlands. Allan Cunningham (1817) collected species from these outcrops and ranges including *Hibbertia*, *Goodenia*, *Grevillea* and *Prostanthera* from Mount Narriah and the Cocoparra Range.

Cambage (1901) recorded species between Mount Hope and Parkes, Beadle (1948) described the *Eucalyptus dealbata* – *E. sideroxylon* Association (using the name *E. dealbata* for what we now know as *E. dwyeri*) occurring on some of these rocky outcrops with notes on soils and erosion, and Moore (1953) described vegetation alliances of the south-eastern Riverina, listing species and discussing the relationships between vegetation and environmental factors. There are also species lists for prominent outcrops and ranges such as The Rock, Mount Galore and Cocoparra National Park and Nature Reserve (Willis 1967; Logan 1974; National Parks & Wildlife Service no date; Bladen no date; Burrows 1989). Cunningham et al (1981) include habit and habitat details for species recorded from these rocky outcrops and ranges. The Con-

Table 1. Site number, locality, map sheet and grid reference (1:250 000 topographic sheet); elevation (m) and area (ha), geology and field observations for sites recorded in this survey.

Site no.	Locality map sheet grid ref.	Elevation (m) area (ha)	Geology	Field observations
1	Mt Bingar NARRANDERA GR 424785	455 m >1000 ha	Late Devonian Cocoparra Group: pebbly sandstone with thin conglomerate bands, sandstone and lithic sandstone	sandstone; shallow brown sandy loam, c. 10cm deep; stones on surface
2	Jimberoo Ck State Forest CARGELLIGO GR 427837	c.300 m >1000 ha	Cocoparra Group: sandstone and siltstone, orthoquartzitic sandstone	sandstone; slope area - dark sandy skeletal material, well drained ridge area - brown loamy sand, shal- low and stony, many boulders
3	McPhersons Range NARRANDERA GR 409778	254 m >1000 ha	as for Site 1	sandstone; soils generally thin; clayey on footslopes & small benches
4	Flagstaff Hill CARGELLIGO GR 410824	380 m >1000 ha	as for Site 1	sandstone; hard compacted reddish clay
5	Lachlan Range CARGELLIGO GR 397855	c. 340 m >1000 ha	as for Site 1	no field data
6	Mt Narriah CARGELLIGO GR 472816	486 m c. 500 ha	as for Site 2	sandstone, abundant outcrops; soils skeletal sandy in parts; more clayey in bench & saddle areas
7	Mt Bunganbil NARRANDERA GR 467743	c. 300 m c. 700 ha	Cocoparra Group: conglomerate, pebbly sandstone, sandstone & siltstone, lithic sandstone	sandstone; shallow loamy well drained soils; deeper soils on benches; summit & eastern aspect with sandy skeletal soil and large exposed bedrock areas
8	Mt Wammera NARRANDERA GR 471734	331 m 200 ha	as for Site 7	sandstone & pebbly sandstone; footslopes - damp shallow clayey sand; westerly bench - shallow sandy soils, deep in parts with higher clay content

Site No.	Locality map sheet grid ref.	Elevation (m) area (ha)	Geology	Field observations
9	Mt Boomanoomana JERILDERIE GR 390567	255 m c. 600 ha	Ordovician low grade metasediments: slates, phyllites, quartzose greywacke	metasediments; shallow sandy soils with many stone fragments on the surface in more exposed areas
10	Bald Hill Tank NARRANDERA GR 483745	284 m <100 ha	Middle Silurian Ardlethan Granite: porphyritic muscovite-biotite granite	granite; coarse sandy granitic soil, shallow in parts over exposed bedrock; seepage areas on lower slopes.
11	Mt Goombargana JERILDERIE GR 459591	403 m c. 600 ha	Jindera Granite: biotite granite	granite; coarse granitic sandy soils
12	Quarry JERILDERIE GR 439596	250 m c. 200 ha	as for Site 11	as for Site 11
13	Berrigan JERILDERIE GR 383592	120 m <100 ha	Berrigan Granite: coarse biotite granite	as for Site 11
14	The Boat Hill JERILDERIE GR 397582	182 m <100 ha	as for Site 13	as for Site 11
15	Grong Grong NARRANDERA GR 478712	189 m <100 ha	Grong Grong Granite: medium-grained muscovite-biotite granite	granite; loamy sand
16	Mt Rossi CARGELLIGO GR 421881	380 m >1000 ha	Silurian (?) Ural volcanics: rhyolite, rhyolite breccia, quartz-feldspar porphyry, chert and tuff	geology not confirmed; dark sandy loam
17	Keginni Range IVANHOE GR 336943	c.150 m >1000 ha	Late Devonian Mulga Downs Group: quartzite and sandstone, pebbly to conglomeratic in part, siltstone and shale.	sandstone; soils not investigated
18	Manfred Range POONCARIE GR 748323	176 m c.1000 ha	as for Site 17	no field data
19	Mt Binya NARRANDERA GR 429774	224 m >1000 ha	as for Site 17	sandstone; soils not investigated

dobolin, Cobar and Hay District Technical Manuals (Soil Conservation Service 1974, 1978, 1986) include information on vegetation, geology and soils for outcrops occurring within their districts and the Forestry Commission (1984) describes vegetation types on ranges within the the Griffith Forestry District.

Climate

The region is semi-arid and displays a rainfall and reliability gradient from east to west. Stations at Jerilderie, Narrandera, Griffith and Lake Cargelligo receive an average annual rainfall between 380–420 mm. Keginni Range receives approximately 330 mm whilst Manfred Range in the west receives 263 mm (Bureau of Meteorology 1991). Over the long term rainfall is generally winter dominant although there have been periods when a summer rainfall influence has extended to the NSW–Victorian border (Cunningham et al 1981).

Average temperatures for the area range from the 30 and 35°C for summer maxima with summer minima between 14 and 18°C. Winter maxima are between 13 and 16°C with winter minima between 3 and 5° C (Bureau of Meteorology 1991).

History and land use

Several Aboriginal tribes occupied the region. To the east the Wiradjuri inhabited the plains and waterways such as the Lachlan River, with their territory extending east to the Western Slopes. The Barkindji occupied country east of the Darling River including the Manara Hills, Manfred Range and the Willandra Lakes system (Allen 1979/1980; Central Mapping Authority 1987).

John Oxley explored the area in 1817. On arriving at the base of Mount Narriah (Site 6) he wrote 'The country having been recently burnt, some good grass was found for the horses a little to the south west' (Oxley 1820). On many occasions he makes reference to the presence of Aboriginal people in the region commenting on their behaviour and use of fire. 'Three or four fires were seen in the north west, and recent traces of the natives were discovered near our tents'.

Squatters moved stock into the area from the late 1830s. Land along the river systems was taken up first, and by 1848 there were a number of runs established (Soil Conservation Service 1974). Cattle at first predominated but were later replaced by sheep (Cunningham et al 1981). Wheat had been sown by 1866 and became the major agricultural product at the end of the nineteenth century (Forestry Commission 1984). Mining has occurred particularly north of Lake Cargelligo where copper mining began in the late 1860s; copper and gold mining were reported at the turn of the century between Mount Tinda and Condobolin (Cambage 1901). Granite outcrops to the south of the study area have been quarried for road and railway construction material.

Clearing of the best agricultural lands between about 1880 and 1910 left islands of vegetation on the more infertile and/or inaccessible outcrops and ranges. State Forests were declared over remnant forest and woodlands in the early twentieth century and many are associated with the range system and include the Lachlan and Melbergen Ranges, the Naradhan Range and associated Jimberoo Creek area. Apart from the economic value of the timber the state forests are used for recreation, education, apiary and grazing (Forestry Commission 1984).

Methods

Potentially rocky areas were identified from the 1:250 000 geological maps, Cargelligo, Narrandera, Jerilderie, Ivanhoe (Geological Survey of New South Wales various dates) and the 1:500 000 Wentworth sheet (1971). The presence of natural vegetation and the isolation and accessibility of these rocky areas were determined from photomosaics (New South Wales Department of Lands 1:50 000 Photomap Series).

Field inspection of a representative range of rocky outcrops was carried out. Four major geological types were sampled; sandstones (Cocoparra Group, Mulga Downs Group), granite (Ardlethan Granite, Jindera Granite, Berrigan Granite, Grong Grong Granite), rhyolite (Ural Volcanics) and slate (low grade metamorphics). The term 'geological type' is used in a generic rather than specific sense as the sites comprise various rock strata. For most sites geology was confirmed in the field (Table 1). Many promising geological areas were seen on the photomosaics to be heavily disturbed and were not visited. This was particularly so for areas of low relief in the south on Ordovician sediments and Silurian granites. Other potential sites deemed worthy of sampling were visited but not sampled because of their obvious clearing of the understorey for pasture; for example, Mount Arthur (NARRANADERA 487694), Mullemblah Hill (JERILDERIE 476059) and Blue Hill (JERILDERIE 489067).

The vegetation of each outcrop was recorded from 20 x 20 m quadrats and traverses. To cover the full range of habitat diversity, quadrats were located on different topographic positions to sample variations in aspect and slope. Up to three quadrats were recorded at a site depending on area and disturbance. In each quadrat floristic composition (both native and exotic), structure (tree height and number of strata) and species abundance (with an abundance scale of frequent, common, occasional and rare) were recorded. In highly disturbed areas with little variation, species were recorded along traverses with brief notes on structure. Most of the data were collected during October 1986 (Sites 2-16). Data from Site 1 was collected in June 1989, Site 17 in June 1988, Site 18 in October 1983, and Site 19 in October 1989.

TWINSpan (two-way indicator species analysis) (Gauch 1982) was used to group Sites 2-16 according to similarities in species composition. Sites 2-16 were used for the numerical analysis as the data were collected at the same time minimising seasonal variation. A total of 248 species comprised the data set. Ordination of the species across sites using the program DECORANA (detrended correspondence analysis and reciprocal averaging) (Gauch 1982) was used as an aid to determine the potential effects of environmental gradients.

Results and discussion

From the nineteen sites and four geological types (sandstone, granite, slate and rhyolite) 338 species were recorded (Appendix) representing 67 families, the dominant being Asteraceae (54 species) and Poaceae (44 species). A total of 25 species were trees, 56 species were shrubs and 257 were ground species. 55 exotic species were recorded, 17 from the Poaceae.

Geological influence

Moore (1953) reported little correlation between vegetation and geological type, explaining that some vegetation alliances develop equally well on soils derived from differing substrates and similar substrates of differing geological ages. In considering dominant tree species this study showed general agreement with Moore (Table 2).

Table 2. General vegetation recorded at each site.**1 Mt Bingar**

Low open-woodland: *Callitris endlicheri* and *Eucalyptus sideroxylon*. Mixed shrubby understorey dominated by *Melaleuca erubescens*, *Grevillea floribunda* and *Calytrix tetragona*.

2 Jimberoo Creek State Forest

Lower slopes dominated by a low open-woodland of *Eucalyptus macrorhyncha*, *E. dwyeri* and *Callitris glaucophylla*. *E. dwyeri* and *Acacia doratoxylon* on ridges. Understorey comprising regenerating shrubs after recent fire (1985).

3 McPhersons Range

Low open-woodland: *Eucalyptus populnea*, *E. dwyeri* and *Acacia doratoxylon*. Dense patches of *Allocasuarina verticillata* amongst *Acacia doratoxylon*. Open grassy understorey.

4 Flagstaff Hill

Low open-forest: *Callitris endlicheri*, occasional *Eucalyptus dwyeri* and *Acacia doratoxylon*. Herbaceous understorey. *Eucalyptus sideroxylon* frequent on slopes with the understorey dominated by dense *C. endlicheri* regeneration.

5 Lachlan Range

Lower slopes a low open-woodland of *Eucalyptus dwyeri* and *Callitris glaucophylla* with a herbaceous understorey (grazed). Steep slopes dominated by a shrubland of *Beyeria viscosa* amongst boulders. Summit dominated by *Acacia doratoxylon*, understorey herbaceous to shrubby (grazed).

6 Mt Narriah

Low open-woodland: *Eucalyptus dwyeri*, *Acacia doratoxylon* and *Callitris glaucophylla*. Shrubby understorey dominated by *Grevillea floribunda*, *Teucrium corymbosum*, *Pandorea pandorana* and *Gonocarpus elatus*. Scattered *Eucalyptus sideroxylon* and *Prostanthera ovalifolia*.

7 Mt Bunganbil

Slopes have a low open-woodland dominated by *Eucalyptus dwyeri*, *Acacia doratoxylon* and *Callitris glaucophylla* with a shrubby understorey of *Grevillea floribunda*, *Cassinia laevis*, *Prostanthera nivea*, *Calytrix tetragona* and *Pandorea pandorana*. *Stypantra glauca* and *Helichrysum semipapposum* common. Summit dominated by *E. dwyeri*, *A. doratoxylon* and *Allocasuarina verticillata*, with *S. glauca*, *C. tetragona* and thickets of *Platysace lanceolata*.

8 Mt Wammera

Slopes dominated by *Eucalyptus dwyeri*, *Acacia doratoxylon* and *Callitris glaucophylla*. Herbaceous understorey comprising *Gonocarpus elatus*, *Stypantra glauca* and various grasses. Ridge areas dominated by *E. dwyeri*, *A. doratoxylon* and *Allocasuarina verticillata* with *Stypantra glauca* and *Platysace lanceolata* and scattered *Prostanthera nivea* and *Calytrix tetragona*.

9 Mt Boomanoomana

Open-woodland: *Eucalyptus microcarpa* and *Callitris glaucophylla*, understorey predominantly grasses with occasional shrubs. *Allocasuarina verticillata* common on stony areas. Dense regrowth of *C. glaucophylla* (4–5 m) on the southern aspect.

10 Bald Hill Tank

Low open-woodland: *Eucalyptus dwyeri* and *Acacia doratoxylon*, herbaceous understorey dominated by *Arctotheca calendula*, *Cheilanthes austrotenuifolia* plus various grasses and forbs.

11 Mt Goombargana

Eucalyptus dwyeri low open-woodland on slopes and summit with occasional *Acacia doratoxylon*. *Allocasuarina verticillata* locally common on flat rock shelves, and small pockets of *Eucalyptus albens* occur below the summit. The herbaceous understorey is dominated by *Gonocarpus elatus*, *Geranium* species, *Erodium botrys*, *Stypantra glauca*, *Vulpia bromoides* and *Bromus rubens*.

12 Quarry

Low open-woodland: *Eucalyptus dwyeri* over a herbaceous understorey dominated by grasses and introduced species.

13 Berrigan

Herbaceous stratum only.

14 The Boat Hill

Low open-woodland: *Eucalyptus melliodora*, *Callitris glaucophylla*, *Crassula* species, *Erodium* species, various grasses and introduced herbs.

15 Grong Grong

Occasional *Eucalyptus dwyeri*, *E. populnea* and *Callitris glaucophylla*. Herbaceous understorey.

16 Mt Rossi

Low open-woodland: *Eucalyptus dwyeri* and *Callitris glaucophylla* on the lower slopes with a herbaceous understorey, massive regrowth of young pine. Midslope dominated by *E. dwyeri*, *Acacia doratoxylon* with occasional *Eremophila longifolia*. Summit carries *E. dwyeri* and *Allocasuarina verticillata* with *Prostanthera nivea*, *Gonocarpus elatus* and occasional *Microseris lanceolata*.

17 Keginni Range

Low open-woodland: *Eucalyptus intertexta*, *Callitris glaucophylla* with scattered *Acacia aneura* and *A. doratoxylon*. Understorey shrubby to herbaceous (grazing) with *Acacia decora* and *Cheilanthes austrotenuifolia*.

18 Manfred Range

Open-shrubland: *Acacia brachystachya*. *Callitris glaucophylla* on escarpment amongst outcropping bedrock, scattered shrubs including *Dodonaea* species. Understorey herbaceous with abundant grasses.

19 Mt Binya

Woodland of *Callitris endlicheri* and *Eucalyptus crebra*. Mixed shrubby understorey with many regenerating *Callitris* species and *Dodonaea* species.

Generally, the lower slopes of outcrops and outcrops of low relief (for example Manfred Range, 176 m) contained the same species as the surrounding country, for example *Callitris glaucophylla*. Outcrops of higher relief (usually greater than 200 m) generally had a low open-woodland structure with two species predominating, *Eucalyptus dwyeri* (68% of sites) and *Acacia doratoxylon* (74% of sites). These two species occurred in a range of habitats at each site and on different geological types.

Tree species did not appear to be influenced by rock type but showed more variation with regard to altitude, soil depth and type and position on slope. *Callitris glaucophylla* commonly occurred especially on the footslopes and on benches where there was greater soil development. *Eucalyptus sideroxylon* occurs sporadically on loamy soils on the footslopes of the larger ranges in the north of the survey area where it often forms extensive stands and dominated the vegetation, for example, in the Lachlan Range State Forest. Low open-forest dominated by *Callitris endlicheri* occurred over the high ridges on stony soils such as in the Lachlan Range.

In contrast the understorey showed strong relations with geological type. On sandstones the understorey comprised a dense to open shrub strata and a varying cover of herbs and grasses (Table 3). On granite and slate sites the understorey was dominated by grasses and herbs, with shrub species almost completely absent. Mount Rossi (Site 16) on rhyolite had some areas dominated by grasses and herbs but other areas having a prominent shrubby component.

Of the total species recorded, the sandstone sites (with 53 species/site) are significantly richer than the granite sites (with 30 species/site) ($t=3.44$, d.f.=11, $p<0.05$), having a large number of shrubby and herbaceous species (Tables 3 & 4). As only one site each was sampled for the slate and rhyolite lithology no comparison of richness has been made.

Table 3. Total number of trees, shrubs and ground species, and total number of species recorded for the four geological types. Figures in brackets denote number of species confined to individual geology (* denotes one site sampled only).

Geological type	No. trees	No. shrubs	No. ground species	Total
sandstone	18 (11)	49 (41)	189 (118)	256 (170)
granite	10 (2)	4 (-)	96 (40)	110 (42)
slate*	5 (-)	4 (4)	39 (11)	48 (15)
rhyolite*	7 (2)	8 (3)	49 (8)	64 (13)

The number of species restricted to each geological type varied considerably; 66% were confined to sandstone, 38% to granite, 31% to slate and 20% to rhyolite (Table 3).

Numerical classification

Classification and ordination using TWINSpan and DECORANA for sites 2–16 confirmed differences in the vegetation between the sandstone and granite lithologies (Figure 2). Generally all sandstone sites are grouped together, as are most of the granite sites. For the sandstone sites there appears to be an east-west geographic separation, i.e. the western sites, (3,4,5), are separate from the more easterly sites (2,6,7,8). Climatically, the western sites are slightly drier, and lithologically, the western sites are more similar to each other when compared with the eastern sandstone sites. The granite sites display a north-south geographic separation, probably reflecting factors such as climatic and geological differences. Exceptions to these general trends are Mount Boomanoomana (Site 9), Bald Hill Tank (Site 10) and Mount Rossi (Site 16). Without more detailed field sampling the interpretation of these results is open to speculation.

Significant species

Several rare plants were recorded. *Phebalium obcordatum* (Rutaceae) (coded 3RCa by Briggs & Leigh 1988) was recorded on the summit of Mount Bingar in Cocoparra National Park and Mount Binya in Binya State Forest at the southern end of the Cocoparra Range. It is also known from Yathong Nature Reserve.

Pomaderris cocoparrana (Rhamnaceae) is a newly described species originally included, but distinct from, the widespread species *P. andromedifolia* (Walsh 1990). It has been recorded for Mount Binya (this survey) and Cocoparra National Park. It has been assessed as 2RCat (Walsh 1990).

Although not recorded for this survey *Acacia curranii* (Fabaceae - Mimosoideae) occurs in the vicinity of Shephards Hill north of the study area. This is lithologically similar to Mount Rossi in the Ural Ranges (Site 16) and the species may occur on more inaccessible areas of the ranges further to the south. This species is coded 3V (Briggs & Leigh 1988) as its population is considered vulnerable and is not reserved.

Fifteen species recorded (12 native, 3 introduced) represented extensions of range for the South Western Slopes and South Western Plains (Appendix). Six were recorded for Jimberoo Creek State Forest (Site 2), burnt by wildfire 10 months previous, and includes the unusual occurrence of *Xanthorrhoea glauca* subsp. *angustifolia* (Xanthorrhoeaceae) which has a scattered distribution and is usually found on rocky lime-

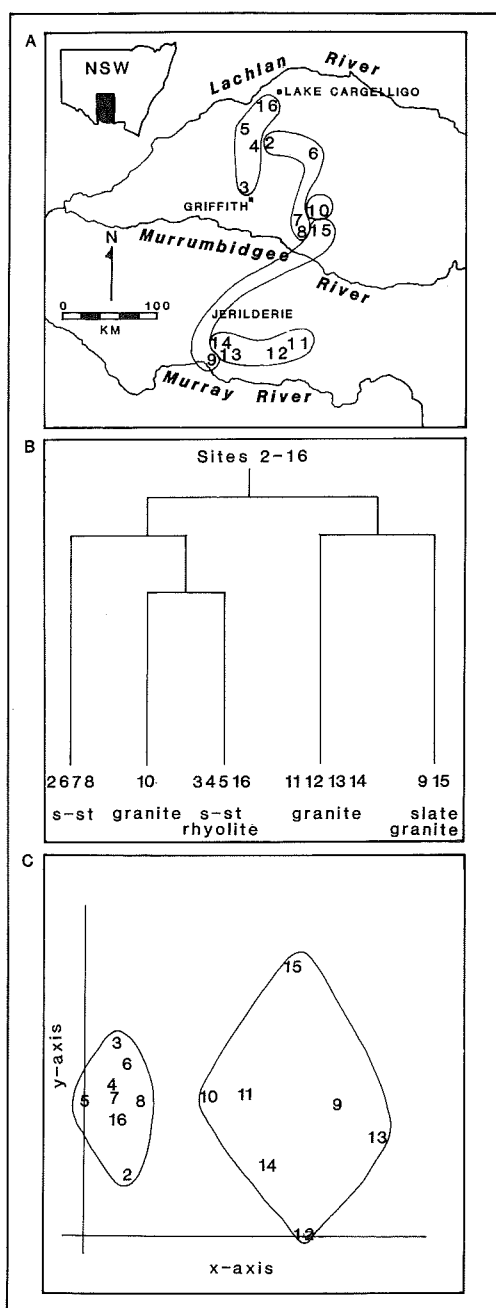


Figure 2. TWINSPAN classification (a & b) and DECORANA ordination (c) for sites 2-16.

Table 4. Geological type, number of sites, mean number of species/site and percentage of introduced species.

Geological type	No. sites	Mean no. species	Mean no. intro. spp.	% introduced species
sandstone sites	11	53 ± 5.09	7	13%
granite sites	6	30 ± 3.8	11	37%
slate site	1	44	9	20%
rhyolite site	1	63	5	8%

stone and trachyte) and gravelly slopes on the Dividing Range further east (Bedford 1988). Jacobs & Lapinuro (1986) record this species as *X. australis* subsp. *australis* 'western form'.

Disturbance

Most of these rocky outcrops and ranges have been disturbed to varying degrees. Granite outcrops of low relief have been the most affected. Many have been quarried for railway construction, most have active rabbit populations, and some are grazed by sheep. These sites have significantly higher numbers of exotic species (37%)

compared with the sandstone sites (13%) ($t=2.59$, d.f.= 11, $p < 0.05$) (Table 4). The sandstone vegetation contains fewer exotic species and disturbance generally is from logging and browsing by goats.

Introduced species

Of the 338 species recorded for this survey 55 (17%) are introduced. Many are species from adjacent agricultural lands. All sites had some exotic species. This infestation ranged from 3 (Site 4) to 14 (Site 14) introduced species. Seven common weed species occur on three of the four geological types, these being *Arctotheca calendula*, *Hypochoeris glabra* (Asteraceae), *Echium plantagineum* (Boraginaceae), *Aira cupaniana*, *Briza minor*, *Bromus rubens* and *Vulpia myuros* (Poaceae).

Feral animals

The predominant feral animal of the outcrops and ranges is the goat (*Capra hirsus*). These are highly selective feeders selecting the most nutritious parts of the plants such as leaves, buds and fruits (Downing & Mitchell 1988). They show a marked preference for browsing small trees and shrubs, but eat grasses and other herbs during drier times (Breckwoldt 1983). Their diet includes a wide selection of native species and some introduced species. Goats are capable of pulling down branches and will readily climb into bushes, destroying them. Obvious damage in Cocoparra Range includes the breaking down of *Acacia deanei* and *Goodia medicaginea* and the browsing of *Callitris endlicheri* and *Maytenus cunninghamii* (Brickhill pers. comm.). Goats are present in moderate numbers in the Keginni Range (Site 17) and in the Cocoparra Range; they were also recorded for Flagstaff Hill (Site 4), Lachlan Range (Site 5), Mount Bunganbil (Site 7), Mount Goombargana (Site 11) and Manfred Range (Site 18).

Rabbits (*Oryctolagus cuniculus*) were noted on sites where the soils are deeper and topography less rugged, particularly on granites in the south including The Boat Hill (Site 14) and also on the McPherson and Manfred Ranges (Site 3 and 18 respectively). Friable soils to a depth of 75 cm or more are favourable for warren construction (Parer & Libke 1985). First introduced to Australia in the late 1850s, they have multiplied and spread throughout much of southern Australia, becoming the most damaging pest in the country (Breckwoldt 1983). Although population numbers were greatly reduced by the introduction of myxomatosis during the 1950s, population numbers are again on the increase.

Rabbits can physically damage shrubs and trees through direct grazing and ringbarking, and overgrazing of both herbs and shrubs together with the effects of burrowing can lead to severe erosion and habitat destruction.

Fire

Only one site, Jimberoo Creek State Forest (Site 2), showed evidence of a recent fire (1985) which was both crown scorch and combustion particularly on the ridge areas (Jolly pers. comm.). Mount Goombargana (Site 11) has carried a wildfire some years previously (Packer pers. comm.) as have areas of the Cocoparra Range. Other large range areas would be expected to carry fire at some time. On many of the smaller outcrops there did not appear to be any evidence of fire. This may be a result of their small area, isolation and/or the open nature of the vegetation. Alterations to the natural fire regimes result from fragmentation through land clearing (Hobbs 1987) and management (forestry, mining and reserves).

Conservation and management

Major conservation reserves in the south western slopes and plains relevant to this study include Yathong Nature Reserve (NR), Nombinnie NR, Mount Bootheragandra NR, Cocoparra NR and National Park, The Rock NR and Mount Galore. Most of these reserves are on sandstone lithology. Plant communities occurring on granite and rhyolite geological types are not represented in any reserves and many are privately owned.

Representative vegetation communities on granite lithology are worthy of protection. The smaller, more isolated granite outcrops in the south of the study area are heavily disturbed. Continued disturbance, isolation and the resulting lack of corridors for species dispersal and reproductive success suggests that these small isolated outcrops will continue to degenerate (Hobbs 1971). Protection of larger areas are necessary if long-term viability is to be maintained.

Control of introduced animals, weed invasion, land use and to a certain degree, fire, are management concerns for conservation areas.

Other rocky outcrops

As a reconnaissance survey it has not been possible to visit all rocky outcrops in the south west and further work on additional sites needs to be done. The significance of the slate and rhyolite sites (9 and 16) requires further sampling. Vegetation on the Manara Hills and Darnick Ranges in the west of the study area is of interest to compare with Keginni and Manfred Ranges (Sites 17 and 18 respectively). Other areas of interest are the olivine leucitite outcrops, a Tertiary alkali basalt, at Mount Melbergen in the Melbergen Ranges west of Rankins Springs, and areas west of Lake Cargelligo.

Conclusion

This study has shown the significance of the vegetation on the outcrops and ranges. The vegetation is characteristic for geological type particularly for sandstone and granite. Although having some tree species in common, sandstones sites are richer in understorey species and have a large shrub component. In contrast granite sites have fewer species most of which are herbaceous.

Of the four geological types, all have species restricted to individual geologies (between 20% and 66%). Many of these outcrops and ranges represent islands of native vegetation amongst extensive tracts of agricultural land and conservation on a variety of vegetation and geological types should be undertaken.

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APPENDIX

Species recorded from sites on rocky outcrops and ranges in south-western NSW (q = quadrat; t = traverse).**Site:**

- 1 Mt Bingar, Cocoparra National Park (qt)
- 2 Jimberoo Creek State Forest (qt)
- 3 McPhersons Range (t)
- 4 Flagstaff Hill, Lachlan Range State Forest (q)
- 5 Lachlan Range (qt)
- 6 Mt Narriah (qt)
- 7 Mt Bungarbil (qt)
- 8 Mt Wammera (qt)
- 17 Keginni Range (t)
- 18 Manfred Range (t)
- 19 Mt Binya, Binya State Forest (qt)
- 9 Mt Boomanoomana (t)
- 10 Bald Hill Tank (t)
- 11 Mt Goombargana (qt)
- 12 Quarry N of Corowa (t)
- 13 Berrigan (t)
- 14 The Boat Hill (t)
- 15 Grong Grong (t)
- 16 Mt Rossi (qt)

* introduced species

new record for New South Wales

! extension of known range in New South Wales

? query on identification

	Sandstone									Slate					Granite					Rhyolite					
	1	2	3	4	5	6	7	8	17	18	19	9	10	11	12	13	14	15	16	16	16	16	16		
PTERIDOPHYTES																									
Adiantaceae																									
<i>Cheilanthes austrotenuifolia</i>	1	2	3	4	5	6	7	8	17	18	19	9	10	11						16					
<i>C. distans</i>						7																			
<i>C. sieberi</i> subsp. <i>sieberi</i>	1												9												16
<i>Pleurosorus rutifolius</i>	1	3	5	6	7	17	18	19																	
<i>P. subglandulosus</i>	1	3	5	6	7	17	18	19	9	11												16			
GYMNOSPERMS																									
Cupressaceae																									
<i>Callitris endlicheri</i>	1	2	6	8																					
<i>C. glaucophylla</i>	1	2	6	7	8	18																			
ANGIOSPERMS																									
Amaranthaceae																									
<i>Ptilotus atriplicifolius</i>																				5					
subsp. <i>atriplicifolius</i>																				18					
<i>P. gaudichaudii</i>																				18					
var. <i>parviflorus</i>																				18					
<i>P. nobilis</i>																				18					
<i>P. polystachyus</i>																				18					
<i>P. spathulatus</i>																				18					
Anthericaceae																									
<i>Arthropodium minus</i>	1	3																							
<i>Thysanotus patersonii</i>	2	3	6	8																					
<i>Tricoryne elatior</i>	1												9	10	11						16				
Apiaceae																									
<i>Daucus glochidiatus</i>	1	2	3	4	5	6	7	8	9	14												16			

	Sandstone																			Slate										Granite										Rhyolite									
	1	2	3	4	5	6	7	8	17	18	19	9	10	11	12	13	14	15	16	17	18	19	9	10	11	12	13	14	15	16	17	18	19	9	10	11	12	13	14	15	16	17	18	19					
Chenopodiaceae																																																	
<i>Atriplex semibaccata</i>																																																	
<i>Chenopodium desertorum</i>																																																	
subsp. <i>anidiophyllum</i>																																																	
subsp. <i>microphyllum</i>																																																	
* <i>C. murale</i>																																																	
<i>Einadia hastata</i>																																																	
<i>E. nutans</i>																																																	
<i>Maireana enchylaenoides</i>																																																	
<i>M. humillima</i>																																																	
<i>Sclerolaena birchii</i>																																																	
<i>S. convexula</i>																																																	
Convolvulaceae																																																	
<i>Convolvulus erubescens</i>																																																	
Crassulaceae																																																	
<i>Crassula colorata</i>																																																	
var. <i>acuminata</i>																																																	
<i>C. decumbens</i>																																																	
var. <i>decumbens</i>																																																	
<i>C. sieberiana</i>																																																	
Cyperaceae																																																	
<i>Carex inversa</i>																																																	
<i>Fimbristylis dichotoma</i>																																																	
<i>Isoplepis marginata</i>																																																	
<i>Lepidosperma laterale</i> s.l.																																																	
Dilleniaceae																																																	
<i>Hibbertia obtusifolia</i>																																																	
<i>H. riparia</i>																																																	
<i>H. sericea</i>																																																	
Droseraceae																																																	
<i>Drosera glanduligera</i>																																																	

	Sandstone																			Slate									Granite									Rhyolite								
	1	2	3	4	5	6	7	8	7	8	17	18	19	9	10	11	12	13	14	15	16	10	11	12	13	14	15	16	10	11	12	13	14	15	16											
<i>Drosera peltata</i>	1	2																					10																							
<i>D. sp.</i>																												14								15										
Epacridaceae																																														
<i>Astroloma humifusum</i>	1																																													
<i>Melichrus urceolatus</i>	1							8																																						
Euphorbiaceae																																														
<i>Beyeria viscosa</i>					5																																									
<i>Chamaesyce drummondii</i> s.l.	1											18																																		
<i>Phyllanthus fuernrohrii</i>	1											17	18																																	
<i>P. hirtellus</i> form b	1																																													
<i>P. hirtellus</i>		2						7	8																																					
Fabaceae-Caesalpinioideae																																														
<i>Senna artemisioides</i>																																				19										
nothosubsp. <i>artemisioides</i>																																				19										
subsp. <i>filifolia</i>																																														
Fabaceae-Faboideae																																														
<i>Daviesia mimosoides</i>																																														
subsp. <i>virgata</i>																																														
<i>D. ulicifolia</i>																																				9										
<i>Dillwynia sericea</i>																																				9										
<i>Goodia medicaginea</i>		2																																												
<i>Glycine canescens</i>	1																																													
<i>G. sp.</i>					5																																									
<i>Hardenbergia violacea</i>	1																																													
<i>Indigofera australis</i>	1																																													
<i>Lotus cruentus</i>		3						6	7	8																										19										
* <i>Medicago laciniata</i>																																				17										
* <i>M. sp.</i>	1																																													
<i>Mirbelia pungens</i>																																														
<i>Swainsona procumbens</i>																																														
<i>Swainsona oroboides</i>																																														
subsp. <i>sericea</i>																																				12										

	Sandstone																			Slate									Granite									Rhyolite		
	1	2	3	4	5	6	7	8	8	17	18	19	9									10	11	12	13	14	15	16												
Goodeniaceae																																								
<i>Dampiera lanceolata</i>	1								8			19																												
var. <i>lanceolata</i>	1	2	4																										16											
<i>Goodenia fascicularis</i>	1			3								19																												
<i>G. glabra</i>	1			3																																				
<i>G. heteromera</i>	1																																							
<i>G. ovata</i>	1																																							
! <i>G. stephensonii</i>																																								
! <i>Velleia arguta</i>					5																						15													
<i>V. paradoxa</i>																																								
Haloragaceae																																								
<i>Gonocarpus elatus</i>	1	2	3	4	5	6	7	8	8	17	18	19										10	11				14	15	16											
! <i>Myriophyllum simulans</i>																								13																
11																																								
Hypoxidaceae																																								
<i>Hypoxis glabella</i>																																								
																											15	15												
Iridaceae																																								
* <i>Romulea rosea</i>																																								
var. <i>australis</i>																																								
##* <i>Sparaxis pillansii</i>																																								
Juncaceae																																								
<i>Juncus subsecundus</i>																											14													
<i>J. sp.</i>	2																										14													
! <i>Luzula flaccida</i>																																								
<i>L. meridionalis</i>																																								
11																																								
Lamiaceae																																								
<i>Ajuga australis</i>	2			5																									16											
<i>Prostanthera nivea</i>								7	8			19																	16											
<i>P. ovalifolia</i>				3		4		6	7																															
<i>P. striatiflora</i>												18																												
<i>Teucrium corymbosum</i>										6																														

	Sandstone										Slate	Granite										Rhyolite
	1	2	3	4	5	6	7	8	17	18	19	9	10	11	12	13	14	15	16			
<i>Leptospermum divaricatum</i>	1	2									19											
<i>Melaleuca erubescens</i>	1					6																
Orchidaceae																						
<i>Caladenia carnea</i>				4			7	8								14						
<i>C. dilatata</i>	2	3																				
<i>Calochilus robertsonii</i>	2							8														
<i>Diuris maculata</i>					6		7	8														
<i>Glossodia major</i>								8											16			
<i>Pterostylis biseta</i>								8?														
<i>P. mutica</i>			3	4			7												16			
<i>P. nana</i>	1																					
<i>P. sp.</i>	1						7					9										
Oxalidaceae																						
<i>Oxalis corniculata</i>	2	3	4	5			7	8														
<i>O. perennans</i>																						
* <i>O. pes-caprae</i>																						
<i>O. radicata</i>	1																					
<i>O. sp.</i>																			15			
Papaveraceae																						
* <i>Papaver aculeatum</i>	2																					
Phormiaceae																						
<i>Dianella sp.</i>	1				6														15			
<i>Stypana glauca</i>	1	2					7	8														
Pittosporaceae																						
<i>Bursaria spinosa</i>																						
<i>Pittosporum phillyreoides</i>																			16			
Plantaginaceae																						
<i>Plantago drummondii</i>																			16			
<i>P. turrifera</i>																			16			

	Sandstone			Slate			Granite			Rhyolite									
	1	2	3	4	5	6	7	8	17	18	19	9	10	11	12	13	14	15	16
<i>Stipa blackii</i>									18										
<i>S. densiflora</i>									19			9							
<i>S. mollis</i>			3	5	6	7	8							11					
<i>S. nitida</i>									18										
<i>S. nodosa</i>									18			9		10	12	14			
<i>S. scabra</i> subsp. <i>scabra</i>	1											9							
subsp. <i>falcata</i>		2	3	4		6								11		15			
<i>S. setacea</i>			3											11					
<i>Thyridolepis mitchelliana</i>	1		3	4	5	6		17	18	19									16
* <i>Vulpia bromoides</i>				4		6							10	11	13				16
* <i>V. myuros</i>		2	3	5	7	8		18	19				10	12	14				
Polygonaceae																			
* <i>Polygonum arenastrum</i>															13				
<i>Rumex brownii</i>									19					12?		14			16
<i>R. dumosus</i>																			
Portulacaceae																			
<i>Calandrinia calypttrata</i>																14			
<i>C. eremaea</i>										18		9				14			
<i>C. sp.</i>	1							17											
Proteaceae																			
<i>Grevillea floribunda</i>	1	2				6	7	8											
<i>Hakea tephrosperma</i>			3	5															
Ranunculaceae																			
<i>Ranunculus lappaceus</i>		2																	16
<i>R. pentandrus</i>																			
var. <i>platycarpus</i>																			
<i>R. sessiliflorus</i>																			
var. <i>sessiliflorus</i>	2						8	18								14			
var. <i>pilulifer</i>													10						

	Sandstone																			Slate					Granite					Rhyolite	
	1	2	3	4	5	6	7	8	17	18	19	9	10	11	12	13	14	15	16	16											
Xanthorrhoeaceae																															
<i>Xanthorrhoea glauca</i>																															
subsp. <i>angustifolia</i>	2																														
Zygophyllaceae																															
<i>Zygophyllum ammophilum</i>																															
<i>Z. eremaeum</i>																															
Total number of species	71	68	54	30	44	47	61	64	27	71	45	44	31	37	27	14	40	30	64												
Number exotic species	4	12	6	3	7	5	7	8	5	9	7	9	8	11	13	8	14	11	7												

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