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NATIVE VEGETATION OF THE OTWAY REGION, VICTORIA

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Abstract: A general account of the vegetation of the Otway Region is presented with emphasis on *Eucalyptus* species, for which most data are available. Detailed maps are given of the distribution of *E. globulus* in the region and of the eucalypts in the Parker River area. The vegetation contrasts between the relatively fertile soils on Cretaceous rocks and the infertile soils of Tertiary sediments are emphasized, and the similarities between the Otways and the South Gippslands hills indicated. Serious problems affecting the native vegetation include invasion by weeds and by the fungal die-back disease *Phytophthora cinnamomi*.

INTRODUCTION

The Otway Ranges are isolated from other mountain areas both by the Cainozoic basalts of the Basalt Plains to the north, and by the drowning of Bass Strait by rising sea-levels in the Quaternary to the south. In addition they are an island of wetness, being roughly contained within the 89 cm (35 in.) mean annual rainfall isohyet and surrounded by drier country on all sides. The acidic, sandy, infertile country surrounding the Ranges is also cut off from similar country by the Basalt Plains and Bass Strait. This isolation of the region has caused some distinctive vegetation characteristics.

The region includes some of the wettest country in Victoria (up to 198 cm (78 in.) mean annual rainfall) and is the furthest west in the State where recorded rainfall exceeds 119 cm (47 in.). Accordingly, it marks the western-most limit of the distribution of a number of plant species and communities. Part of the distinctiveness of the Otway Ranges in Victoria lies in the occurrence of high rainfall country at lower altitudes and closer to the coast than elsewhere (D. H. Ashton, unpublished).

The present paper deals with the whole area of Cretaceous rocks making up the Otway Ranges themselves. It includes also all areas of Tertiary and Quaternary sediments between the inland boundary of the Cretaceous rocks and the coast, plus the flanking Tertiary sediments both around the north-east end of the ranges and as far west as the Gellibrand River.

The Cretaceous rocks are felspathic sandstones, siltstones and mudstones and weather to give moderately fertile soils with loamy topsoils. The Tertiary sediments usually produce highly infertile soils with sandy topsoils (including both deep sands and duplex soils with shallow sandy topsoils over clayey subsoils). The Quaternary sediments include aeolian calcarenites and calcareous and siliceous coastal sands of varying fertility.

This paper attempts to review what is known of the plant communities in the area. Nomenclature for plant names follows Willis (1970, 1972) unless otherwise stated and for vegetation forms follows Specht (1970) as modified by Victoria: Land Conservation Council 1976 (abbreviated here to VLCC 1976).

The vegetation is poorly known; VLCC (1973, 1976) provides some description and mapping in broad structural categories. Block names and boundaries within the area follow VLCC (1973, 1976). Throughout this paper, areas, sites, soils and slopes found on geological deposits of a given age (as Cretaceous or Tertiary) will, for the sake of conciseness, be referred to by phrases like 'Cretaceous sites' or 'Tertiary slopes'.

CLOSED-FORESTS

Tall closed-forests dominated by *Nothofagus cunninghamii* (often including trees of *Acacia melanoxylon*) occur in sheltered gullies where mean annual rainfall (MAR) exceeds 127 cm (50 in.), and extend onto broad valleys and saddles where MAR exceeds 178 cm (70 in.) on the Beech Forest plateau. Howard and Ashton (1973) give an account of their ecology and floristics, including mosses and liverworts, although the exact distribution of these forests has not been mapped. Common understorey species include

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Hedycarya angustifolia, Clematis aristata, Australina muelleri, Dicksonia antarctica and *Blechnum wattsii* Tindale (formerly called *B. procerum*) as well as a profusion of epiphytes including mosses, liverworts and filmy ferns. Despite the surprising absence of *Atherosperma moschatum* which is so common in such forests in the rest of Victoria and Tasmania, the Otways *Nothofagus* forests are not greatly different floristically from those of other low altitude areas in Victoria (Howard & Ashton 1973). The Otway Ranges are thought to be especially vulnerable to fire because they are exposed to dry country on their whole north-west flank. *A. moschatum* may have been eliminated by widespread past fires (Howard & Ashton 1973).

From apparently reliable measurements, it is claimed that *N. cunninghamii* formerly reached heights of 61 m (200 ft.) and girths of 4.6 m (15 ft.) in the upper Elliott River Valley (Hardy 1905).

OPEN-FORESTS WITH HEIGHTS EXCEEDING 40 METRES.

Such forests occur where MAR exceeds 152 cm (60 in.) on northern slopes and 114 cm (45 in.) on southern slopes (VLCC 1976). *Eucalyptus regnans* is commonly dominant on the wettest sites (MAR higher than 127 cm (50 in.)) and a tree at Olangalah last century was 100 m (329 ft.) high with 20 m (63 ft.) girth. The species forms pure stands especially above altitudes of 488 m (1600 ft.), but in the southern Otways below 488 m it commonly forms mixed stands with one or more of *E. cypellocarpa, E. obliqua* and *E. viminalis*. Near the lower limit of *E. regnans* between 122 and 274 m (400 to 900 ft.), *E. globulus* enters the mixture as in the Parker and Kennett River areas (see Fig. 3). Elsewhere in Victoria, *E. regnans* forms mixed stands only in narrow ecotones.

Where *E. regnans* and *E. obliqua* occur together, trees intermediate between these species are common and are locally called 'Otways messmate'. There is good evidence that these trees are hybrids between the two species, and such hybrids are common wherever the two species meet elsewhere (Ashton 1958).

Major understorey species in the *E. regnans* forests are *Hedycarya angustifolia, Olearia argophylla, Phebalium squameum* and to a lesser extent *Pomaderris aspera* and *Bedfordia arborescens* Hochr. (formerly called *B. salicina*). *H. angustifolia* is much more predominant in the Otways than in Central Victoria and the importance of this species and *O. argophylla* may be an expression of the very high rainfalls in the south central Otways (D. H. Ashton, unpublished). *P. squameum* subsp. *squameum* occurs in Tasmania, New South Wales, Queensland and the Otways, but nowhere else in Victoria.

In areas drier than the *E. regnans* forests, *E. cypellocarpa, E. globulus, E. obliqua, E. viminalis* and *Acacia melanoxylon* 40-70 m high occur over *P. aspera, O. argophylla, B. arborescens, Pimelea axiflora, Tetrarrhena juncea* and other understorey species. The understorey types above will be referred to collectively as broad-leaved shrub understories.

Large areas where *E. regnans* has been cleared now support secondary scrub of *A. melanoxylon* with *O. argophylla, H. angustifolia, Phebalium squameum* and *Pomaderris aspera* with *Polystichum proliferum* dominant among other ferns in the generally sparse understorey. On similar sites subjected to greater or more persistent disturbance, dense stands of *Pteridium esculentum*, introduced *Rubus* spp. and of the introduced noxious weeds *Hypericum androsaemum* and *Senecio jacobaea* can be found (Parsons 1973, D. H. Ashton, unpublished). The tragic economic and social consequences of the destruction of much of the original wet forest are discussed by Webb (1968).

OPEN-FORESTS WITH HEIGHTS LESS THAN 40 METRES.

These forests are highly variable in structure and floristics and are poorly known. The available data, summarized in Table 1, are generalized and far from comprehensive. Categories are based on dominant species. Most of the available ecological data relate to tree species and these are discussed in turn below.

(1) *E. globulus* (blue gum)

This is ecologically the best-known tree species following intensive work (Kirkpatrick 1970, 1975a, this paper). Despite previous uncertainty about the exact identity of the Otways populations of blue gum (Hall, Johnston & Chippendale 1970, Willis 1972) it is now clear that they are part of a cline between *E. globulus* subsp. *globulus* and *E. globulus* subsp. *pseudoglobulus* (Naudin ex Maiden) Kirkpatrick (see Kirkpatrick 1974). The Otways stands are not typical 'core populations' of either subspecies. They are most like typical subsp. *globulus* within 0.5 km of the coast (especially all such coastal stands seen north-east of Apollo Bay), while the more inland stands vary from these in the direction of subsp. *pseudoglobulus* (Kirkpatrick 1971, 1974, 1975a). The Otways populations then are transitional between the typical subsp. *globulus* of Tasmania and King Is. and the typical subsp. *pseudoglobulus* found to the north at Lerderderg Gorge.

The altitudinal range for *E. globulus* in the Otways is from just above sea level to 442 m (1450 ft.) and MAR varies from 69 cm (27 in.) to 140 cm (55 in.), but is typically between 76 cm and 114 cm. The higher rainfall areas are, with the western Tasmanian

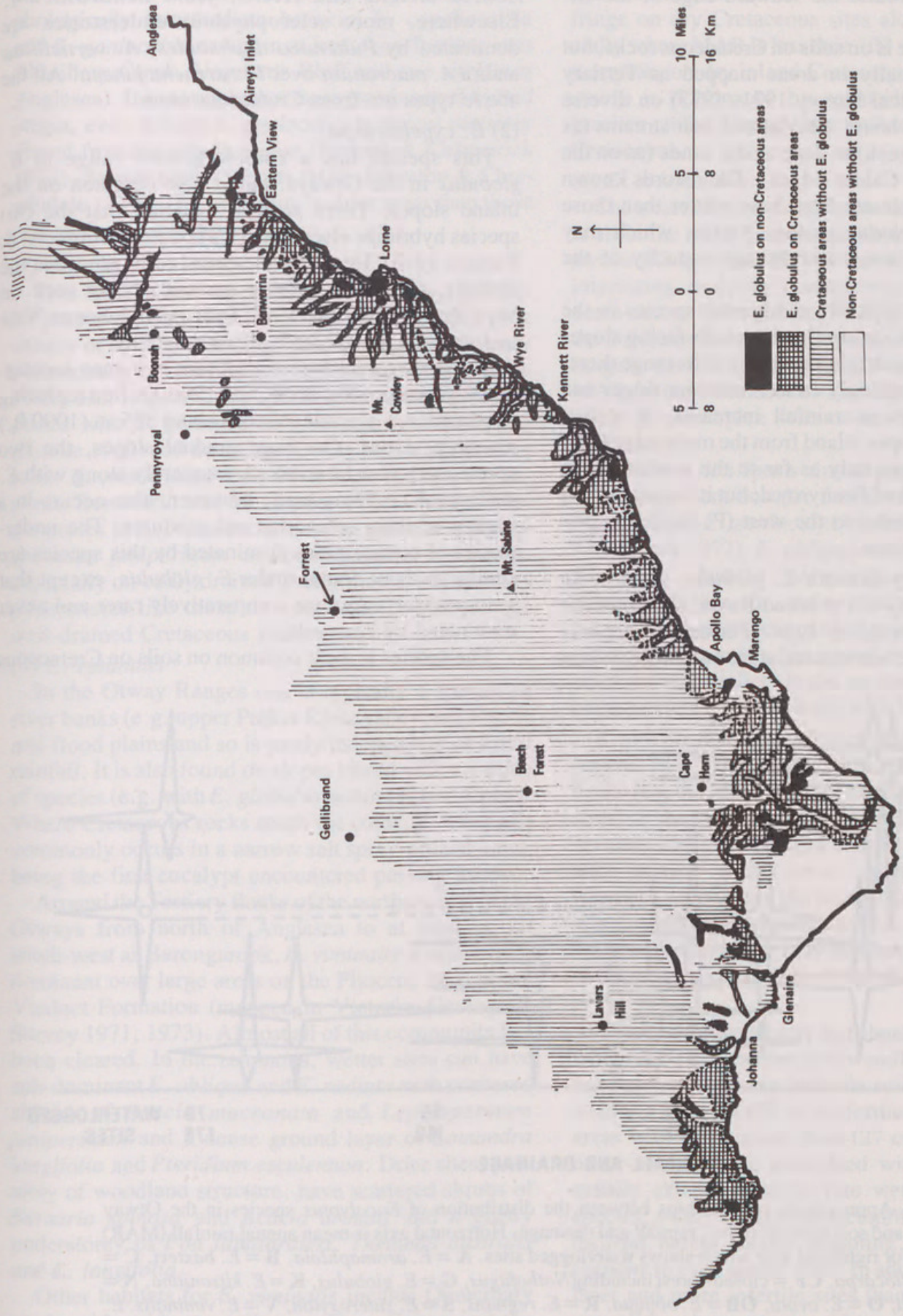

FIG. 1—Distribution of *Eucalyptus globulus* in the Otway Region mapped from ground traverse of all available roads and vehicle tracks. Dashed lines show extrapolated boundaries in cleared areas. In the *E. globulus* area shown in the extreme NE., the species follows watercourses. Geological boundaries from Victoria: Geological Survey 1971, 1973. The *E. globulus* occurrences shown on non-Cretaceous are virtually all on areas mapped as Tertiary. Some inland slope records from P. Denham (personal communication).

occurrences, the wettest sites from which *E. globulus* is known (Kirkpatrick 1975a). The species occurs as a dissected fringe around the seaward edge of the Otways (Fig. 1).

Most of its range is on soils on Cretaceous rocks, but it occurs occasionally in areas mapped as Tertiary (Victoria: Geological Survey 1971, 1973) on diverse soils ranging from heavy alluvial soil near streams (as along Breakfast Creek) to deep acidic sands (as on the Wait-a-While and Calder ridges). The records known to be on deep sands are from sites wetter than those typical for *E. globulus* in the Otways, which may partly reflect the low water storage capacity of the sands.

Although most typically a ridge-top species in the Otways, *E. globulus* is confined to south-facing slopes and stream margins in the driest parts of its range there, and becomes increasingly concentrated on ridges and north-facing slopes as rainfall increases. It is less common on the slopes inland from the main ridge (Fig. 1), being seen there only as far to the south-west as Dunse Track south of Pennyroyal; but it occurs also on Norman Track nearby to the west (P. Denham, personal communication).

The understorey beneath *E. globulus* varies with rainfall from grassy to the broad-leaved shrubs of the *E. regnans* understorey type. *Themeda australis* dominates in some near-coastal areas but further inland *Poa sieberana* Spreng. and *P. labillardieri* Steud. are the dominant grasses with a sparse shrub layer of *Acacia stricta* and *Helichrysum dendroideum*. Elsewhere, more sclerophyllous understories are dominated by *Pultenaea daphnoides, A. verticillata* and/or *A. mucronata* over *Tetrarrhena juncea*. All the above types are from Cretaceous areas.

(2) *E. cypellocarpa*

This species has a similar general range to *E. globulus* in the Otways, but is also common on the inland slopes. There is good evidence that the two species hybridize elsewhere (Kirkpatrick, Simmons & Parsons 1973). Despite widespread co-existence in the Otways, presumed hybrids are rare, being seen on Wye River Track, the T.W. Spur, near Johanna Vale and near the St. Georges River reservoir.

E. cypellocarpa typically occurs in a zone separating *E. globulus* from *E. regnans* forest, often replacing *E. globulus* as altitude exceeds about 305 m (1000 ft.) on steep slopes. On more gradual slopes, the two species are often intermixed, frequently along with *E. obliqua*. *E. cypellocarpa*, however, also occurs in a variety of other situations and mixtures. The understories of communities dominated by this species are similar to those found under *E. globulus*, except that grassy understories are comparatively rarer and never dominated by *Themeda*.

The species is most common on soils on Cretaceous

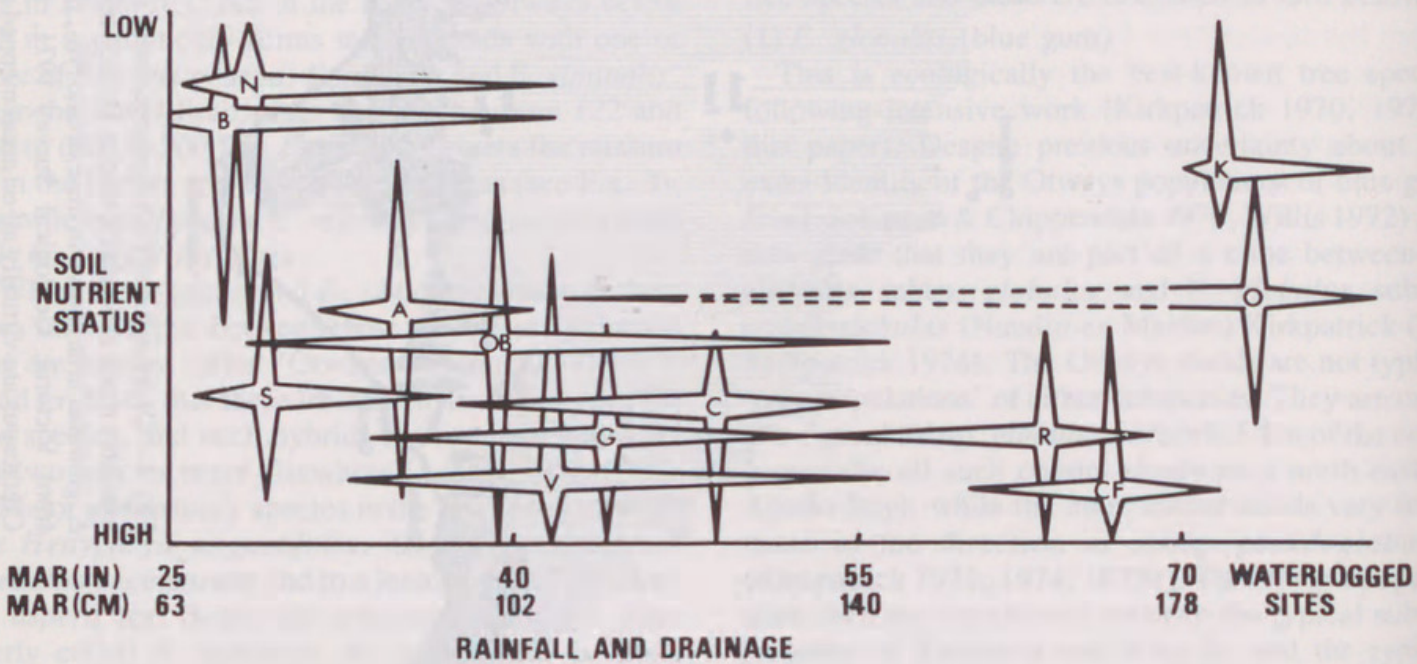

FIG. 2—Approximate relationships between the distribution of *Eucalyptus* species in the Otway Region and soil nutrient status, rainfall and drainage. Horizontal axis is mean annual rainfall (MAR) except for righthand side which shows waterlogged sites. **A** = *E. aromaphloia*, **B** = *E. baxteri*, **C** = *E. cypellocarpa*, **CF** = closed-forest including *Nothofagus*, **G** = *E. globulus*, **K** = *E. kitsoniana*, **N** = *E. nitida*, **O** = *E. ovata*, **OB** = *E. obliqua*, **R** = *E. regnans*, **S** = *E. sideroxylon*, **V** = *E. viminalis*. *E. radiata* not shown but its range on this diagram would be closely similar to that of *E. aromaphloia*.

Soil nutrient status inferred from profile descriptions and limited chemical analyses.

rocks, but is known from Tertiary areas (e.g. inland from Cape Otway, east of Johanna), although not in the north-east of the area. Here, populations morphologically intermediate between *E. cypellocarpa* and *E. goniocalyx* occur on at least four Tertiary sites (Distillery Creek, Urquharts Bluff and two sites near Anglesea). It is possible that these stands are of hybrid origin, even though *E. goniocalyx* is almost certainly absent from the whole region (Parsons & Kirkpatrick 1972), despite earlier reports (Hall, Johnston & Chippendale 1970). The stands are in drier areas than those typical for *E. cypellocarpa*.

(3) *E. ovata*

This species is widespread in the Otways, typically on poorly-drained sites in valleys and flats on a wide variety of soils as elsewhere. However, it also occurs occasionally on well-drained ridges and slopes as on Peters Hill ridge and the Elliott River area where it is mixed with *E. globulus* as well as near Wattle Hill (Hooke 1960) and near Cape Otway on the Lighthouse road. *E. ovata* more than 28 m high is common between Benwerrin and Mt. Sabine (VLCC 1976). Understories to *E. ovata* include dense thickets of *Leptospermum juniperinum* and/or *Melaleuca squarrosa*, especially on badly drained Tertiary sites, and shrubby understories like those described for *E. globulus* on well-drained Cretaceous sites.

(4) *E. viminalis*

In the Otway Ranges this is typically a species of river banks (e.g. upper Parker River valley; see Fig. 3) and flood plains and so is partly independent of direct rainfall. It is also found on slopes mixed with a variety of species (e.g. with *E. globulus* around Elliott River). Where Cretaceous rocks reach the coast, *E. viminalis* commonly occurs in a narrow salt spray-pruned band, being the first eucalypt encountered passing inland.

Around the Tertiary flanks of the northern half of the Otways from north of Anglesea to at least as far south-west as Barongarook, *E. viminalis* was formerly dominant over large areas on the Pliocene Moorabool Viaduct Formation (mapped in Victoria: Geological Survey 1971, 1973). Almost all of this community has been cleared. In the remnants, wetter sites can have sub-dominant *E. obliqua* and *E. radiata* with scattered shrubs of *Acacia mucronata* and *Leptospermum juniperinum* and a dense ground layer of *Lomandra longifolia* and *Pteridium esculentum*. Drier sites, possibly of woodland structure, have scattered shrubs of *Bursaria spinosa* and *Acacia armata* and a grassy understorey of *Poa labillardieri, Themeda australis* and *L. longifolia*.

Other habitats for *E. viminalis* include Quaternary sands with acidic topsoils near Cape Otway and the steep sides of the Cumberland River Gorge.

(5) *E. aromaphloia*

This species is extensive on Tertiary inland slopes with *E. obliqua* and *E. radiata* and forms a narrow fringe on dry Cretaceous sites along the coast especially where MAR is less than 102 cm (40 in.). As well it appears on dry inland Cretaceous areas. The understorey is dominated by sclerophyllous shrubs and bracken on the Tertiary and by *Poa* and *Acacia* on the Cretaceous.

(6) *E. sideroxylon*

The exact Otways distribution has been mapped and is all in the north-east within an area 13 km (8 miles) across (Kirkpatrick 1970). The nearest stands to this interesting outlying coastal occurrence are to the north-east at Point Addis (VLCC 1973) and inland in the Brisbane Ranges to the north. The species rainfall range in the Otways is 69 cm (27 in.) to 84 cm (33 in.) MAR on both Cretaceous and Tertiary areas (on relatively fertile duplex soils on the Tertiary rather than deep sands).

E. sideroxylon forms almost pure stands over much of its range here but also forms mixed stands with *E. cypellocarpa-E. goniocalyx* intermediates (Parsons & Kirkpatrick 1972), *E. obliqua* and to a lesser extent *E. globulus*. *Acacia verniciflua* and *Pultenaea daphnoides* are the main shrubs found under *E. sideroxylon*, often occurring in patches interspersed by an herbaceous cover dominated by *Poa sieberana*. In some areas the taller shrubs are largely absent and the herbs occur in a patchwork with bare ground.

E. sideroxylon generally occupies exposed sites that appear drier than nearby ones carrying *E. globulus*. Following the 1967/68 drought, in an even-aged mixed stand of the two species, *E. globulus* trees were more severely drought damaged than *E. sideroxylon* (which were smaller in this area), suggesting that drought tolerance is greater in the latter. Nearby, suppressed *E. sideroxylon* can be found under *E. globulus*, suggesting that *E. globulus* may suppress *E. sideroxylon* if moisture is adequate (Kirkpatrick 1970).

(7) *E. obliqua*

This is the most widely distributed tree species in the Otways and ranges from low woodlands (described in a later section) on very infertile soils on Tertiary areas with MAR 61 cm (25 in.) to fertile soils on Cretaceous areas with MAR more than 127 cm (50 in.). It is the most common tree associated with *E. globulus* and usually extends upslope into wetter areas than this species, where it associates commonly with *E. cypellocarpa* before finally adjoining or mixing with *E. regnans* in even wetter sites. In addition it extends into drier and more infertile sites than those occupied by any of the above species where it associates with *E. radiata, E. nitida, E. aromaphloia, E. baxteri* and *E.*

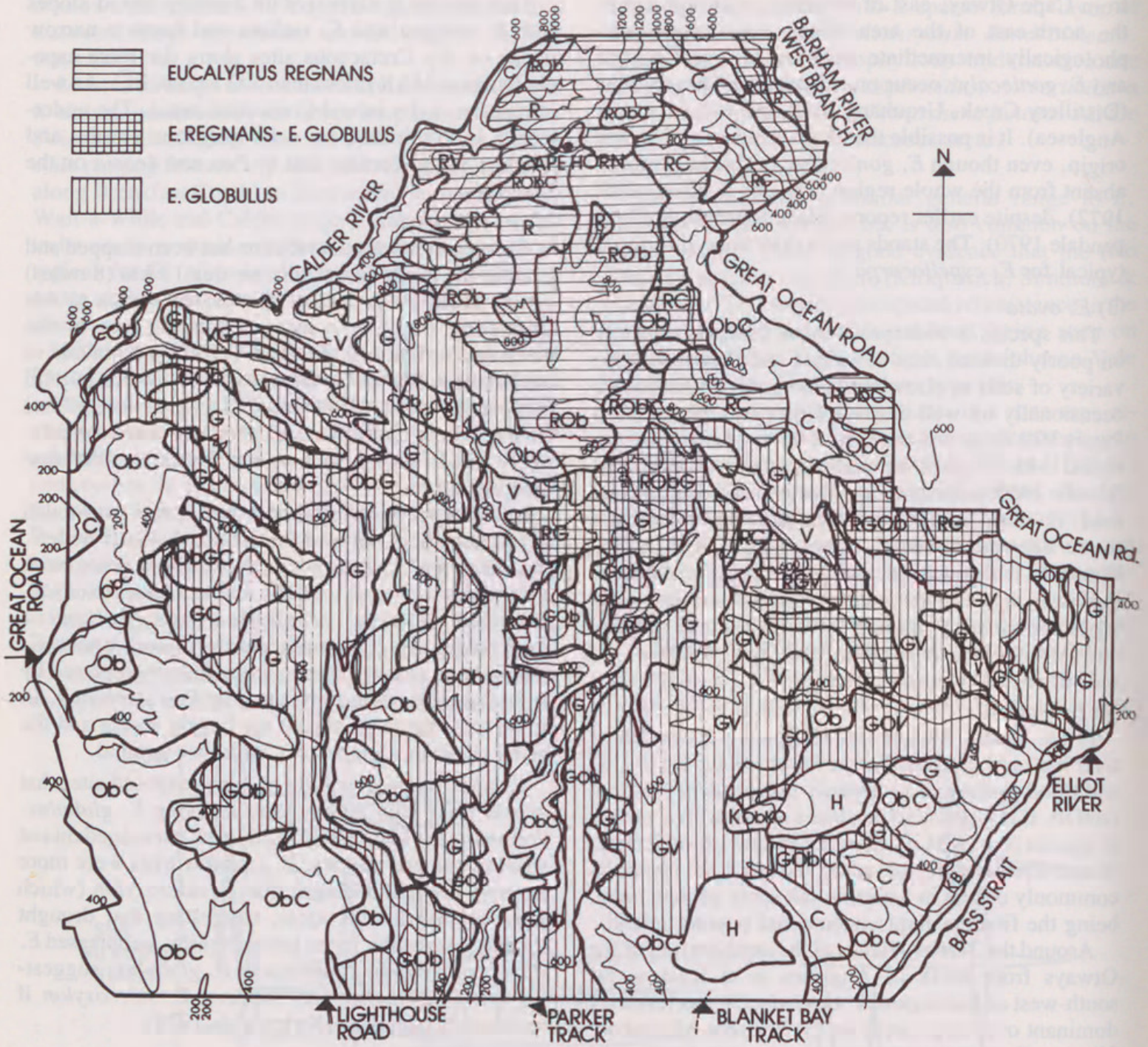

FIG. 3—Distribution of *Eucalyptus* species in relation to altitude in part of the Cape Otway Block. *E. regnans* and *E. globulus* hatched as in legend on map. **B** = *E. baxteri*, **C** = *E. cypellocarpa*, **G** = *E. globulus*, **K** = *E. kitsoniana*, **O** = *E. ovata*, **Ob** = *E. obliqua*, **R** = *E. regnans*, **V** = *E. viminalis*, **H** = heath. Species listed in order of abundance in each type. All contours in feet. Mean annual rainfall increases from south to north (very approximately from 94 cm (37 in.) to 140 cm (55 in.)). Mostly Cretaceous, but Victoria: Geological Survey (1973) maps some Tertiary sediments in the SW and SE corners. Both heath areas shown are on Tertiary. Source is Victoria: Forests Commission (1936) 'Forest contour and type map of Otway' (unpublished). Mapping from field traverses. Distribution of *E. viminalis* closely related to creek-lines. Arrowheads show position where named features cross study area boundary.

viminalis. Unlike *E. globulus* it is widespread on both the inland and coastal flanks of the Otways.

E. obliqua is found with a wide variety of understorey types including all the types found under *E. cypellocarpa* as well as bracken and sclerophyll shrub understories typical of the well-drained Tertiary sites.

(8) *E. radiata*

Found particularly on the inland slopes sometimes as pure stands and known mainly from Tertiary areas where the understorey is dominated by bracken and sclerophyll shrubs, the most important of which are *Leptospermum juniperinum, Banksia marginata, L. myrsinoides* and *Aotus ericoides*. Occurrences on Cretaceous areas are confined largely to the dry north-east.

(9) *E. dives*

Although a few isolated records exist of this species (e.g. Hooke 1960), it has not been seen during extensive field work by the present authors or by Beauglehole or Thornley, unpublished. Detailed field checking is required, especially of the inland slopes. Isolated records could refer to occasional *E. obliqua-E. radiata* hybrids, or even to forms of *E. nitida*.

(10) *E. baxteri*

More typically a woodland tree in this area, but occurs in forest in the Cape Otway Block. It is common on Tertiary areas and is either very rare or absent from Cretaceous ones. Anomalous trees in the Cape Otway Block are almost certainly hybrid swarms between this species and *E. obliqua* (D. H. Ashton, unpublished).

WOODLAND

Woodlands in this area are virtually confined to areas where MAR is less than 102 cm (40 in.) and are closely associated with highly acidic infertile soils on Tertiary sediments, often with an impeding horizon which can cause waterlogging of the topsoil in winter and increased evaporation and drought in summer (VLCC 1976). Of the forest eucalypts, *E. obliqua* and *E. baxteri* both occur commonly in woodlands as well, where the latter often appears to occupy more infertile soils than the former (e.g. the pure stands of *E. baxteri* in the Cape Otway Block).

In the north-east south of Wurdiboluc Reservoir, there is a sharp change in geology from Pliocene to Palaeocene sediments across the Bambra Fault (Victoria: Geological Survey 1971). This coincides with a sharp change in vegetation from *E. viminalis* to *E. obliqua* woodland (A. Thornley, personal communication) and probably correlates with a decrease in soil fertility.

In the wetter areas of the Cape Otway Block, eucalypts can form woodlands up to 21 m (70 ft.) high over dense understories of *Leptospermum juniperinum* from 3 m (10 ft.) to 12 m (40 ft.) high. (D. H. Ashton, unpublished).

E. ovata can also occur in woodland on Tertiary areas, especially in swamp margins. In addition, the following eucalypts usually absent from forest are found:

(1) *E. kitsoniana*

This rare species is only found in the Cape Otway Block up to 5 km (3 miles) inland and north-westerly from Blanket Bay (Hooke 1960 and see Fig. 3), and elsewhere is known only from Wilsons Promontory and nearby areas (Parsons 1963) and far south-west Victoria (Gibbons & Downes 1964). It is a species of infertile, badly-drained sites and is uniquely well-developed in the Otways, single-stemmed trees sometimes reaching heights of about 18 m (60 ft.).

(2) *E. nitida*

This species is very common on Tertiary areas on the inland flanks of the Otways between Gellibrand and Chapple Vale and on the Bald Hills near Anglesea, often with *E. baxteri* (VLCC 1976), and often on very infertile soils which appear to have the lowest water storage capacities or the driest topographic positions of those seen. On more favourable sites carrying forest (e.g. around Karwarren), populations intermediate between *E. nitida* and *E. radiata* can be found. The inland flanks of the Otways would be ideal sites to study the ecological and taxonomic relationships of these two closely related species.

E. nitida and all the other species mentioned above are components of woodlands with understories dominated by sclerophyllous shrubs.

(3) *E. pauciflora*

Three very small outlying populations of this species have been recorded on north-east Tertiary areas. Three trees occurred at Anglesea rubbish tip, on the east side of Camp Road 1 km from its southern end; these have already been destroyed by clearing (A. Thornley, personal communication). A second population is found from the junction of Gundries Road and Vickery Road up to 0.5 km north along Vickery Road (8 km north-east of Anglesea). About 20 trees remain as roadside remnants with an understorey including *Poa sieberana, Pteridium esculentum* and *Themeda australis*. Finally, a remnant of about 20 trees occurs south-east of Lake Modewarre at grid reference 205780 on the Anglesea 1:63,360 military survey map (A. Pitt, personal communication).

Conservation is urgently needed of these disjunct stands, as along the coast to the west stands do not recur until the vicinity of Heywood in far south-west Victoria (Gibbons & Downes 1964).

(4) *E. leucoxylon*

Scattered trees of this species have been recorded in

roadside remnants near the Henty Main Road north of Anglesea (A. Thornley, personal communication) on the Pliocene Moorabool Viaduct Formation which carries soils comparatively fertile for Tertiary areas. Woodlands of *E. viminalis* and to a lesser extent *Casuarina stricta* were formerly widespread on this Formation before clearing.

Some general topographic and soil nutrient and water relations of the main tree species of both forests and woodlands are shown in Figs. 2 and 3.

HEATH

These completely treeless communities dominated by sclerophyllous shrubs are much less common than woodlands. They are found principally on very infertile highly acidic soils of Tertiary areas. Coastal heaths are common in the Anglesea area and have been mapped there (Turner, Ashton & Bird 1968). *Leptospermum juniperinum* and *L. myrsinoides* are often co-dominant and occur with *Casuarina pusilla, Gahnia radula* and many other species. The reasons for the treelessness of such coastal heaths are poorly understood. Salt spray damage to adjacent eucalypts suggests that this factor is often important but extreme infertility, periodic waterlogging, fire history or some combination of these and other factors may also be important.

Inland heaths are most common in the Carlisle Block. Dominants include *Melaleuca squarrosa, L. juniperinum,* and *Gymnoschoenus sphaerocephalus* which occur with *Sprengelia incarnata, Gahnia sieberana, Empodisma minus* (Hook.f.) L. A. S. Johnson & Cutler (formerly *Calorophus lateriflorus*) and many others. These heaths occupy swampy valley bottoms and elevated areas of strongly impeded drainage. Treelessness may be related to soil waterlogging, extreme infertility and other factors but salt spray is clearly not important. MAR is around 109 cm (43 in.) here compared to 66 cm (26 in.) at Anglesea.

In contrast to these two extreme situations are the heaths at Cape Otway. These are in exposed coastal locations but are floristically much more similar to the Carlisle heaths than to the Anglesea ones, with 'wet' elements like *M. squarrosa* and *S. incarnata* important. MAR here is 86 cm (34 in.), so it appears that increasing rainfall has an important effect on heath floristics, presumably partly by increasing the severity of waterlogging and thus favouring the 'wet' heath elements. However, detailed soil comparisons are badly needed to clarify the situation.

As examples of these important floristic differences, *Epacris lanuginosa, Gymnoschoenus sphaerocephalus* and *Hibbertia procumbens* are completely absent from the Anglesea Block, but are common at Cape Otway and Carlisle, while the reverse is true for *Casuarina pusilla, Spyridium vexilliferum, Thysanotus dichotomus* and *Goodenia geniculata*. *C. paludosa, Sprengelia incarnata* and *E. obtusifolia* are all very rare at Anglesea, but common at Cape Otway and Carlisle. There are also some important differences between the Cape Otway and Carlisle heaths, *Melaleuca squamea* and *Hibbertia acicularis* being recorded only from Carlisle. The 'wet' heaths often grade into closed-scrubs dominated by *M. squarrosa* and *L. juniperinum* often 3-4 m up to 6 m high.

Coastal heaths at Marengo, (MAR of 112 cm (44 in.)) superficially similar to those at Cape Otway, are being increasingly disturbed and destroyed and urgently need detailed study.

Both the woodlands and heaths usually have very high plant species diversity. The sclerophyllous vegetation of the Tertiary area around Anglesea includes interesting disjunct occurrences of species otherwise known in Victoria only from much further west (notably the Grampians and the far south-west). These include *Conospermum mitchellii, Schoenus breviculmis* and *Thysanotus dichotomus* (Willis 1962). Within a 13 km (8 miles) radius of Anglesea, no less than 86 species and 3 varieties of native orchids can be found, out of the Victorian total of about 169 species and 19 varieties, excluding presumed hybrid taxa in all cases (Beauglehole, Carr & Parsons 1977). Willis (1962) has emphasized the paucity of *Grevillea* species in the Otway region: only one highly localized species is known. In this respect, the region is similar to Wilsons Promontory, the Holey Plains or the heathy coastal country south-west of Mallacoota (one *Grevillea* species in each area).

COASTAL COMPLEX

On seaward coastal dunes the grasses *Spinifex hirsutus, Ammophila arenaria* and *Festuca littoralis* are common, with herbs like *Tetragonia implexicoma* and *Swainsona lessertiifolia*. On landward dunes, the shrubs *Leucopogon parviflorus* and *Acacia longifolia* var. *sophorae* are more or less frequent throughout. *Melaleuca lanceolata* is very important through the Anglesea-Aireys Inlet area; we have not re-located the record from Lorne (Willis 1948). The species does not re-appear west of Lorne until near Warrnambool (Willis 1948), being generally absent at the coast where MAR exceeds about 89 cm (35 in.).

The distribution and status of the widely planted *Leptospermum laevigatum* is puzzling. It is widespread as dense scrub and clearly indigenous north-east of the study area at Ocean Grove and is common around Torquay. It occurs on dunes at Anglesea and Eastern View, but as scattered patches rather than widespread stands, suggesting the possibility that it is a garden escape in these areas. Even the stand of old

trees at the Erskine River mouth at Lorne could be planted rather than indigenous. It is also known from Cape Otway. The absolute western limit of indigenous stands must fall somewhere within the areas mentioned and historical research may help to resolve this problem. Spasmodic occurrences along the coast from Cape Otway to Nelson are apparently all escapes from gardens or hedges planted as wind breaks (A. C. Beauglehole, personal communication).

L. laevigatum has not been seen anywhere in the coastal fringe where the Cretaceous rocks come to the coast, but *Leucopogon parviflorus* is widespread in such sites. The tree *Casuarina stricta* is important on exposed coastal cliffs and slopes, particularly before the eucalypt zone is reached passing inland. Carr (1970) gives further details on the coastal vegetation.

The only Victorian record of *Correa reflexa* var. *nummulariifolia* is from the mouth of the Parker River around the coast to Cape Otway, at the base of aeolian calcarenite slopes often just above high tide level on shallow calcareous sand over calcarenite (this study). This is the only mainland occurrence of a variety known elsewhere only from Kangaroo Island and islands in Bass Strait. Some species more or less characteristic of soils on calcarenite and rare or absent elsewhere in the area are also found here, viz. *Acrotriche affinis, Beyeria leschenaultii, Exocarpos syrticola* and *Olearia glutinosa*.

OTHER COMMUNITIES

Salt marsh was examined at the mouth of Anglesea River, where *Salicornia quinqueflora* and *Juncus kraussii* Hochst. (formerly called *J. maritimus*) are important dominants and associated species include *Disphyma blackii, Hemichroa pentandra* and *Sebaea albidiflora*. On low-lying estuarine flats at the mouth of the Aire River, *J. kraussii, Phragmites australis* (Cav.) Trin. ex Steud., *Scirpus pungens* Vahl (formerly called *S. americanus*) and *S. validus* are important.

Melaleuca ericifolia, which occurs throughout eastern Victoria on low-lying sub-saline sites inland from salt marsh, does not extend as far west as the Otway region. At the mouth of the Anglesea River, such sites are occupied, surprisingly, by *M. lanceolata* which throughout the rest of its range is a species of elevated, well-drained, non-saline sites. *M. halmaturorum* is characteristic of swampy saline sites in South Australia and Western Victoria, but is not known further east than Cope Cope near Donald (J. H. Willis, personal communication).

In non-saline swamps, closed-scrubs are usually dominated by *M. squarrosa* and, especially in the west Otways, *Leptospermum lanigerum*. The nature and ecology of all the swamp communities are very poorly known and need further work.

CONSERVATION

State-owned plantations of introduced softwoods (mainly *Pinus radiata*) in the Otways zone at present occupy 3400 ha. Current scheduled planting is 200 ha per year and the planned plantation area for the zone is 8000 ha (Williams 1975). Presumably much of the future increase will be at the expense of native vegetation. Private companies own a further 8000 ha, all of which is intended for softwood plantations (A. Pitt, personal communication). Probably at least half of this will be at the expense of native forest rather than formerly cleared land.

Death of native vegetation from fungal die-back disease caused by *Phytophthora cinnamomi* Rands has been recorded in heath and woodland vegetation on Tertiary areas in the Great Ocean Road Flora Reserve near Anglesea, in Angahook Forest Park (Weste & Marks 1975) and near Point Addis (Weste 1975). The eastern Otways and Gellibrand are said to have 'small pockets of infection and very few die-back patches' (Marks, Fagg & Kassaby 1975). No work whatever is being done on the disease in the Otways region at present. Clearly, information is urgently needed on exact distribution, and whether the disease is likely to cause damage on Cretaceous areas as well as Tertiary ones. Such data may help to avert disastrous epidemics like those in Western Australia and East Gippsland. Certainly, compulsory testing of road gravel supplies and nursery stock and proper cleaning of road-making equipment as suggested by Weste and Marks (1975) should be implemented in the area immediately.

The most serious weed problem affecting native vegetation is *Chrysanthemoides monilifera* both because it is already widespread, especially along the whole coast north-east of Cape Otway and because it frequently invades both disturbed and completely undisturbed native communities. Gravel carting from infested areas should be strictly avoided (Parsons 1973). Introduced *Rubus* spp. are widespread and serious weeds and *Pittosporum undulatum* is already an important weed in some areas (e.g. coastal vegetation at Eastern View). The latter is also causing concern in Nine Mile Reserve (Heathmere) and Bolwarra Quarry Reserve north of Portland (A. C. Beauglehole, personal communication).

DISCUSSION

The most striking features in the macrovariation pattern of vegetation in the Otway Ranges are the ecological shifts and terminations occasioned by the Tertiary-Lower Cretaceous boundary, and the gradual

changes in species dominance and vegetation structure within each geological unit responding to degrees of availability or excess of soil moisture. The set of eucalypt species found on the Cretaceous overlaps with the set found on the Tertiary, differences being due in part to the frequently drier climates experienced on the latter. However, the general absence of species such as *E. baxteri* and *E. nitida* from the Cretaceous and the rarity of *E. cypellocarpa* from the Tertiary probably reflect differences in nutrient status more than differences in moisture status. Marked structural shifts occur along the geological boundary. Most commonly there is a shift from heath or woodland with a sclerophyll shrub understorey on the Tertiary to open-forest with a grassy understorey on the Cretaceous. Where drainage is impeded in soils on the Tertiary, heaths and scrubs can directly adjoin tall open-forest on the well-drained soils on the Cretaceous. Grassy understories are more characteristic of the Cretaceous than the Tertiary on which sclerophyllous shrub understories or communities dominate. However, soils on the Tertiary Moorabool Viaduct Formation support grassy woodlands, possibly as a synergistic result of lower rainfall and higher fertility of the soil parent material. These compare with some Tertiary areas dominated by *E. sideroxylon* near Aireys Inlet

TABLE 1

MAJOR FOREST AND WOODLAND COMMUNITIES OF THE OTWAY REGION VLCC (1976)

D. H. Ashton (unpublished) and The Present Study.

Structural forms	Dominant species with associated tree species in brackets. VP=varying proportions	Geology	Common understorey species
Closed-forest	*Nothofagus cunninghamii (Acacia melanoxylon)*	Cretaceous	*Hedycarya angustifolia, Dicksonia antarctica, Blechnum procerum*
Open-forest 40m high	*Eucalyptus regnans* (see text)	Cretaceous	*H.angustifolia, Olearia argophylla, Phebalium squameum*
	E.cypellocarpa, E.globulus, E.obliqua, E.viminalis VP	Cretaceous	*Pomaderris aspera, O. argophylla, Bedfordia arborescens*
Open-forest 28-40m high	*E. obliqua (E. cypellocarpa)*	Cretaceous	*Acacia mucronata, A. melanoxylon, Pimelea axiflora*
	E. globulus (E. obliqua, E. cypellocarpa)	Cretaceous	as above
	E. ovata (E. obliqua, E. cypellocarpa)	Cretaceous	as above
Open-forest 15-28m high	*E. obliqua, E. globulus, E. cypellocarpa* VP	Cretaceous	*A. mucronata, A. verticellata, A. verniciflua*
	E. baxteri, E. obliqua, E. radiata VP	Tertiary	*Banksia marginata, Leptospermum juniperinum, A. verticellata*
Open-forest 15m high	*E. globulus* E. sideroxylon* VP	Cretaceous	*A. verniciflua, Pultenaea daphnoides, Goodenia ovata*
	E. aromaphloia, E. obliqua, E. radiata VP	Cretaceous and Tertiary	various
	E. sideroxylon, E. obliqua, E.cypellocarpa* VP	Tertiary	*A. verniciflua, P. daphnoides, Poa sieberana*
	E. obliqua (E.baxteri)	Tertiary	*B. marginata, Epacris impressa, Xanthorrhoea australia*
	E. viminalis (E. obliqua)	Quaternary sands	*Pteridium esculentum, Poa* spp., *Lomandra longifolia*
Woodland	*E. baxteri, E. nitida, E. obliqua* VP	Tertiary	*Leptospermum juniperinum, L. myrsinoides, B. marginata*
	E. kitsoniana (E. ovata, E. baxteri)	Tertiary	*Leptospermum juniperinum, Melaleuca squarrosa*

* = can form pure stands

and *E. ovata* near Anglesea, where some facies of the Tertiary deposits appear to be of higher fertility than normal or to accumulate nutrients through downslope movement.

Sclerophyllous shrub understories do occur on the Cretaceous but have a distinctly taller and more diffuse character than the heath-like understories on the Tertiary, this character being imparted by species such as *Acacia verticillata, Pultenaea daphnoides* and *Acacia mucronata*. The herbaceous component of the sclerophyll understories on the Cretaceous is also more prominent than in sclerophyll understories on the Tertiary, where, however, bracken is considerably more common. Broad-leaved shrub understories may be found on both substrates, but are naturally more extensive on the Cretaceous which includes most of the high rainfall country.

The Cretaceous core of the Otways exhibits an apparently moisture-related continuum of eucalypt communities. The set of eucalypts confined to the driest Cretaceous areas is *E. sideroxylon, E. radiata* and *E. aromaphloia* with *E. sideroxylon* generally in drier areas than the other two. *E. viminalis, E. globulus, E. cypellocarpa* and *E. obliqua* form a central set in putative order from dry to wet. *E. regnans* occupies the wettest areas, and the middle set overlaps with both extreme sets. Changes from one community to another are usually gradual, and recognized communities are probably points on a continuum. However, the three broad understorey types of grassy, sclerophyll shrub and broad-leaved shrub are often sharply distinct and jaggedly contiguous, suggesting that fire history may be of considerable importance in setting their boundaries. The *Poa*- and *Themeda*-dominated grassy understories are usually replaced by sclerophyll shrub understories with sparse suppressed grasses where the eucalypt canopy is opened and shrub germination encouraged by severe fire. However, a succession of ground fires will tend to reinforce the grassiness of the understorey, as will a lack of fire for a period greater than the relatively short lifespan of the understorey shrub species. Some shrub establishment that might occur even under the reduced light intensities of a mid-dense eucalypt canopy may be suppressed by the activity of both native and introduced herbivores who often produce a low, evenly-grazed, herbaceous sward.

Local inhabitants tell of much more extensive grassy forests in the past in areas where *Acacia verticillata* and *Goodenia ovata* now dominate the understorey. Grassy forest floors are now most common around holiday settlements and grazing lands where accidental and deliberate fires are still frequent.

There appears to be much more variation in the fertility of the soils on Tertiary deposits than in the soils on Cretaceous rocks, so generalizations on the sequence of eucalypts are not so easily related to precipitation. Well-drained sites on the Tertiary support low open *E. nitida* woodland in the driest situations, *E. nitida-E. baxteri* woodland in slightly wetter situations and *E. obliqua-E. aromaphloia-E. radiata* open-forests as moisture becomes even more abundant. Tall open-forests of *E. obliqua, E. globulus* and *E. viminalis* are found in the wettest areas. *E. sideroxylon* woodland is spatially restricted and difficult to fit within this sequence, its occurrence possibly being related to particular nutrient conditions as much as moisture availability. *E. ovata* and *E. kitsoniana* occur on the fringes of wet heaths in areas of impeded drainage, the latter possibly only where drought does not greatly inhibit growth in the dry season.

An interesting feature of the Otways vegetation is the widespread occurrence of mixed stands of eucalypts known to be capable of inter-breeding, such as *E. regnans-E. obliqua, E. cypellocarpa-E. globulus* and *E. obliqua-E. radiata,* whereas Pryor (1953) suggests that eucalypt species capable of interbreeding occur together only in ecotones or severely disturbed areas. One of the major problems raised by the present data is the width of range overlap that can still be considered ecotonal (Kirkpatrick 1975a) and further work is clearly needed.

The Otway Ranges and the South Gippsland Hills have identical Cretaceous geology and show other marked similarities. Although the South Gippsland vegetation is now largely destroyed, the remnants show the same relationships between eucalypts on the Cretaceous (only *E. sideroxylon* is absent), the same marked shifts and terminations on contact with the surrounding Tertiary deposits, and even the same pattern of geographic variation in *E. globulus* (Kirkpatrick 1975b). *Nothofagus cunninghamii* closed-forest occurs in both areas, as do communities dominated by *E. kitsoniana* on the Tertiary. However, the vegetation on the Tertiary areas surrounding the South Gippsland Hills differs in many respects from that found in the Otways (VLCC 1972) and there are interesting floristic differences in the closed-forest; most notably the lack of *Atherosperma* in the Otways and the absence of *Phebalium squameum* subsp. *squameum* in the South Gippsland Hills.

In general, the Otway Ranges are not strongly distinguished by floristic peculiarities. The only plant species endemic to the area is the little-known *Leptorhynchos gatesii,* of which the only collection is from 'dry hillsides at Lorne' (Willis 1957b). However, many species reach their extreme eastern or western limits in the Otways (see Beauglehole, Carr & Parsons 1977). One such species is *Acacia nanodealbata* whose range was significantly extended in the present

work when it was found at low altitudes (less than 70 m) in the western Otways (e.g. at junction of Caroline Creek with Gellibrand River road). This south-central Victorian species was thought to be montane or sub-alpine except for the only previous Otways record at Lorne (Willis 1957a). Apart from the Lorne record, the species is apparently centred in the south-west Otways, where the closely related and otherwise widespread *A. dealbata* is apparently absent. The *A. nanodealbata* seen in the Otways differs from the type description (Willis 1957a) in its longer leaves (up to 15 cm), much more distant pinnae and non-glaucous stems. Clearly more work on its distribution and taxonomy is needed.

The Otways deserve strong consideration for a much extended system of reserves. The magnificent variety of the heaths, scrubs and forests, the lack of gross disturbance of much of the vegetation of the ranges and the scenic amenity of the juxtaposition of mountains, sea, heath, woodland and forest deserve more than accelerating extension of pine plantations, ugly coastal shack development and clearing of marginal land for farming.

ACKNOWLEDGMENTS

We thank D. H. Ashton, A. C. Beauglehole, A. Pitt, A. Thornley and J. H. Willis for helpful comments on the manuscript and J. Minchinton for general assistance.

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