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A NEW PHYTOGEOGRAPHIC MAP OF WESTERN AUSTRALIA

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ABSTRACT

F. von Mueller (1867) first drew attention to the special character of Southwestern Australia as a phytogeographic region. Diels (1906) delimited a South-West Botanical Province and an Eremaean Province and divided them into Botanical Districts. Clarke (1926) divided the State into Natural Regions on an ecological basis. Gardner (1942) added a Northern Botanical Province and (1956) extended Diels' Botanical Districts to the whole State. There is a considerable degree of agreement between Clarke's and Gardner's treatments but both were restricted to small-scale sketch maps for the expression of their ideas as mapping techniques had not yet become sufficiently developed. Detailed vegetation mapping (Beard 1969 et seq.*) has shown that ecological regions can be recognised and given precise boundaries on a larger scale, published at 1:1,000,000 and reduced to 1:2,500,000 in the general map which accompanies this paper. Details of the climate, geology, soils, and vegetation of each botanical district are given.*

The recognition of phytogeographic or other natural ecological regions has received little attention in Australia except in the west where it has a long-standing tradition. The subject was first raised for Western Australia by F. von Mueller (1867, 1883) who drew attention to the special character of the south-western flora, and indicated (but with no map) a boundary running from Shark Bay to Israelite Bay. L. Diels (1906), in treating Western Australia south of the tropic divided the area into two Botanical Provinces, the South-west Province and the Eremaean Province. The latter term, applied to the desert area, was first proposed by Tate (1890) for a portion of northern South Australia and spelt Eremia from the Greek, meaning solitude or wilderness. The reason for the change of spelling by Diels is not known. The boundary between the two, said Diels, coincided approximately with the 30 cm isohyet, separated the internal drainage area of the country from the portions draining to the sea (not actually true), was of importance to human settlement in being the boundary od cereal cultivation, and had also recently (at that time) been picked up in zoogeography (Woodward, 1900). "It follows that the biological boundary between the Eremaea and the South-west Province is essentially climatically determined" (Diels, *loc. cit.*).

Diels proceeded to divide the South-west Province into 6 Botanical Districts and the southern Eremaea as far as known to him into 2. Each of these was characterised by a range of rainfall, by particular types of vegetation and by species distribution. A sketch map was provided (Fig. 1).

Fig. 1. The botanical districts, copied from Diels (1906), with the boundary of the South-west Province indicated by a thicker, dashed line.

Gardner (1942), in an account of the vegetation of the whole State, added the concept of a Northern Botanical Province including the Kimberley and Pilbara districts. He later expanded Diels' Botanical districts on a State-wide basis (Gardner & Bennetts 1956; Fig. 2), so there were now 5 districts in the Northern Province, 5 in the Eremaea (which he wrote as Eremea, introducing a third spelling), and 6 in the South-west. Details of the rainfall, climate, soils and vegetation of each district were given in the text. Comparison of Figs. 1 and 2 shows that Gardner had moved the boundary of the South-west Province somewhat further east. (See Marchant 1973, Fig. 1).

In the meantime a geologist, E. de C. Clarke (1926), had proposed a regional subdivision of the State on the basis of a synthesis of all ecological factors to determine "natural regions". These were selected in the following way:

A. The State was primarily divided into major physical regions.
B. It was again divided into major geological regions, effecting a subdivision of the major physical regions.
C. Climatic considerations, chiefly the amount and season of rainfall, were found to necessitate further subdivision of A & B.

"By this stage", wrote Clarke, "we should have arrived at a classification into natural regions and our result should be in harmony with the distribution of distinctive plant associations."

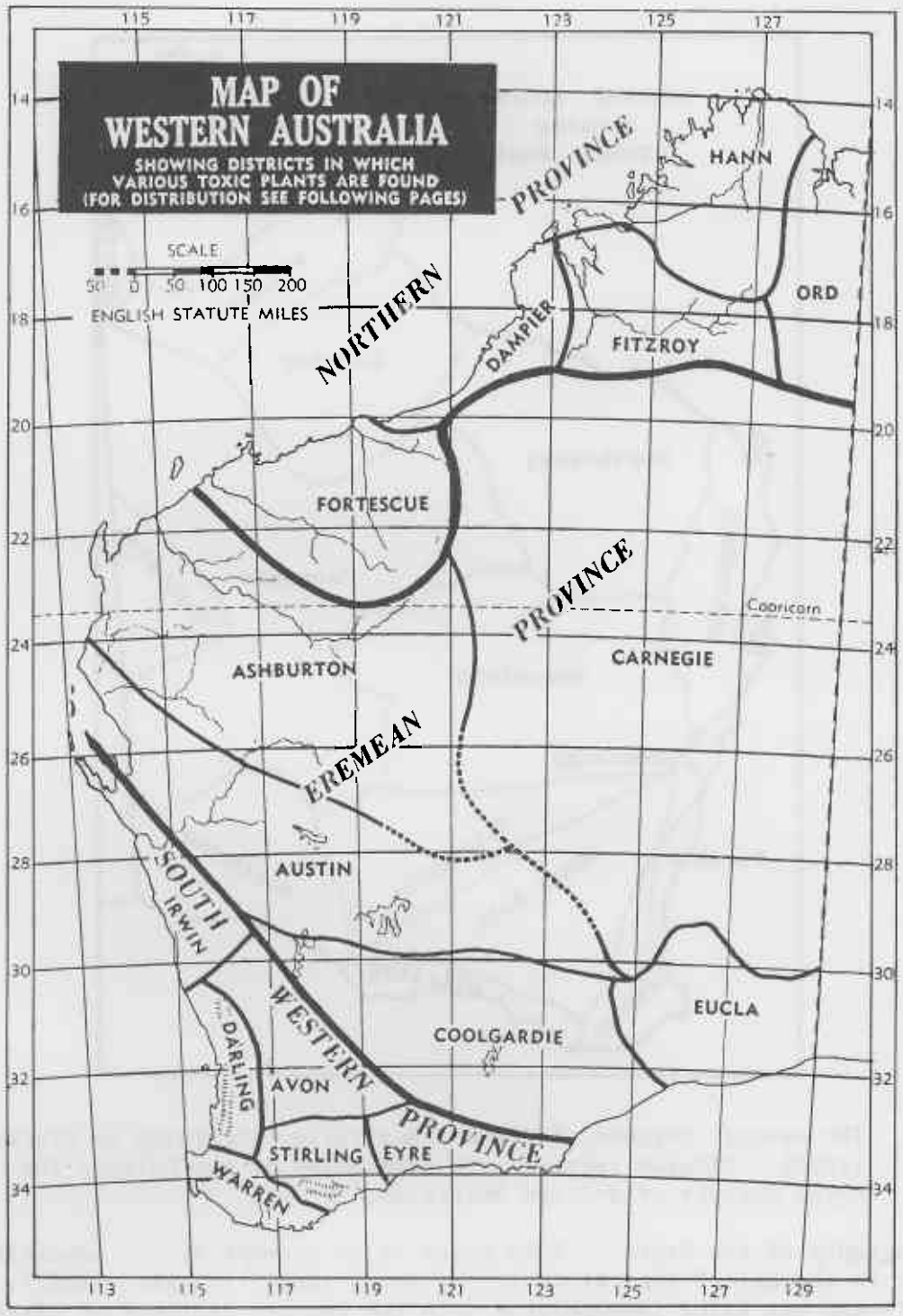

Fig. 2. The botanical provinces and districts of Western Australia, according to Gardner & Bennetts (1956). Copied with permission of the Publishers, West Australian Newspapers Ltd.

In this way Clarke arrived at 15 natural regions and one sub-region shown in a sketch map reproduced here as Fig. 3, and gave a general description of the geology, topography, rainfall, soils and vegetation of each. Clarke recognised the scanty state of knowledge of many parts of the State at that time, so that his approach could only be provisional; but he evidently regarded it as a significant contribution to the understanding of

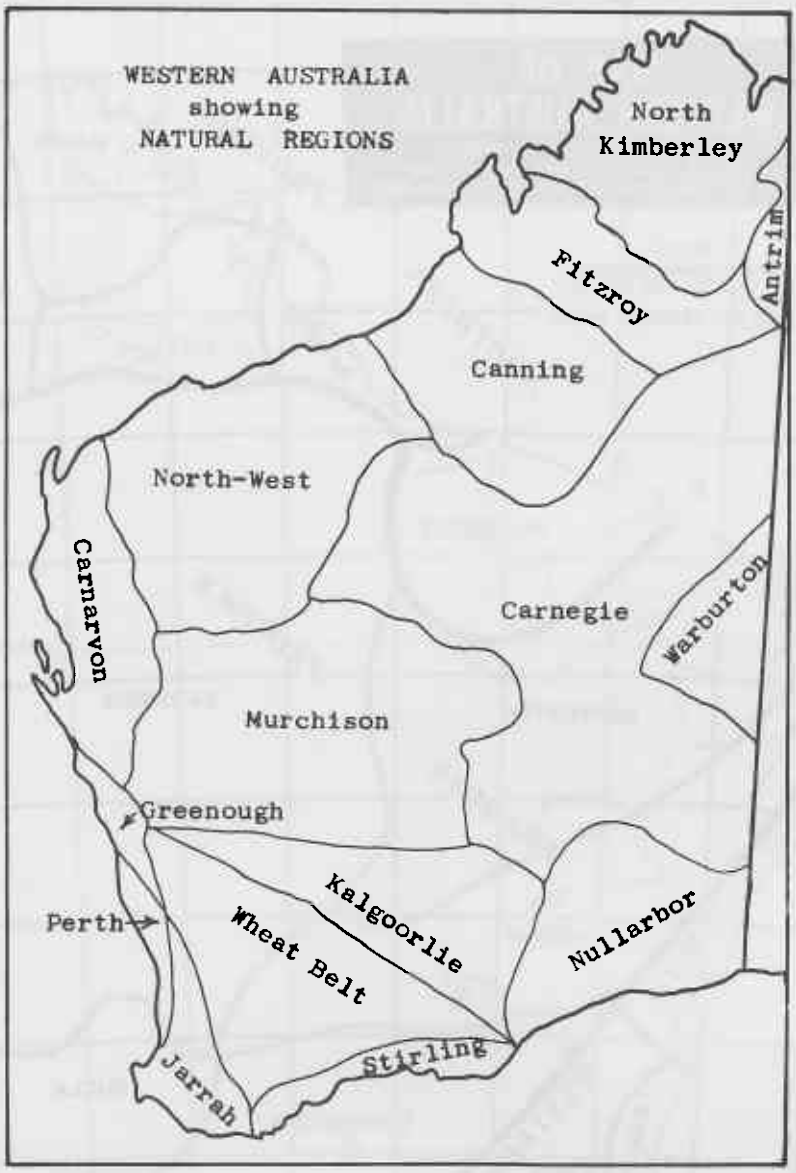

Fig. 3. The natural regions of Western Australia, according to Clarke (1926). Diagram redrawn with permission of the Editor, The Royal Society of Western Australia.

the geography of the State. "This paper is an attempt at ... subdivision, and not in the belief that it is in any sense final" (Clarke, *ibid.*). Clarke's map was later incorporated into the geology textbook of Clarke, Prider and Teichert (1948, and subsequent editions).

Gardner's approach to phytogeographic regionalisation was also ecological. In the explanatory notes to the map, reproduced here as Fig. 2, it was made clear that the classification was based upon climate and vegetation, e.g. "The South-West Province is that part of Western Australia which receives a winter rainfall of 10 inches or more. Apart from its area of sandplain and thicket growth on laterite, it consists of *Eucalyptus* woodland and mallee lands, and the jarrah of the South-West. In addition it ... is precisely the area to which the main elements of the South-West flora are limited, e.g. the heaths, kangaroo paws etc."

In view of Gardner's ecological approach it is not surprising that, outside the South-West Province in which the botanical districts had been taken up from Diels' work, they frequently agreed rather closely with Clarke's Natural Regions (compare Figs. 2 and 3). Unfortunately the utility of the regionalisation, however soundly based, was much reduced for practical purposes to other workers such as taxonomists, field naturalists, conservationists and others by the small scale of the maps provided. Unfortunately too it would have been impossible for either Clarke or Gardner to have provided definite boundaries on larger scale maps at that time since geographical knowledge of the State was still scanty, there were no detailed topographic maps, aerial photography was not yet available and travel facilities were still minimal. The pioneers realised that there was a valid basis for ecological regionalisation but had no means of laying down precise boundaries. Such a means has only recently come to hand.

A modification to Diels' botanical districts of the South-west was suggested by N.H. Speck in 1958 who proposed a Le Sueur District centred on the mountain of that name and inserted between the Irwin and Darling Districts. This treatment was adopted by B.J. Grieve and W.E. Blackall in Part IV of "How to know Western Australian wildflowers" (1975) although Diels' original map was reproduced in the previous three parts (Blackall & Grieve 1954, 1956, 1965). In all cases the boundary of the South-west Province was Diels' and not Gardner's. Gardner's map was reproduced by Beard (1965).

N.T. Burbidge (1960) proposed an Australia-wide treatment (Fig. 4) dividing the continent into three "Principal Floristic Zones" with intermediate "Interzone Areas" between them based essentially on climate.

> "Treated broadly the continent can be divided into three main climatic zones, and these are referred to here as the Tropical, Temperate and Eremaean Zones ... Each of the zones shows characteristics related to geography and it is interesting to find that they correspond with the main features of the zoogeographic 'regions' recognised by Main, Lee and Littlejohn (1958)." (Burbidge 1960).

Burbidge retained Diels' spelling Eremaean.

Dealing with the Interzone areas, Burbidge wrote:

> "In general the southern boundary of the Eremaea is based on the position of the 10-in. (250 mm) isohyet. However in Western Australia there is a triangular area lying between the South-West Province and the Eremaea proper ... Within it there is some mingling of the genera of the sand-heath associations of the Province with the aridity-tolerant genera of the Eremaea."

This area constitutes Interzone 1 and is the Coolgardie Botanical District of Diels and Gardner.

It may be appropriate at this point to review the parallel situation in zoogeography, following Burbidge's allusion quoted above. It has not been possible to trace Woodward's map of 1900 cited by Diels (1906) and it may be that no more copies are extant. The map published by Main, Lee and Littlejohn (1958) was very small and very diagrammatic but it is sufficiently clear that the three regions represented, named Torresian, Eyrean and Bassian, correspond to Burbidge's Tropical, Eremaean and

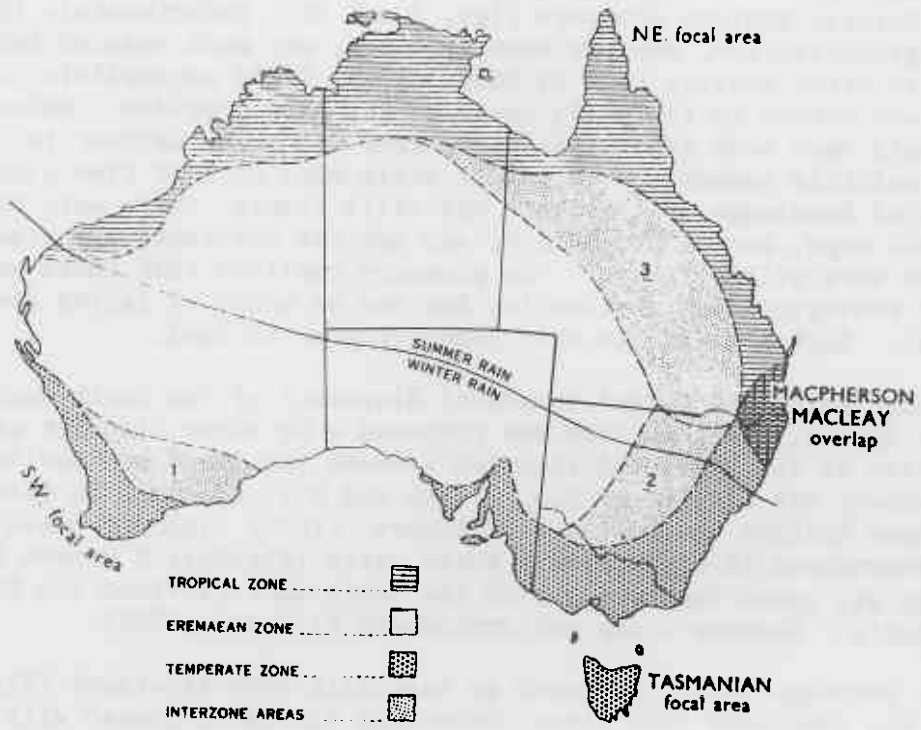

Fig. 4. The principal floristic zones of the Australian region, according to Burbidge (1960). Copied from the Australian Journal of Botany 8 (1960).

Temperate Zones, except that Bassian was restricted, strictly speaking, to south-eastern Australia and its extension to south-western Australia treated as controversial. The names of the zoogeographic regions had been originated by W.B. Spencer in 1896 who treated the south-west as part of the Eyrean region. G.E. Nicholls, on the other hand, in 1933 concluded that the south-west of Australia should be recognised as a biogeographic province and proposed the name Hesperonotian. "This however has not found favour as zoologists, especially ornithologists, while appreciating the validity of the faunal boundary realised that faunal elements rather than static faunal provinces ought to be recognised." (Main, Lee & Littlejohn 1958). D.L. Serventy and H.M. Whittell (1951) modified Spencer's terminology and spoke of Bassian and Eyrian (sic) faunas. They noted that the south-west contains both Eyrian and Bassian elements. It appears that in the succeeding period no general reappraisement of zoogeography has been made, in fact the subject has fallen out of favour, zoologists preferring to regard animals as desert-adapted or not, rather than Eyrean or Bassian (A.R. Main, pers. comm.). A contribution has nonetheless been made by Pianka (1969) who published a map of the "sub-regions of the Australian desert" (i.e. of the Eyrean region) accompanying a paper on desert lizards. This map, showing 13 sub-regions, is reproduced here as Fig. 5. Little was said about the individual sub-regions in the text but it is clear that they were ecologically conceived, separating the sandridge, hamada, limestone and other types of desert. The author claimed "a fair correspondence between the distributions of *Ctenotus* species and the geographic sub-regions."

Ten years after Burbidge, H. Doing (1970) made a further impressive contribution to Australian plant geography although his paper, published in

Fig. 5. Sub-regions of the Australian desert, according to Pianka (Ecology 50: 1013, 1969). Copyright 1969 by the Ecological Society of America.

Holland, seems to have attracted little attention in Australia. In mapping it represented a big advance on Burbidge, as the paper was accompanied by a map, scale 1:16,000,000, printed in colour on a finely detailed topographic base (Fig. 6). Doing distinguished between phytogeography in a strict sense of geographical aspects of taxonomy and what he called "vegetation geography" (after Schmithüsen 1968) based on the distribution of plant communities. In the latter, cover and abundance of species and structural aspects of vegetation are of paramount importance, while the former considers the distribution of all plant species including rare and endemic ones. Doing thought it possible to combine both aspects in his treatment. He divided the Australian Plant Kingdom into two Subkingdoms, the Central Australian Subkingdom and the *Eucalyptus* Subkingdom. The former, discarding the traditional name, is essentially the Eremaean Zone or Province of previous authors, while the *Eucalyptus* Subkingdom comprises the whole of the periphery. Each Subkingdom is divided into Regions and these into Provinces. It seems to this reviewer that Doing's treatments are open to some criticism. The Central Australian Subkingdom is divided into a Desert Region and a Mulga Region, the former defined as largely treeless and the latter as dominated by phyllodineous *Acacias* including mulga (*Acacia aneura*). It is difficult to match this picture with actuality; mulga and similar *Acacias* are nowhere dominant in the northern half of the desert, for example. A comparison with Pianka's ecological units in Fig. 5, shows little similarity between the two treatments of the Eremaean Zone. In the *Eucalyptus* Subkingdom, in Western Australia the Southwestern Forest Province (Ewf) is acceptable being the Darling Botanical District of later work (Fig. 7) but the Southwestern Heath Province (Ehw) is too narrow, following Diels' boundary of the South-west Botanical Province (Fig. 1) rather than Gardner's (Fig. 2) or Beard's (Fig. 7). The Western Mallee Province (Emw) is an enlarged Southwestern Interzone (Fig. 4) and is not happily named since only a small proportion of it has a mallee vegetation - the Roe District of Fig. 7.

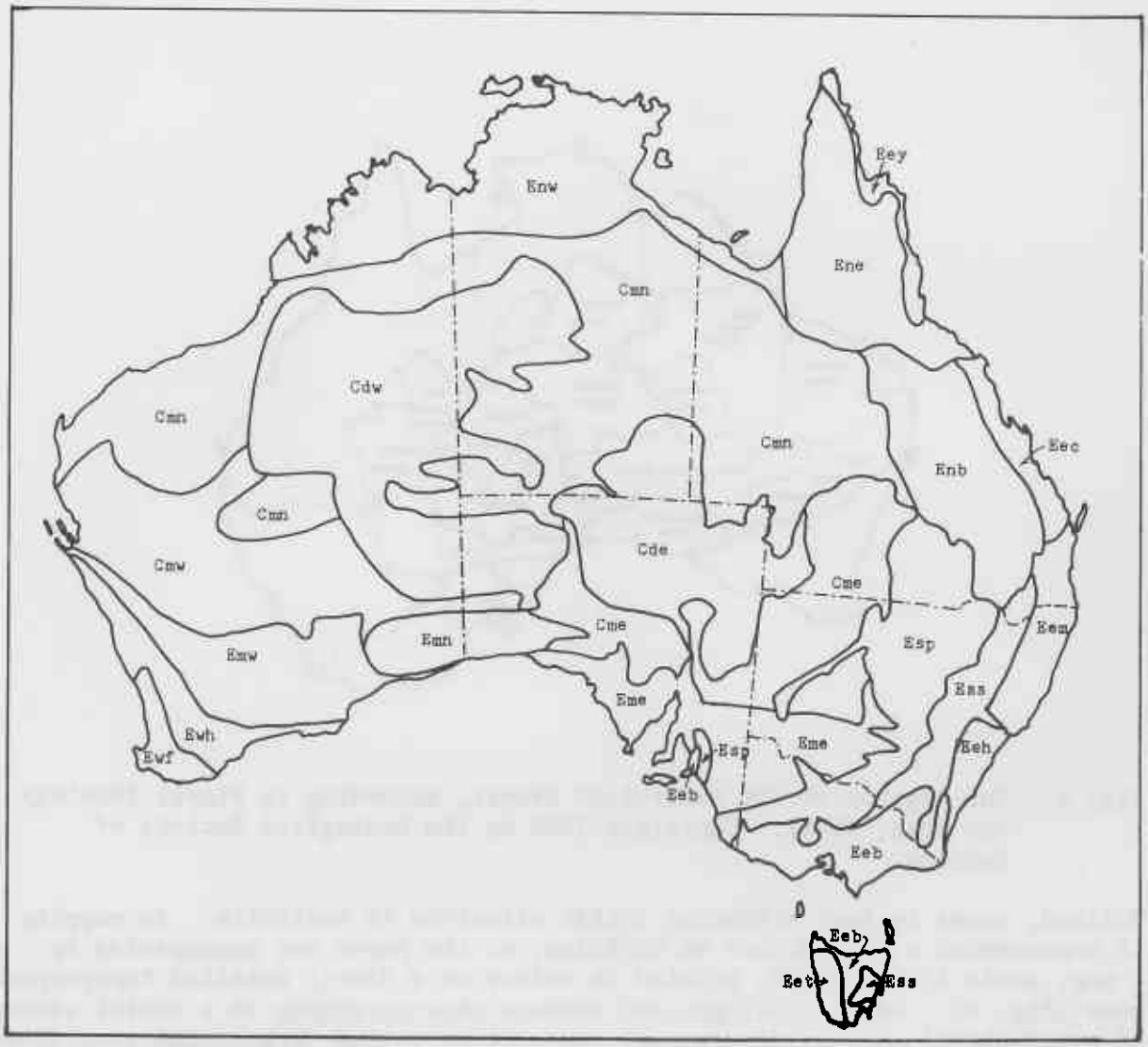

Fig. 6. Botanical Geographical Map of the Australian plant kingdoms, by H. Doing (1970). Redrawn and simplified from original coloured map.

It was remarked earlier in this paper that regional maps of Australia had suffered from small scale and inadequate basic information, but that a means of improving the situation had now been found. In 1964 a vegetation-mapping project, the Vegetation Survey of Western Australia, was established by Prof. M.J. Webb and myself, as a result of which vegetation maps covering the greater part of the State at the 1:1,000,000 scale have already been published (Beard & Webb 1974, Beard 1974, 1975, 1976 a & b). In the course of field work for mapping the writer first came to appreciate the reality of the ecological regionalisations of Clarke and Gardner. Later when maps were prepared it quickly became obvious that the natural regionalisation made itself apparent from the grouping of the map colours. In 1969, when the first maps were ready but had not yet been published, the writer drew attention to this in a paper dealing with the desert areas in the eastern half of the State (Beard 1969). To quote:

> "The desert area is divisible naturally into a number of quite distinct regions each having a characteristic landscape and vegetation. The boundaries of these regions, as shown in Fig.

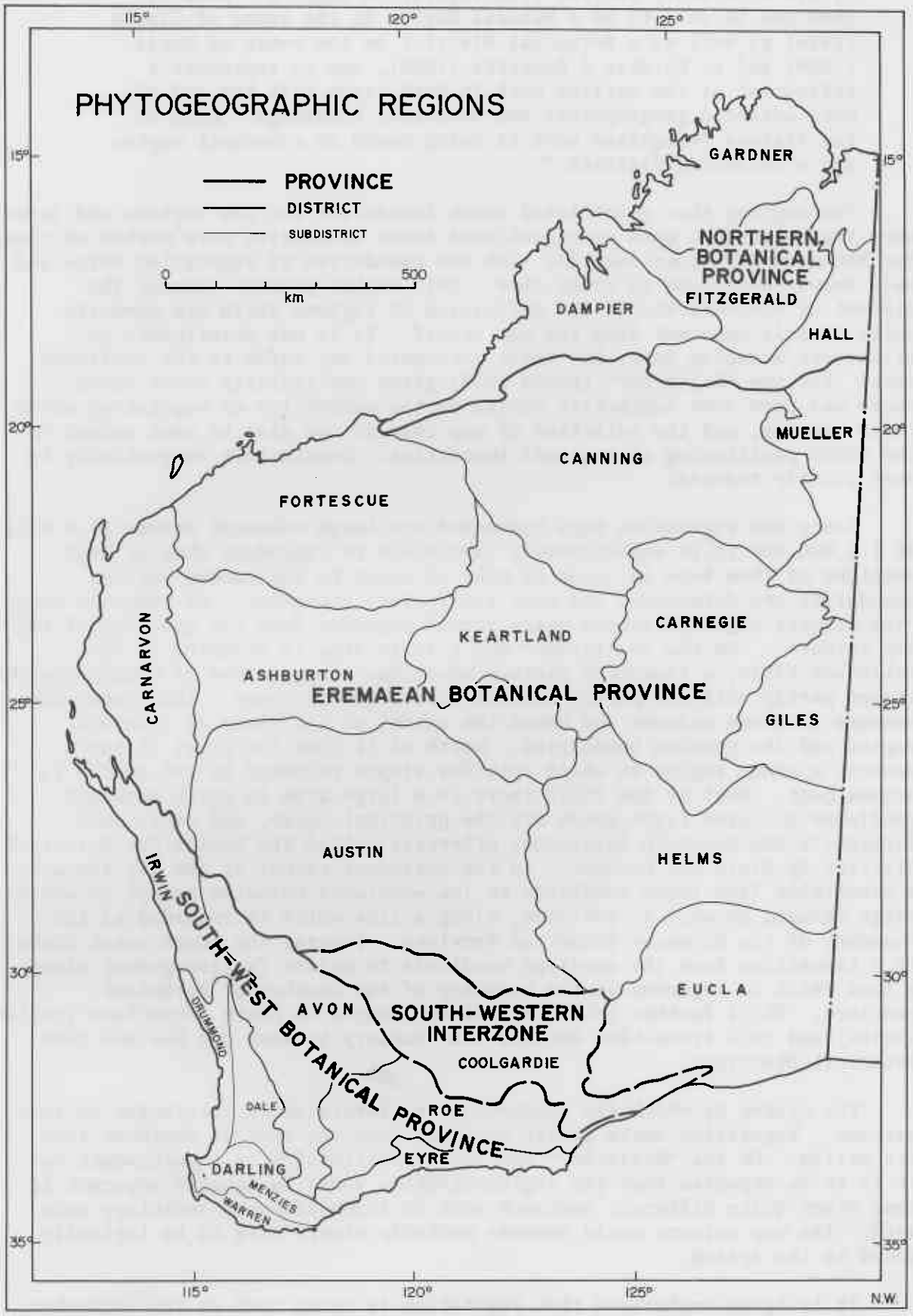

Fig. 7. Phytogeographic regions of Western Australia as determined by vegetation mapping, by author.

> 5, are accurately derived from vegetation mapping. Each of them can be said to be a Natural Region in the sense of Clarke (1926) as well as a Botanical District in the sense of Diels (1906) and of Gardner & Bennetts (1956), and to represent a refinement of the earlier work in both cases with the aid of more advanced geographical and botanical knowledge. Each of the regions recognised here is being named as a natural region and a botanical district."

The mapping thus established exact boundaries for the regions and later when the vegetation maps were published these boundaries were marked on them. For the most part they coincide with the boundaries of vegetation units and only rarely are drawn to cross them. This method greatly reduces the element of subjectivity in the definition of regions which are normally quite clearly apparent from the map itself. It is not practicable to illustrate examples here, but those interested may refer to the published work: the map "Nullarbor" (Beard 1975) gives particularly clear cases. There has been some subjective choice in the definition of vegetation units, their mapping, and the selection of map colours and also to some extent in the exact positioning of regional boundaries. Nonetheless subjectivity is very greatly reduced.

Since the vegetation maps concerned are large coloured sheets at a scale of 1:1,000,000 it is unfortunately impossible to reproduce them or even sections of them here in order to make it clear to the reader how the boundaries are determined and what the regions represent. As remarked above "the natural regionalisation makes itself apparent from the grouping of the map colours". On the "Nullarbor" map, a large area is occupied by the Nullarbor Plain, a limestone plateau which has a vegetation of Chenopodiaceous steppe partly with and partly without scattered low trees. This vegetation appears in brown colours and shows the extent of the Plain as a natural region and its precise boundaries. North of it lies the Great Victoria Desert, a sandy region in which spinifex steppe coloured in red shades is predominant. West of the Plain there is a large area in which Eucalypt woodlands coloured light green are the principal cover, and consistute Burbidge's Southwestern Interzone, otherwise called the Coolgardie Botanical District by Diels and Gardner. In the northwest corner of the map there is a transition from these woodlands to low woodlands coloured orange in which mulga (*Acacia aneura*) is dominant, along a line which is regarded as the boundary of the Eremaean Botanical Province. Towards the south coast there is a transition from the eucalypt woodlands to mallee (yellow-green) along a line which is regarded as the boundary of the South-west Botanical Province. Still further south the mallee changes to heath formations (yellow shades) and this transition defines the boundary between the Roe and Eyre Botanical Districts.

The system by which the vegetation is classified is irrelevant to this outcome. Vegetation units remain distinct from one another whatever they are called. On the "Nullarbor" map the classification is physiognomic but it is to be expected that the regionalisation would be equally apparent if some other quite different approach such as Braun-Blanquet sociology were used. The map colours would however probably always have to be logically coded to the system.

It is again emphasised that vegetation is being used as the indicator of natural ecological regions each of which possesses its own characteristic landscape due to its particular features of climate, geology, landforms, soils and vegetation. It is to be expected that the flora of each region will also

show characteristic features, but it is vegetation, not flora, which defines the region. Since vegetation provides animal habitats it is to be expected that the fauna of each region will show characteristic features.

Clarke's (1926) method, cited earlier in this paper, was to consider physiography, geology and climate after which "the result should be in harmony with the distribution of distinctive plant associations". It is therefore obviously possible to work from the other end, to map the distinctive plant associations and to use them to define natural regions.

The utility of the regionalisation in practice has also been considerably enhanced. Previously, botanists had legitimate reason to complain that the botanical provinces and districts were so vague that they frequently had difficulty in deciding in which one a particular botanical collection or plant community or study area was located. Now with the boundaries precisely shown on topographically based maps of a reasonably large scale (1:1,000,000) this difficulty falls away. Given the large size of most Australian States it is a convenience to taxonomists to work with a system of subdivisions, and both the Western Australian Herbarium and the National Herbarium, Sydney, have already been using ecological units. The system now becoming available as vegetation mapping proceeds may, it is hoped, be of use to workers in other fields as well.

With the approach to completion of the vegetation mapping in Western Australia it has recently become possible to prepare a State map showing the boundaries of the botanical provinces and districts derived by reduction from the vegetation maps. A map at 1:2,500,000 drawn on a detailed topographic base for locality references is available for practical use and accompanies this paper. A further reduced diagram showing the outlines of the districts only has also been prepared (Beard 1979a) and is reproduced here as Fig. 7. In the Eremaean Province there are now 11 districts. In the remote interior there has been substantial revision based on information not previously available (Beard 1969). The Fortescue district has been transferred from the Northern Province according to arguments advanced in Beard (1976a) and a new Carnarvon district created (*ibid.*). The Ashburton, Austin and Eucla districts are essentially as Gardner conceived them.

The Northern Province has had to undergo substantial revision since the vegetation map of the Kimberley District (Beard in prep.) on completion proved to be not in accord with Gardner's earlier treatment (Fig. 2). With the scanty information of earlier days it is evident that Gardner was too greatly influenced by Clarke (Fig. 3) whose treatment mainly followed the geological structure. The distribution of vegetation is more strongly influenced by rainfall. After discussion among the Western Australian botanists it was decided to conserve the name of the Dampier district from Gardner but to rename the other three districts which are entirely new in concept. One is named after C.A. Gardner himself in honour of his pioneer botanical work in that area in 1921.

The Coolgardie district is equated with Burbidge's Southwestern Interzone and is essentially as conceived by both Gardner and Burbidge.

The South-West Botanical Province is bounded essentially as conceived by von Mueller (1883), Gardner (1942, 1956) and Burbidge (1960). Vegetation mapping has closely confirmed the views of these authors. Diels (see Fig. 1) took a boundary running much closer to the coast. On the continued criterion of mapping according to vegetation it was found necessary to revise Diels' districts very considerably and again after discussion at the Western

Australian Herbarium it was decided to institute five sub-districts. Diels' names are conserved in four cases (Irwin, Darling, Avon, Eyre) while the Warren District is reduced to a sub-district and the Stirling District has been discarded. A new Roe District has been instituted which comprises the mallee country. No basis could be seen in vegetation mapping for conserving Speck's Le Sueur District.

Details of the Botanical Provinces and Districts follow.

THE NORTHERN BOTANICAL PROVINCE

Tropical portion of the State lying below the 19th parallel (approximately). Summer rainfall 300-400 mm. Tropical grasslands and shrublands.

(a) Gardner Botanical District.

The name commemorates C.A. Gardner for his pioneer botanical exploration of the District in 1921 (Beard 1979a).
High-grass savanna woodlands. *Eucalyptus tetrodonta-E. miniata* alliance with *Plectrachne pungens* and annual *Sorghum* spp. on sandstone; *E. tectifica-E. grandifolia* alliance with *Sehima nervosum* and *Sorghum* on basalt.
Climate: Dry hot 'tropical'; precipitation > 700 mm per annum, summer wet season 4-6 months.
Geology: siliceous sedimentary and basic volcanic rocks of Proterozoic age.
Topography and soils: a dissected plateau with mesa shape hills and ranges. Chiefly shallow stony and sandy soils on sandstones; neutral red and yellow earths on basalt.
Boundaries: The southern boundary is the mapped boundary of the high-grass savanna and corresponds approximately to the 700 mm isohyet.

(b) Fitzgerald Botanical District

The name commemorates W.V. Fitzgerald for his pioneer botanical exploration of the area in 1905-6 (Beard 1979a).
Curly spinifex (*Plectrachne pungens*) with low trees of *E. phoenicea-E. ferruginea* or *E. brevifolia-E. dichromophloia* on sandstones, ribbon grass (*Chrysopogon*) with *E. tectifica* on basalt.
Climate: dry hot 'tropical'; precipitation 400-800 mm per annum, summer wet season of four months.
Geology: siliceous sedimentary and basic volcanic rocks of Proterozoic age, overlying locally exposed basement of Archaean granite, acid volcanics and siltstones.
Topography and soils: hilly to mountainous country with the harder siliceous rocks forming parallel ranges; volcanics in the valleys.
Boundaries: Boundaries were drawn to encompass the curly spinifex communities. The northern boundary is the transition to high-grass savanna, the southern follows the boundary of Precambrian rocks from King Sound to the Margaret River, thereafter the vegetation boundary between curly spinifex and semi-desert spinifex steppe.

(c) Dampier Botanical District

Named after Wm. Dampier, Buccaneer and early navigator. His name is often

applied to that part of the world as Dampierland, and exists officially in the Dampier Peninsula (Gardner & Bennetts 1956).
Tree savanna of *Chrysopogon-Dichanthium* with scattered *E. microtheca* and *Lysiphyllum cunninghamii* on river plains; pindan on sandplains. This is a three-layered community, an open upper stratum of low trees, a closed middle layer of *Acacia* and an open ground layer of curly spinifex; hummock grassland with scattered trees on uplands.
Climate: semi-arid to dry hot 'tropical'; precipitation 250-800 mm per annum, summer wet season 2-4 months.
Geology: Quaternary sandplain overlying Jurassic sandstones; Quaternary marine deposits on coastal plains. Devonian reef limestones and extensive alluvial river plains.
Topography and soils: Extensive riverine plains with grey and brown cracking clays; extensive sandplains on red earthy sands, low uplands of sandstone and limestone with shallow stony soils.
Boundaries: The southern boundary is drawn according to vegetation at the edge of desert sandplains and dunefields; the northern and eastern boundaries at the vegetation change with the transition from Phanerozoic to Precambrian rocks.

(d) Hall Botanical District

Named after Charles Hall whose name survives in Hall's Creek where he discovered gold in 1884.
Hummock grassland of *Triodia* spp. with sparse trees on ranges; short grass of *Enneapogon* spp. on dry calcareous plains, medium-height grasses *Astrebla* and *Dichanthium* on cracking clays.
Climate: semi-arid to dry hot 'tropical', precipitation 350-500 mm, summer wet season 2-4 months.
Geology: very varied Archaean, Proterozoic and Phanerozoic rocks both acid and basic.
Topography and soils: harder siliceous rocks form abrupt parallel ranges with shallow stony sand and loam soils; volcanics and limestones form extensive plains with neutral red earths and red loams or grey and brown cracking clays.
Boundaries: Drawn according to vegetation changes as noted above in bounding with the other districts. The southern boundary is the edge of desert sandplains and dunefields.

THE EREMAEAN BOTANICAL PROVINCE

Central portion of the State, desert. Hummock grassland, low woodland and scrub. Rainfall < 300 mm, seasonal pattern changing from summer in the north through bixeric to non-seasonal in the south.

(a) Canning Botanical District (Great Sandy Desert)

Named after A.W. Canning, surveyor of Stock Route, also Canning Basin which is equivalent (Beard 1969).
Tree steppe grading to shrub steppe in the south-east, comprising open hummock grassland of *Triodia pungens* and *Plectrachne schinzii* with scattered trees of *Owenia reticulata, Eucalyptus* spp. and shrubs of *Acacia* and *Grevillea*.
Climate: arid 'tropical' with summer rain; precipitation 200-300 mm per annum.
Geology: Quaternary sandplain overlying Cretaceous and Jurassic sandstones which are exposed locally.
Topography and soils: gently undulating plain dominated by longitudinal

dunes of varying frequency tending mainly WNW-ESE. Chief soils are red earthy sands and red siliceous sands, with exposures of ironstone gravels locally.
Boundaries: Drawn all round at the limit of desert sandplains and dunefields on Mesozoic rocks.

(b) Mueller Botanical District (Tanami Desert)

Named after Baron Ferdinand for his participation in the Gregory expedition of 1856 to that area (Beard 1969).
Shrub steppe as general cover with *Triodia pungens*. Sparse tree steppe on some ranges, locally plains with short-grass savanna.
Climate: arid 'tropical' with summer rain; precipitation 200-300 mm per annum.
Geology: Quaternary sandplain overlying Proterozoic and Permian rocks which are exposed locally.
Topography and soils: gently undulating sandy plain, dominated by longitudinal dunes south of latitude 20°30'S and with occasional low rocky ranges of Proterozoics; laterite-crusted uplands on Permian.
Boundaries: The western boundary with the Canning District is the limit of desert sandplains and dunefields on Mesozoic rocks. The short southern boundary is the northern limit of mulga.

(c) Carnarvon Botanical District

District name: geographical, equates with geological Carnarvon Basin (Beard 1975).
Mainly *Acacia* scrub and low woodland becoming tree and shrub steppe in the north, and with halophytes along the lower river courses.
Climate: semi-arid bixeric at the coast becoming arid with summer and winter rain further inland; annual precipitation 200 to 250 mm.
Geology: sedimentary basin with locally exposed rocks of Permian to Recent age; most of the surface covered by alluvium and colluvium.
Topography and soils: gently undulating plain with mesa shape remnants in the east and fields of longitudinal dunes. Hard alkaline red soils predominate in the plains with red sands in the dunefields.
Boundaries: The eastern boundary is drawn according to the vegetational expression of the geological boundary of the Carnarvon Basin.

(d) Fortescue Botanical District (Pilbara Region)

District name: geographical from river of same name (Gardner & Bennetts 1956).
Essentially tree and shrub steppe communities with *Eucalyptus* trees, *Acacia* shrubs, *Triodia pungens* and *T. wiseana*. Some mulga occurs in valleys and there are short-grass plains on alluvia.
Climate: arid tropical with summer rain; annual precipitation 250-300 mm.
Geology: a basement of Archaean granite and volcanics, overlain by massive deposits of Proterozoic sediments (including jaspilite and dolomite) and volcanics.
Topography and soils: a mountainous region rising to 1250 mm. Chiefly hard alkaline red soils on plains and pediments, shallow and skeletal soils on the ranges.
Boundaries: On east and west, according to vegetation expression of the margins of the Carnarvon and Canning Basins. On the south the boundary is

that between *Triodia*-dominated steppe and *Acacia*-dominated scrub, climatically controlled with local geological modification.

(e) Keartland Botanical District (Little Sandy Desert)

Named after Keartland, collector with the ill-fated Wells expedition of 1896 (Beard 1969).
Shrub steppe of *Acacia* and *Grevillea, Triodia* spp. on and between dunes, patches of desert oak and mulga.
Climate: arid 'tropical' with summer rain' annual precipitation 200-250 mm.
Geology: Quaternary sandplain with longitudinal dunes developed over locally exposed Proterozoic siliceous rocks.
Topography and soils: sandplain with numerous low hills and small ranges, with mainly bare rock and shallow stony soils on these; red earthy sands in the plains.
Boundaries: N.-change in underlying rocks from Precambrian to Mesozoic. E.-edge of laterite plains country of Gibson Desert. S. & W.-edge of desert sandplains and dunefields.

(f) Carnegie Botanical District (Gibson Desert)

Named after Hon. D.W. Carnegie, explorer and collector 1896 (Gardner & Bennetts 1956).
The cover of the laterite plains is a mosaic of mulga (*Acacia aneura* low woodland) and shrub steppe (*Hakea, Acacia, Triodia basedowii*). Shrub steppe covers the sandy areas.
Climate: arid with summer rain; annual precipitation 200 mm.
Geology: flat-lying Cretaceous and Jurassic sandstones.
Topography and soils: monotonous, gently undulating plain with a few sandstone mesas. Stripped laterite surfaces are general on the uplands with sands in the valleys, often with longitudinal dunes.
Boundaries: N., S. & W.-edge of laterite plains country. E.-edge of sedimentary basin.

(g) Giles Botanical District

Named after Ernest Giles, explorer and collector (Beard 1969).
Acacia scrub on quartzitic ranges, mulga on volcanics and the heavier plain soils; otherwise tree and shrub steppe. Stands of desert oak are common in depressions.
Climate: arid with both summer and winter rain; annual precipitation 200 mm.
Geology: ranges and hills of Proterozoic rocks including both volcanics and quartizites, interspersed in Quaternary sandplains with some Permian exposures.
Topography and soils: shallow rocky loams on the ranges; red earthy sands and red earths in the plains.
Boundaries: Throughout, the limit of underlying Precambrian rocks. In the south and northwest arbitrary lines have had to be drawn across sandplains as these rocks have no surface outcrop.

(h) Ashburton Botanical District

District name: geographical, from Ashburton River (Gardner & Bennetts 1956).
Almost entirely mulga (*Acacia aneura*) as scrub on the hills and as low wood-

land on the plains. Some areas of dwarf scrub of *Eremophila* and *Cassia*.

Climate: arid with summer and winter rain; annual precipitation 200-250 mm
Geology: middle Proterozoic rocks, mainly sandstone, and some granite.
Topography and soils: mountainous, with low ranges divided by broad, flat valleys. Chiefly shallow earthy loams overlying red-brown hardpan on the plains, with shallow stony soils on the ranges.
Boundaries: N. & E.-boundary between *Triodia*-dominated steppe and *Acacia*-dominated scrub. S. & W.-geological boundaries of the Yilgarn block and Carnarvon Basin respectively, in their vegetational expression.

(i) Austin Botanical District (Murchison Region)

District name: geographical (I assume) from Lake Austin (Diels 1906).
Predominantly mulga low woodland (*Acacia aneura*) on plains, reduced to scrub on hills. Tree steppe of *Eucalyptus* spp. and *Triodia basedowii* on sandplains.

Climate: arid with summer and winter rain; annual precipitation 200 mm.
Geology: Archaean granite with infolded volcanics and meta-sediments (greenstones) of like age, forming the Yilgarn Block.
Topography and soils: undulating, with occasional ranges of low hills, and extensive sandplains in the eastern half. The principal soil type is shallow earthy loam overlying red-brown hardpan; shallow stony loams on hills and red earthy sands on sandplains.
Boundaries: N., E. & W.-vegetational expression of geological boundaries of the Yilgarn Block. S.-climatically determined "*Eucalyptus-Acacia* line" between *Acacia* low woodland and *Eucalyptus* medium-height woodland on lower-slope soils, parallel changes in sandplains.

(j) Helms Botanical District (Great Victoria Desert)

Named after Helms, botanical collector with the Elder Exploring Expedition of 1891 (Beard 1969).
Mulga low woodland on hardpan soils between dunes; otherwise tree steppe of *Eucalyptus gongylocarpa, E. youngiana, Triodia basedowii*.
Climate: arid with summer and winter rain; annual precipitation 200 mm.
Geology: Quaternary sandplain overlying Permian and Mesozoic rocks which are occasionally exposed.
Topography and soils: undulating, somewhat featureless, mostly with longitudinal dunes. Shallow earthy loams overlying red-brown hardpan frequently occur between the dunes; otherwise red earthy sands, with red-brown sands in the dunes.
Boundaries: Edge of desert sandplains and dunefields all round. N.-transition to laterite plains country of Gibson Desert and Precambrian country of Warburton Region. S.-edge of Nullarbor Plain, bluebush plains on limestone W.-edge of mulga country on Yilgarn Block.

(k) Eucla Botanical District (Nullarbor Region)

District name: geographical; equates with geological Eucla Basin (Gardner & Bennetts 1956).
Bluebush steppe of perennial *Maireana sedifolia* (formerly *Kochia sedifolia*) with annual grasses and forbs; treeless in the centre, peripherally with low trees of *Acacia sowdenii, A. aneura, Casuarina cristata*.

Climate: arid non-seasonal (rain in any month); annual precipitation 150-200 mm.
Geology: sedimentary basin, exposing Eocene to Miocene sediments, mainly limestone.
Topography and soils: gently undulating, featureless plain, with shallow calcareous loam.
Boundaries: Edge of bluebush plains on limestone. The boundary coincides with the limestone boundary except in the southwest where higher rainfall brings *Eucalyptus* woodland onto the limestone.

THE SOUTHWESTERN INTERZONE

(a) Coolgardie Botanical District

District name: geographical after settlement of same name. (Diels 1906).
Predominantly eucalypt woodlands, becoming open and with saltbush-bluebush understorey on the more calcareous soils. Patches of shrub steppe adjoining the Great Victoria Desert. Scrub heath and *Casuarina* thickets on sandplains.
Climate: arid non-seasonal to semi-arid 'mediterranean'; annual precipitation 200-300 mm.
Geology: Proterozoic granite and gneiss of the Fraser Range Block; Archaean granite with infolded volcanics and meta-sediments of the Yilgarn Block.
Topography and soils: gently undulating with occasional ranges of low hills; sandplains in the western part and some large playa lakes. Principally brown calcareous earths.
Boundaries: N.-climatically determined "*Eucalyptus-Acacia* line" between *Acacia* low woodland and *Eucalyptus* woodland on lower-slope soils, and between mallee-spinifex steppe and *Acacia* thickets on sandplains. E.-edge of bluebush plains on limestone. S. & W.-boundary of the South-west Botanical Province, see below.

THE SOUTHWESTERN BOTANICAL PROVINCE

Southwestern extremity of the State. Heath, thicket, mallee, woodland and forest. Winter rainfall 300-1500 mm.

The provincial boundary running from Shark Bay to Israelite Bay as indicated by von Mueller (1867) is quite clearly delimited by vegetation. From Shark Bay to Mullewa it is the boundary of mixed "tree heath" and *Acacia-Casuarina* thicket with *Acacia ramulosa* scrub on the Toolonga Plateau. From Mullewa to Lake Moore on the Darling Plateau it is drawn between middle-height *Eucalyptus* woodlands and *Acacia ramulosa* scrub with scattered low trees on lower-slope soils and between *Acacia* thickets of different composition on the upper-slope sandplain soils. From Lake Moore to Southern Cross the differences are more delicate. The vegetation of shallow granitic soils was taken as the criterion between Lake Moore and Bullfinch, *Casuarina* thickets in the SWP., *Acacia* scrub in the Interzone. From Bullfinch to the Parker Range patches of mallee in the woodlands of the SWP., no mallee and mixture of goldfields eucalypts in the Interzone. From this point eastward the boundary is once more clear and distinct, the inland limit of the mallee formation running right out to Point Culver on the Great Australian Bight.

(a) Irwin Botanical District

District name: geographical after river of same name (Diels 1906).
Scrub heath on sandplains near the coast; *Acacia-Casuarina* thickets further inland. *Acacia* scrub with scattered trees of *Eucalyptus loxophleba* on the hard-setting loams.
Climate: dry, warm 'mediterranean'; winter precipitation 300-500 mm, with 7-8 dry months per year.
Geology: mainly sedimentary basins exposing Permian to Cretaceous sediments; horsts of Proterozoic rocks.
Topography and soils: prior land surface forming extensive lateritic sandplain, locally dissected especially near the coast. The sandplains are covered with leached sandy soils near the coast, and yellow sands with an earthy fabric further inland, both overlying laterite. Soils developed after stripping of the sandplain are mostly hard-setting loams with red clay subsoils.
Boundaries: NE.-provincial boundary. E.-vegetational expression of the Darling Fault, with a lobe towards Dalwallinu and Pithara occasioned by a major sheet of aeolian sand. S.-northern limit of *Banksia* low woodland

(b) Darling Botanical District

District name: geographical after Darling Range (Diels 1906).

(i) Drummond Subdistrict. Mainly *Banksia* low woodland on leached sands with *Melaleuca* swamps where ill-drained; woodland of tuart (*Eucalyptus gomphocephala*), jarrah (*E. marginata*) and marri (*E. calophylla*) on less leached soils.
Climate: warm 'mediterranean'; winter precipitation 600-1000 mm with 5-6 dry months per year.
Geology: Mesozoic to Recent sediments of the Perth Basin.
Topography and soils: a coastal plain, low-lying, often swampy, with sandhills; soils mainly recent sands or swamp deposits. Also dissected country rising to the duricrusted Dandaragan plateau on Mesozoics, mainly yellow sandy soils.
Boundaries: N.-northern limit of *Banksia* low woodland as above. E. & S.-geological boundary of the Perth Basin, mostly coinciding with the Darling Scarp but including a portion of the Dandaragan plateau in the north.

(ii) Dale Subdistrict. Named after Lt. Dale, explorer (Beard 1979a).
Jarrah (*E. marginata*) forest on ironstone gravels, marri-wandoo (*E. calophylla-E. wandoo*) woodlands on loamy soils, sclerophyll understories.

Climate: warm 'mediterranean' winter precipitation 600-1200 mm, with 5-6 dry months per year.
Geology: Archaean granite of the Yilgarn Block.
Topography and soils: duricrusted plateau on the Yilgarn Block, surfaced with ironstone gravels, dissected towards the east with hard-setting loamy soils.
Boundaries: E.-where *E. accedens* and *E. astringens* replace *E. marginata* on lateritic residuals, *E. calophylla* retires from woodlands of mid slope, and *E. loxophleba* and/or *E. occidentalis* appear on lower slopes. S.-ill-defined line where ironstone gravels become less prevalent and the understory changes. W.-Darling Scarp.

(iii) Menzies Subdistrict. Named after Archibald Menzies, collector with Vancouver expedition of 1791 (Beard 1979a).

Forest and woodlands as in the Dale Subdistrict, but understories differ in composition, becoming more similar to those of the Warren Subdistrict (below). Climate, geology, topography and soils are essentially as for the Dale Subdistrict, though conditons are slightly more humid.
Boundaries: N.-with Drummond and Dale subd., as above. NE.-boundary of *E. marginata* forest, low forest and woodland. S.-boundary of Warren Subd., see below.

(iv) Warren Subdistrict. District name: geographical after river of same name (Diels 1906).
Tall forest of karri (*Eucalyptus diversicolor*) on deep loams, forest of jarrah-marri (*E. marginata-E. calophylla*) on the leached sands. Extensive paperbark (*Melaleuca*) and sedge swamps in valleys.
Climate: moderate 'mediterranean'; winter precipitation ranges from 650 to 1500 mm per annum, essential feature is short dry season of only 3-4 dry months.
Geology: Archaean granite and infolded metamorphic rocks of the Yilgarn Block.
Topography and soils: dissected undulating country of small relief, hard-setting loamy soils alternating with leached sand soils.
Boundary: The norther boundary is drawn where *E. diversicolor* ceases to be a significant component.

(c) Avon Botanical District

District name: geographical after river of same name (Diels 1906).
The typical sequences of vegetation comprise scrub heath on sandplain, *Acacia-Casuarina* thickets on ironstone gravels, woodlands of York gum (*Eucalyptus loxophleba*) salmon gum (*E. salmonophloia*) and wandoo (*E. wandoo*) on loams, halophytes on saline soils.
Climate: dry warm 'mediterranean'; winter precipitation 300-650 mm per annum, with 7-8 dry months.
Geology: Archaean granites with infolded metamorphics of the Yilgarn Block.
Topography and soils: undulating plateau, mostly with disorganized drainage. Remnants of prior land surface are preserved, giving rise to catenary sequences of soils, typically yellow earths on sandplain, with ironstone gravels peripheral to same, hard-setting loam soils on slopes and bottomlands, and saline soils in depressions.
Boundaries: NE.-provincial boundary as defined. SE.-boundary of the mallee formation. W.-Darling District as defined above.

(d) Roe Botanical District

Named after John Septimus Roe, Surveyor-General, explorer of that area 1848, and collector (Beard 1979a).
The general cover is mallee with *Eucalyptus eremophila* the most consistent species. Patches of eucalypt woodland occur on lower ground, and scrub heath and *Casuarina* thickets on residual plateau soils.
Climate: dry warm 'mediterranean', winter precipitation annual total 300-500 mm, with 7-8 dry months.
Geology: Archaean and Proterozoic granites overlain in the east by early Tertiary sediments.
Topography and soils: gently undulating country of low relief with duplex mallee soils i.e. sand overlying clay.
Boundaries: The limit of the mallee formation is the all-round boundary.

On the north and west the mallee gives way to eucalypt woodland and on the south to mallee-heath.

(e) Eyre Botanical District

Named after John Eyre, explorer, 1841 (Diels 1906).
Scrub heath and mallee heath on sandplain with tallerack (*Eucalyptus tetragona*) as characteristic species. Mallee (*E. redunca, E. incrassata*) occupies valleys incised in the plain.
Climate: warm 'mediterranean'; winter precipitation, total of 500-700 mm per annum, with 5-6 dry months.
Geology: mainly Eocene sediments with outcrops of granites and quartzites.
Topography and soils: a plain with a little-dissected prior land surface rising gently from near sea level to a height of 200 m, broken by quartzite ranges (Barren Ranges, Russell Range) and granite domes. Soils are sandy overlying clay or ironstone gravels.
Boundaries: The limit of the predominant mallee-heath formation is the all-round boundary. On the north it gives way to mallee and at the western end to low woodland.

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APPENDIX I

Recommended standard abbreviations for botanical regions:

Provinces:

N = Northern	S = South-west
E = Eremaean	I = Interzone

Districts:

Northern Province

Nd = Dampier	Ng = Gardner
Nf = Fitzgerald	Nh = Hall

Eremaean Province

Eas = Ashburton	Efo = Fortescue
Eau = Austin	Egi = Giles
Eca = Canning	Ehe = Helms
Ecn = Carnarvon	Eke = Keartland
Ece = Carnegie	Emu = Mueller
Eeu = Eucla	

Southwestern Interzone

Ic = Coolgardie

South-west Province
- Sav = Avon
- Sda = Darling
- Sey = Eyre
- Sir = Irwin
- Sro = Roe

Subdistricts of Darling
- Sda(dr) = Drummond
- Sda(dl) = Dale
- Sda(me) = Menzies
- Sda(wa) = Warren