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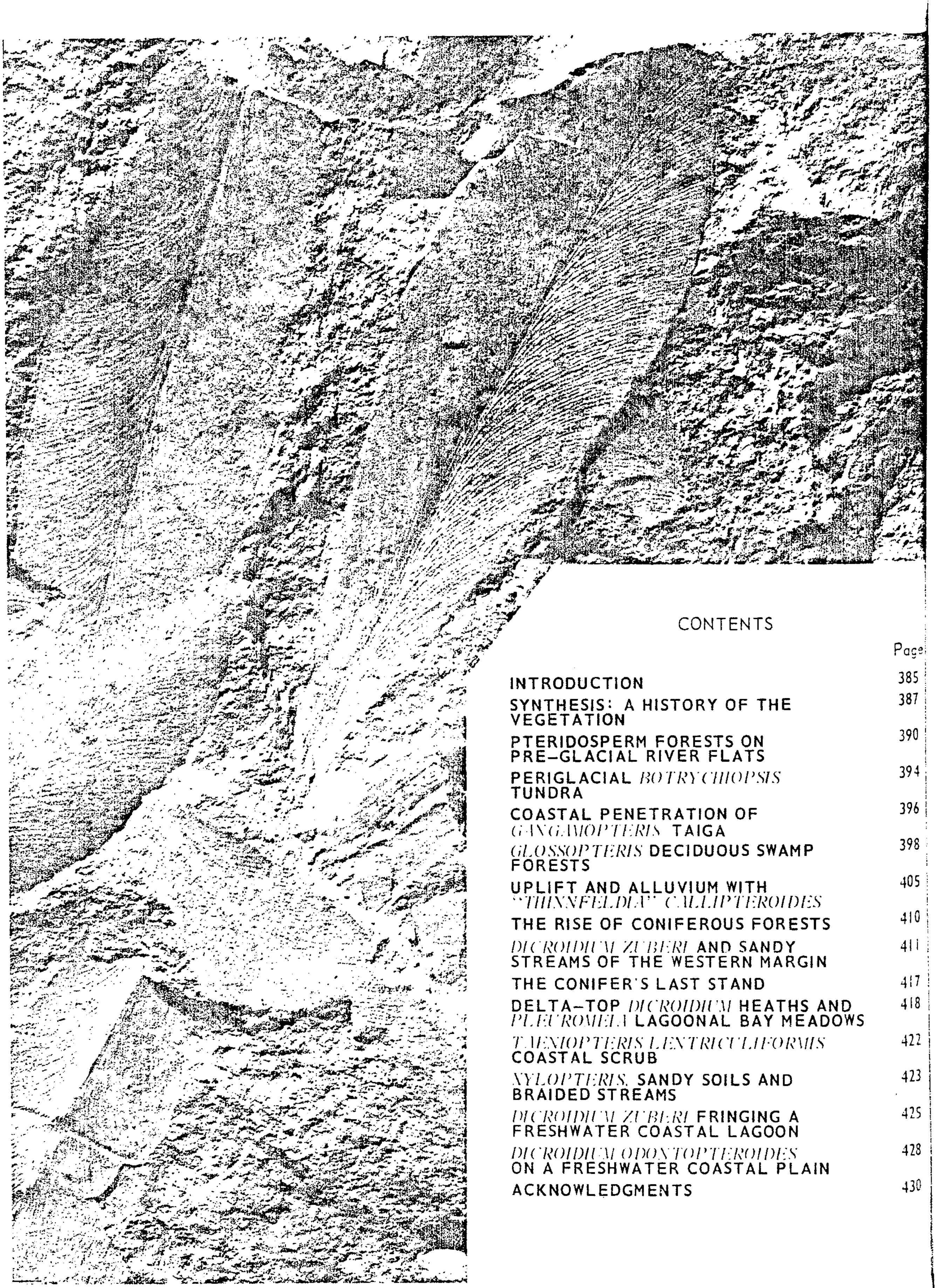


CONTENTS

21. LATE CARBONIFEROUS TO MIDDLE TRIASSIC MEGAFOSSIL FLORAS FROM THE SYDNEY BASIN

GREG RETALLACK

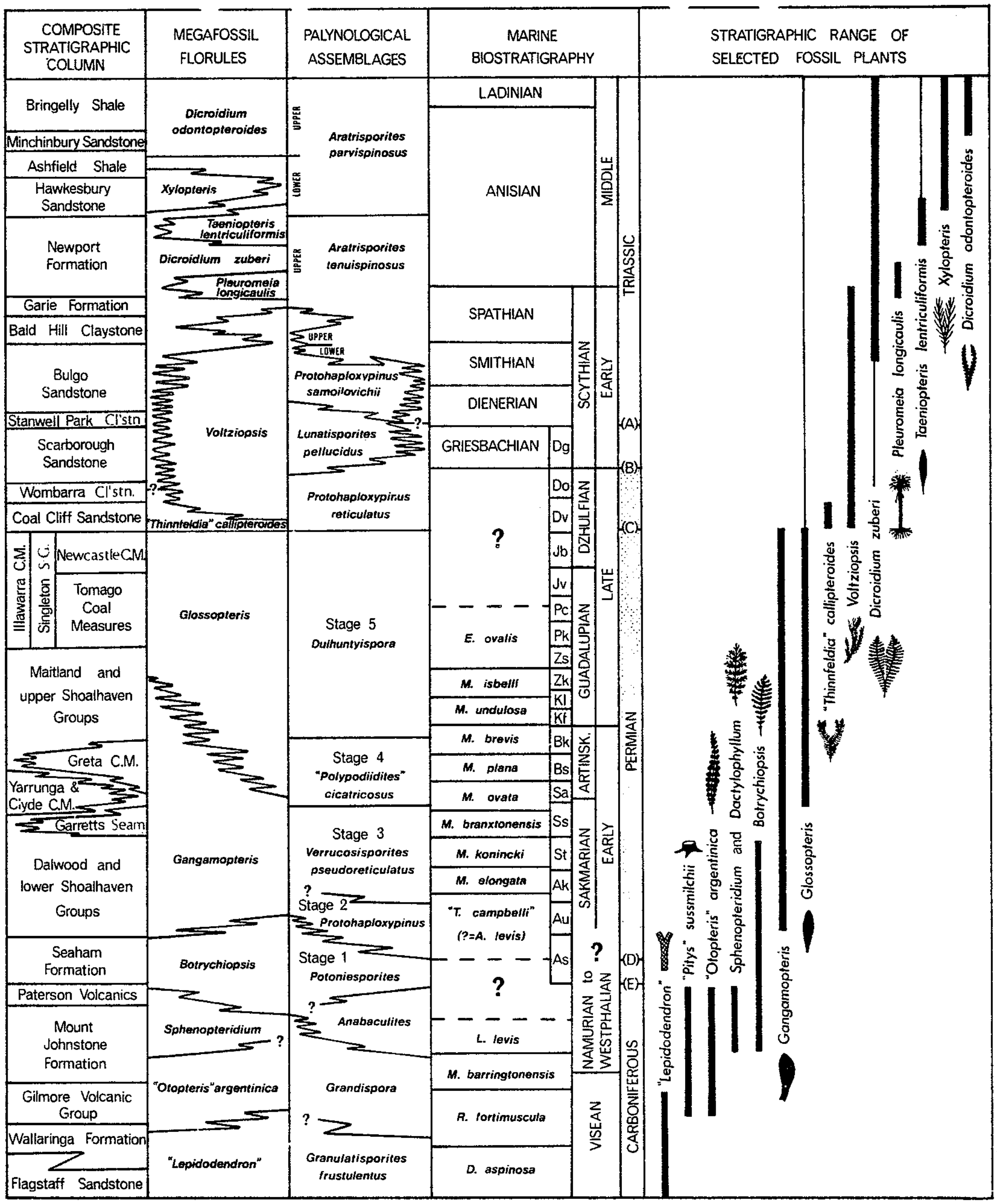
INTRODUCTION

The sequence of fossil plant remains in the Sydney Basin (figure 21.1) indicates a clear succession of ancient floras. These can be related to sedimentary environments, palaeoclimates, marine biostratigraphy, and isotopic dating to reconstruct a detailed history of vegetation in the area (figure 21.2). Although much work remains to be done, the Sydney Basin is presently one of the more informative areas for understanding the provincial floras of Gondwanaland during the Late Palaeozoic and Early Mesozoic.

"*Facies control*" is a striking feature of the fossil floras. In practice, this means that the actual occurrence, and many features, of a fossil florule are most easily related to the palaeoenvironment. In the following sections, I shall discuss florules for which the controlling ecological factor appears to have been severe climate, marine influence, water table stability and soil type. The succession of floral facies in a small area, such as the Sydney Basin, is only one facet of the palaeogeography and biostratigraphy of Gondwanaland. A more detailed treatment of the last subject, with recourse to information beyond the Sydney Basin, has been published elsewhere (Retallack 1977c). For the moment, I merely intend to discuss how and when successive floras waxed and waned with changing conditions in and around the Sydney Basin.

I have ignored fragmentary plant fossils in poorly correlated rocks unless they add to the overall picture or deserve further attention. For the same reasons I have avoided naming many of the less important sterile fern and equisetalean remains. Parts of currently used species names, which I regard as inconsistent with modern taxonomy, have been placed in quotation marks. It has been difficult in many such cases not to digress into systematic palaeobotany and to avoid *nomina nuda*. However, because of their biostratigraphic importance I could not avoid some taxonomic revision of the Carboniferous pteridosperms and have proposed *Botrychiopsis ovata* (McCoy) comb. nov. Many inaccurate records of fossil plants from the Sydney Basin have arisen because floral lists have been reinterpreted and generalized without re-examination of the original specimens. To avoid this, I have cited specimen and locality numbers extensively, using the following abbreviations:

New South Wales Geological Survey — Bulletin 26, 384-430, 13 figs


COMPOSITE STRATIGRAPHIC COLUMN
MEGAFOSSIL FLORULES
PALYNOLOGICAL ASSEMBLAGES
MARINE BIOSTRATIGRAPHY
STRATIGRAPHIC RANGE OF SELECTED FOSSIL PLANTS
Bringelly Shale
Minchinbury Sandstone
Ashfield Shale
Hawkesbury Sandstone
Newport Formation
Garie Formation
Bald Hill Claystone
Bulgo Sandstone
Stanwell Park Cl'stn
Scarborough Sandstone
Wombarra Cl'stn.
Coal Cliff Sandstone
Illawarra C.M.
Singleton S.G.
Newcastle C.M.
Tomago Coal Measures
Maitland and upper Shoalhaven Groups
Greta C.M.
Yarrunga & Clyde C.M.
Garretts Seam
Dalwood and lower Shoalhaven Groups
Seaham Formation
Paterson Volcanics
Mount Johnstone Formation
Gilmore Volcanic Group
Wallaringa Formation
Flagstaff Sandstone
Dicroidium odontopteroides
Xylopteris
Taeniopteris lentriculiformis
Dicroidium zuberi
Pleuromeia longicaulis
Voltziopsis
?
"Thinnfeldia" callipteroides
Glossopteris
Gangamopteris
Botrychiopsis
Sphenopteridium
?
"Otopteris" argentinica
"Lepidodendron"
UPPER
LOWER
UPPER
Aratrisporites parvispinosus
Aratrisporites tenuispinosus
UPPER
LOWER
Protohaploxypinus samoilovichii
?
Lunatisporites pellucidus
Protohaploxypinus reticulatus
Stage 5
Dulhuntyispora
Stage 4
"Polypodiidites" cicatricosus
Stage 3
Verrucosisporites pseudoreticulatus
?
Stage 2
Protohaploxypinus
Stage 1
Potoniesporites
?
Anabaculites
Grandispora
?
Granulatisporites frustulentus
LADINIAN
ANISIAN
SPATHIAN
SMITHIAN
DIENERIAN
GRIESBACHIAN
Dg
?
Do
Dv
Jb
Jv
Pc
Pk
Zs
Zk
Kl
Kf
Bk
Bs
Sa
Ss
St
Ak
Au
As
E. ovalis
M. isbelli
M. undulosa
M. brevis
M. plana
M. ovata
M. branxtonensis
M. konincki
M. elongata
"T. campbelli" (?=A. levis)
?
L. levis
M. barringtonensis
R. fortimuscula
D. aspinosa
MIDDLE
SCYTHIAN
EARLY
DZHULFIAN
GUADALUPIAN
LATE
ARTINSK.
SAKMARIAN
EARLY
?
NAMURIAN to WESTPHALIAN
VISEAN
TRIASSIC
(A)
(B)
(C)
PERMIAN
(D)
(E)
CARBONIFEROUS
"Lepidodendron"
"Pitys" sussmilchii
"Otopteris" argentinica
Sphenopteridium and Dactylophyllum
Botrychiopsis
Gangamopteris
Glossopteris
"Thinnfeldia" callipteroides
Voltziopsis
Dicroidium zuberi
Pleuromeia longicaulis
Taeniopteris lentriculiformis
Xylopteris
Dicroidium odontopteroides

pteridosperm, "*Thinnfeldia*" *callipteroides*, dominated a broadleaf scrub on scroll bars and levees.

Conifers continued to forest most of the Sydney Basin into the Triassic. A system of brackish lagoons penetrated the coastal coniferous forests during a global marine transgression culminating in the Smithian. In the late Scythian, a broadleaf flora dominated by *Dicroidium zuberi* spread across the Sydney Basin with more quartzose sediments from the north and west (Banks Wall and upper Bulgo Sandstones and lower Gosford Formation). Some time after this, conifers again became locally prominent in the central eastern Sydney Basin. For a considerable time when the water table was unusually low, these coniferous forests grew on red sandstone and claystone (Bald Hill Claystone) derived from an eastern volcanic ridge. These coniferous forests were gradually overwhelmed by broadleaf floras colonizing quartzose sediments of freshwater lagoons and deltas (Newport and upper Gosford Formations). The lagoonal shores were fringed by dense monodominant stands of *Pleuromeia*. This distinctive lycopod appears to have spread along the world's seaways as a falcultative mangrove in the late Scythian and early Anisian. *Dicroidium zuberi* dominated a broadleaf heath association growing in the sandy soils of small deltas building out into the lagoons.

By the Anisian, the water table rose at a slower rate within the broad river flats covering most of the Sydney Basin. A coastal scrub largely of *Taeniopteris lentriculiformis* replaced the *Dicroidium zuberi* flora in the central eastern Sydney Basin. Later in the Anisian, uplift to the south of the Sydney Basin and a relatively stable water table caused the sandy floodplain (Hawkesbury Sandstone) to be even more frequently reworked by the violent flooding of braided streams. The dominantly sandy substrate encouraged the development of xerophytic pteridosperms, such as *Xylopteris*. A similar flora persisted when the water table began to rise again so that the sandy

Figure 21.2. The relationship between selected rock units, megafossil plants, palynological assemblages, and marine biostratigraphy in Carboniferous to Middle Triassic rocks of the Sydney Basin. Palynology after Kemp (1975), Paten (1969), and Helby (1973). Marine biostratigraphy mainly after Jones et al. (1973), Roberts et al. (1976), Runnegar and Campbell (1976), Runnegar and McClung (1975), Furnish (1973), and Tozer (1971). The initials are the new system of substages for the Permian proposed by Waterhouse (1976, tables 1,40), in which he recognized Middle (Kl-Jb) and Late Permian (Dv-Dg) series. Waterhouse's stage identifications for the Sydney Basin are quite specific, but some authors (Runnegar and McClung 1975) doubt whether such detailed, essentially Russian and Asian, schemes can be realistically applied to the provincial floras and faunas of the Sydney Basin. A-C, Permian - Triassic boundaries; A, after Waterhouse (1976); B, after Balme (1969) and Nakazawa et al. (1975); C, after David (1950); D-E, Carboniferous - Permian boundaries; D, after Jones et al. (1973); E, after Helby (1969a) and Waterhouse (1976). Stippling represents my preference for the duration of the Permian Period in the Sydney Basin.

floodplain was covered by widespread lagoonal shale (Ashfield Shale).

By the late Anisian or Early Ladinian this lagoonal system was filled by a variety of coastal plain sediments (Minchinbury Sandstone and Bringelly Shale). These supported a broadleaf flora similar to the *Dicroidium zuberi* flora, but with several new elements. Most notable among these are the pteridosperm *Dicroidium odontopteroides* and a conifer, *Rissikia media.*

PTERIDOSPERM FORESTS ON PRE-GLACIAL RIVER FLATS
(Late Carboniferous)

The dramatic floral changes produced by glaciation in the Sydney Basin during the Late Carboniferous and Early Permian are best appreciated by first considering the pre-glacial vegetation. The Carboniferous succession in the Hunter Valley, contains an earlier "*Lepidodendron*" (more likely *Lepidodendropsis* or *Sublepidodendron* according to Rigby 1969c, 1973) followed by an "*Otopteris*" *argentinica* dominated fossil flora (cf Morris 1975 and article 18). These correspond to the *Granulatisporites frustulentus* and *Grandispora maculosa* (palynological) Assemblages respectively (Kemp et al. 1977). The succeeding megafossil flora, where my story begins, was dominated by pteridosperms of the *Sphenopteridium* complex. This is the "modified *Rhacopteris* flora" of Morris (1975) and probably corresponds to the *Anabaculites yberti* (palynological) Assemblage (Kemp et al. 1977). The correspondence of these megafossil floras and palynological assemblages does not appear to be exact, as the *Anabaculites yberti* Assemblage is apparently absent in the upper Italia Road and Mount Johnstone Formations, where it would be expected from the evidence of other plant remains (R. Helby pers. comm. 1976). According to Gould (1976), the silicified logs, "*Pitys*" *sussmilchii*, do not have the biostratigraphic significance implied by Morris (1975). They are additional remains of the pteridosperm forests, both of the "*Otopteris*" *argentinica* and *Sphenopteridium* dominated floras.

Remains of the *Sphenopteridium* complex may be found associated with fossil logs in partly reddened rocks showing fluvial cycles which fine upwards from conglomerate to coal (Rattigan 1967). These rivers drained a forested coastal plain studded with active andesitic volcanoes (Campbell and McKelvey 1972). In the varied landscape of this time it is possible that "*Otopteris*" *argentinica* flourished downstream of the seaward limit of *Sphenopteridium* and also that protected seashores were locally fringed by lepidodendroid mangroves, a common life style for these plants (Retallack 1975, p.13). From such a lateral distribution the observed vertical succession would be preserved as individual localities became progressively more distant from the sea. The exact interplay of these vegetation types in space and time remains to be determined by more detailed work.

The *Sphenopteridium* flora is best known from the upper Mount Johnstone Formation near Paterson (figure 21.3A). This is most likely the locality described by Nashar (1964, p.66). The following species can be identified from published illustrations. Asterisks mark the more abundant forms (according to Morris 1975).

**Cyclopteris* sp. (of Rigby 1973; = *Cardiopteris frondosa* of Morris 1975; Dun 1899, pl.15, figs 3-5; Rigby 1973, figs 8, 9)

Botrychiopsis weissiana Kurtz 1895 (= *Noeggerathia* sp. of Walkom 1934, pl.23, fig. 3)

"*Otopteris*" *argentinica* Geinitz 1876 (= *Rhacopteris ovata* of Dun 1905, pl.22, fig. 3 and David 1907, pl.33, fig. 1)

Sphenopteridium intermedium (Feistmantel) Rigby 1973 (figure 21,3D; = *Rhacopteris intermedia* of Dun 1905, pl.27, fig. 2 and David 1907, pl.33, fig. 2)

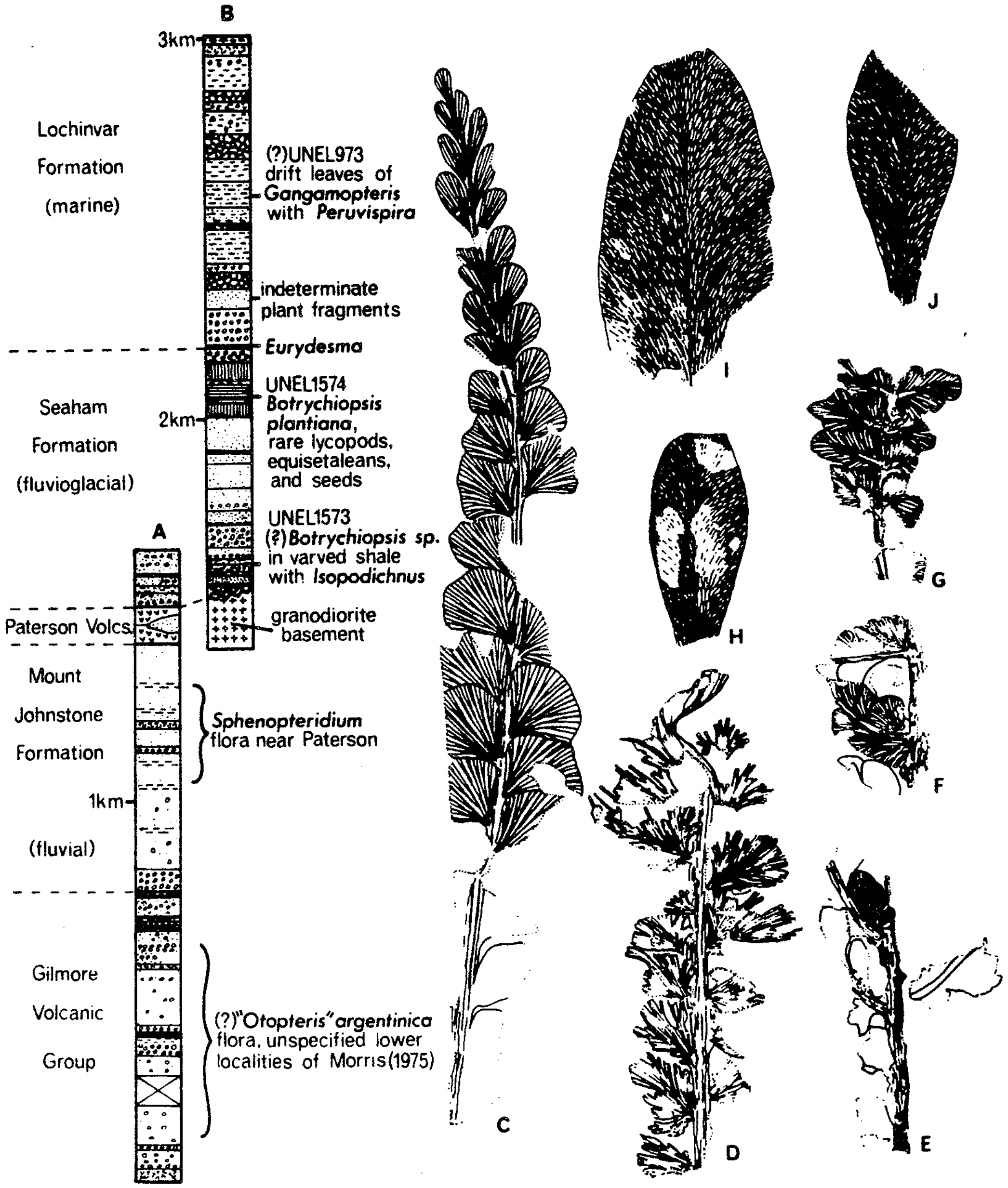
**Dactylophyllum digitatum* (Etheridge) Morris 1975 (Morris 1975, fig. 8.3a, q).

Unfigured identifications of Morris (1975, p.107) and of Süssmilch and David (1920, p.267) indicate that equisetaleans, lycopods, and a further variety of pteridosperm leaves are also present. Similar floras have been noted from near Stroud and Booral (Morris 1975, Feistmantel 1890) and in the upper Italia Road Formation near Balickera (Rigby 1973, Rattigan 1967b), in the northeastern Hunter Valley.

The appearance of *Botrychiopsis* at this level supports the correlations proposed by Archangelsky and Arrondo (1971) and Rigby (1973). The *Sphenopteridium* flora at Paterson flourished at a time between the eruption of the Gilmore Volcanic Group, dated at 323 to 332 m.y., and the Paterson Volcanics, dated at 295 to 302 m.y. (Green and Webb 1974, Runnegar et al. in prep.). It was probably coeval with the *Levipustula levis* marine brachiopod assemblage (Jones 1973, Roberts et al. 1976).

All the coriaceous fern-like leaves found in Carboniferous rocks of eastern Australia, such as *Sphenopteridium*, *Dactylophyllum*, *Botrychiopsis*, and "*Otopteris*" *argentinica*, have been traditionally regarded as pteridosperms. The main reason for this is their common association with seeds (Walkom 1935). However, in view of our presently poor understanding of associated "microsporophylls" (Etheridge 1891, Morris 1975) and the silicified logs identified as "*Pitys*" (which should be *Pitus* according to Arnold 1970), they could equally be regarded as progymnosperms in the extended sense suggested by Beck (1963).

Botrychiopsis and "*Otopteris*" *argentinica* have been commonly confused in the past. "*Otopteris*" *argentinica* (figure 21.3C; "*Pseudorhacopteris*" of Rigby 1973) had slender unipinnate fronds, with more or less petiolate, entire, rounded, rhomboid, or cuneate pinnules borne on a strongly lignified rachis. Especially characteristic is its sparsely forked, straight, radiating,


B
3km
Lochinvar
Formation
(marine)
(?)UNEL973
drift leaves of
Gangamopteris
with *Peruvispira*
indeterminate
plant fragments
Eurydesma
UNEL1574
Botrychiopsis
plantiana,
rare lycopods,
equisetaleans,
and seeds
Seaham
Formation
(fluvioglacial)
2km
UNEL1573
(?)*Botrychiopsis sp.*
in varved shale
with *Isopodichnus*
A
Paterson Volcs.
granodiorite
basement
Mount
Johnstone
Formation
Sphenopteridium
flora near Paterson
1km
(fluvial)
Gilmore
Volcanic
Group
(?)"*Otopteris*" *argentinica*
flora, unspecified lower
localities of Morris (1975)
C
D
E
F
G
H
I
J

secondary venation, with numerous interveinal striae. These leaves were at first included within the Northern Hemisphere genus *Rhacopteris* by Feistmantel (1890). Similar northern fronds (discussed by Boureau and Doubinger 1975) differ in their asymmetric pinnules which may be irregularly laciniate in *Rhacopteris (sensu stricto)* or entire and rounded in *Anisopteris*. The holotype of the type species of "*Pseudorhacopteris*" (Rigby 1973) was interpreted from a very poor illustration (McCoy 1847, pl.9, fig. 2). This specimen has now been clearly photographed by Boureau and Doubinger (1975, fig. 548). From this photograph it appears that McCoy's name is a senior synonym of *Botrychiopsis* "*valida*" (of Archangelsky and Arrondo 1971), and thus Rigby's genus is a *nomen vanum*. "*Otopteris*" *argentinica* Geinitz (1876, pl. 2, figs 5a, b) is the next oldest name for a leaf of this type. These should be placed in a new genus, as *Otopteris* has been submerged within *Otozamites* (Harris 1969, p.10). The unfortunate confusion of Geinitz's specimen with some Mesozoic leaves has been clarified by Frenguelli (1942a).

"*Rhacopteris*" *chubutiana* Archangelsky and Arrondo 1966, found in Argentina with *Gangamopteris* and *Glossopteris* (Archangelsky and Arrondo 1969), does not represent a Permian lineage of leaves like "*Otopteris*" *argentinica*. Although unipinnate, it has more features in common with *Botrychiopsis* than with "*Otopteris*" *argentinica*, but is perhaps best placed in a new genus because of its many distinctive features. The pinnae are attached by most of their base to the top of an alate rachis. They are well spaced at the base of the frond and become imbricate towards the apex. The curved lateral venation arises from a broad area of the pinna base.

I have simply followed Rigby (1973) and Morris (1975) in referring fronds with dissected pinnules to *Dactylophyllum* and *Sphenopteridium* (figure 21.3D).

Figure 21.3. Carboniferous and Early Permian plant fossils and stratigraphy.

A, geological succession near Paterson (after the type sections of G. Hamilton et al. 1975).
B, Winders Hill to Lochinvar (after Browne 1927, Osborne 1949).
C, "*Otopteris*" *argentinica* Geinitz 1876, from Sugarloaf Creek, Stroud (after Dun 1905).
D, *Sphenopteridium intermedium* (Feistmantel) Rigby 1973 from Paterson (after Dun 1905).
E-G, *Botrychiopsis* leaves from Cranky Corner (UNEL663). E, *Botrychiopsis weissiana* Kurtz 1895 (UNEF14728), F, *B. plantiana* (Carruthers) Archangelsky and Arrondo 1971 (UNEF14727), G, *B. ovata* (McCoy) comb. nov. (UNEF14729).
H-J, *Gangamopteris* leaves from north of Pebbly Beach (UNEL1662) identified after the scheme of Chandra (1974), H, *Gangamopteris spathulata* McCoy 1847 (UNEF14733). I. *Ga. cyclopteroides* Feistmantel 1879 (UNEF14732); J, *Ga. major* Feistmantel 1879 (UNEF14732). Plant drawings all half natural size.

PERIGLACIAL *BOTRYCHIOPSIS* TUNDRA
(latest Carboniferous to earliest Permian)

During the Late Carboniferous, the Australian part of Gondwanaland moved from a palaeolatitude of 50°S to 70°S and glaciers advanced over the Sydney Basin (G. Hamilton et al. 1975). As the ice began to retreat in the southern Sydney Basin valleys, cut into folded Devonian and older sediments, were slowly filled with fluvioglacial conglomerate (Herbert 1972). In the northern Sydney Basin, fluvioglacial conglomerate and varved shale were deposited over a glacial pavement scoured into the Paterson Volcanics (Campbell 1969b). The severe glacial climate had decimated the *Sphenopteridium* flora. Among the pteridosperms, *Botrychiopsis* appears to have been the only survivor. Coal, fossil logs, and pedological lithologies, including redbeds, have not or only rarely been observed at this level. Thus the impoverished *Botrychiopsis* flora was probably a sparse, low-growing, tundra vegetation, colonizing glacial outwash deposits. Analogous modern vegetation, found today in Alaska and Arctic Canada, is discussed by Strahler (1969).

A pre-glacial *Botrychiopsis* taphoflora may be present in the Blue Metal and Gravel Pty Ltd quarry at Raymond Terrace, if the correlation of the dacite there with the Paterson Volcanics is accepted (from Nashar et al. 1976). This flora contains only the supposed aphlebiae, microsporophylls, and leaves of *Botrychiopsis plantiana (="Triphyllopteris austrina"* in Morris 1975).

In the post-glacial rock succession exposed north of Lochinvar (figure 21.3B), the oldest plant fossils are found in varved shale 100 m above granodiorite basement on the northern slopes of Winders Hill (locality UNEL1573): fragmentary pinnules of (?)*Botrychiopsis* sp. (specimen UNEF14722), a seed (UNEF15093), and "coffee bean" resting traces and narrow double trails referable to *Isopodichnus osbornei* Glaessner 1957 (UNEF14721). A more definitive flora has been collected in the cherty shales of an old excavation (Davids Cut) on Hut Hill, 530 m above basement (UNEL1574). *Botrychiopsis plantiana* (UNEF14723) is the most common fossil, with some seeds (UNEF14726), lycopod axes (UNEF14725), and equisetalean axes (UNEF14724). It is also possible that some of the specimens figured by Walkom (1934), regarded as *Botrychiopsis weissiana* by Archangelsky and Arrondo (1971), could have come from here, but exact specimen localities were not given.

Archangelsky and Arrondo (1971) and Rigby (1973) discussed the distribution of this impoverished *Botrychiopsis* flora in Australia and overseas. Additional localities include cherty shale at Cranky Corner (UNEL663), which contains all three species of *Botrychiopsis* (figures 21.3E, F, G). According to McClung (article 19), this plant locality is on a similar stratigraphic horizon to a "*Trigonotreta* *campbelli*" marine brachiopod assemblage (which Roberts et al. 1976 regarded as time equivalent with the *Auriculispina levis* assemblage), and is overlain by marine rocks containing the *Martiniopsis elongata* assemblage. A *Botrychiopsis* flora also occurs in the Wynyard Tillite, in northern Tasmania (Clarke and Banks 1975). where it includes *Botrychiopsis ovata* (Gould 1976, fig. 3C), seed-like fruiting bodies, and aphlebia-like leaves (Gould 1976, fig. 3D, and further leaves like those figured by Morris 1975, fig. 8.1).

The *Botrychiopsis* flora occurs widely in rocks containing the *Potonieisporites* or Stage 1 (palynological) Assemblage (Kemp et al. 1977). From this wide association, it is tempting to regard *Potonieisporites* as the pollen of *Botrychiopsis*. Generally similar pollen have been extracted from pteridosperm, progymnosperm, and cordaitalean remains (Millay and Taylor 1976), but in the northern hemisphere *Potonieisporites* was, at least in part, the pollen of primitive lebachiacean conifers (Scott 1974).

Botrychiopsis differs from "*Otopteris*" *argentinica* in being bipinnate to bipinnatifid and having a venation which dichotomizes more frequently (figure 21.3E, F, G). The venation is "finer, more graceful, less rigid, and at the same time somewhat closer, more radiating and spreading" (Arber 1902, p.21). When distinguished from "*Rhacopteris*", *Botrychiopsis* has commonly been referred to as *Cardiopteris* (Black et al. 1972) and *Gondwanidium* (Rigby 1973), and also as *Neuropteridium* (Arber 1905), *Aneimites* (Dun 1905), and *Triphyllopteris* (Morris 1975). There are now three species of *Botrychiopsis*, since the Angaran material has been transferred to *Paragondwanidium* (Meyen 1969). In order of stratigraphic appearance from the Late Carboniferous to the Early Permian, these are: *Botrychiopsis weissiana* Kurtz 1895 (figure 21.3E, with larger, broader, more separated, subtriangular pinnules, and pinnae inserted on the rachis at an angle of 45° to 50°); *B. plantiana* (Carruthers) Archangelsky and Arrondo 1971 (figure 21.3F, with subcircular, touching, and overlapping pinnules, and pinnae inserted on the rachis at an angle of 45° to 70°); and finally *B. ovata* (McCoy) comb. nov. (figure 21.3G, with pinnatifid pinnae at an angle of 70° to 80° to the rachis, including *B.* "*valida*" of Archangelsky and Arrondo 1971, and "*Gondwanidium indicum*" of Maithy 1965b).

The shapes and stratigraphic distribution of these leaves lend some support to the suggestion of Morris (1975) that all the key plant fossils of Gondwanaland during the late Palaeozoic were derived from a single evolving lineage: a "growth retardation series" (Asama 1969) from *Sphenopteridium* to *Botrychiopsis weissiana* to *B. plantiana* to *B. ovata* to *Botrychiopsis* aphlebiae to the protoglossopterids (of Plumstead 1969), to *Gangamopteris*, and finally *Glossopteris*. This hypothesis could be more effectively evaluated if we knew more about the fructifications of all these leaves. Only a few compressed seeds and microsporophylls have been found associated with these leaves in New South Wales. They were loosely identified with European genera (Walkom 1935, Etheridge 1891, Morris 1975).

COASTAL PENETRATION OF *GANGAMOPTERIS* TAIGA (Early Permian)

In the Early Permian, a permafrost climate persisted as late as the *Martiniopsis konincki* brachiopod assemblage (as defined by Runnegar and McClung (1975). Such a climate is indicated by lobate solifluction flows at Myrtle Beach, on the south coast, described by Gostin and Herbert (1973). Unlike ordinary slump or mudflow breccias, these contain large upended, very gently deformed blocks of low-angle crossbedded sandstone, which appear to have been fragments of contemporaneous unconsolidated beach sandstone which were incorporated in the flow when frozen. The climate was somewhat ameliorated by rising sea level, which eventually reached a rocky coast near the western margin of the Sydney Basin and covered much of the northern Sydney Basin except for a few volcanic islands. Drift leaves of *Gangamopteris* were widespread in these Early Permian marine rocks. *Gangamopteris* was still more abundant than *Glossopteris* in coastal swamp forests below the *Martiniopsis brevis* Zone (of Runnegar and McClung 1975). The first appearance of *Gangamopteris* probably marks the southward penetration of the polar tree line concurrent with climatic improvement and marine transgression. The *Gangamopteris* forest was thus analogous to the modern birch (*Betula*) taiga of Scandinavia, Canada, and Alaska (described by Strahler 1969). Although the *Gangamopteris* taiga lived very close to the seashore, no convincing evidence has yet been found for it being an intertidal mangrove vegetation. It seems more likely that it was a freshwater association for which the seaside offered a more stable local climate in the prevailing permafrost conditions. *Gangamopteris* probably invaded from the north as coastal sites became suitable, and then dispersed inland into the *Botrychiopsis*-dominated tundra. *Gangamopteris* trees did not entirely displace *Botrychiopsis* shrubs. Mixed *Gangamopteris*-*Botrychiopsis* floras have been found in the Markwell Coal Measures north of Newcastle, in the Joe Joe Formation of central Queensland (Rigby 1973), and at a locality near "Nychum" homestead in northern Queensland (Black et al. 1972).

The incoming of the *Gangamopteris* taiga was heralded by a rain of striatid pollen which characterize the *Protohaploxypinus* or Stage 2 Assemblage (Paten 1969, Kemp et al. 1977). Pollen similar to *Protohaploxypinus* have been extracted from glossopterid microsporophylls (Pant and Nautiyal 1960). The pollen rain may have arrived some time before the parent trees, as modern taiga pollen is carried thousands of kilometres over treeless tundra by the wind (Krasilov 1975, p.152). *Gangamopteris* trees were certainly established in the northern Sydney Basin by the time a basalt, dated at 283 m.y. (Runnegar et al. in prep.), flowed over the area around Comerfords quarry, north of Maitland. This allows less than 16 m.y. of glacial conditions from the destruction to the return of trees in the Hunter Valley region.

In Australia, the Carboniferous - Permian boundary has been traditionally recognized at the incoming of *Gangamopteris* leaf fossils, striatid (*Protohaploxypinus*) pollen, or transgressive marine rocks containing *Auriculispina levis* and "*Trigonotreta campbelli*" assemblages (Jones et al. 1973, Roberts et al. 1976). These provincial fossils cannot be correlated with those of the northern hemisphere where the Carboniferous - Permian boundary is best recognized. Furthermore, their appearance was intimately related to the gradual amelioration of glaciation and the consequent rise in sea level, events which had a critical effect on life at different times for different places. Two solutions to these objections have been proposed to date. Firstly, Runnegar and Campbell (1976) would prefer to ignore the Carboniferous and Permian biostratigraphy of the Northern Hemisphere and establish boundary stratotypes for seven ages and nineteen zones in Gondwanaland from the top of the Devonian to the bottom of the Triassic. Secondly, Helby (1969a) has suggested that, for Australia, the Carboniferous - Permian boundary is more closely approximated by global climatic changes shortly after the Kiaman Magnetic Interval or PCR (of Irving and Pullaiah 1976). In the Hunter Valley, this was at the onset of glaciation and the appearance of the impoverished *Botrychiopsis* flora and palynomorphs of the *Potonieisporites* or Stage 1 Assemblage (best regarded as the base of the Seaham Formation). At this time in Europe, Carboniferous peat swamps were drained and overlain by a sequence including redbeds just above the base of the Stephanian C. This redbed sequence contains a *Potonieisporites - Illinites* palynological assemblage and a megafossil flora dominated, at first, by *Lebachia piniformis* and then by *Callipteris conferta* (Helby 1969a, Remy and Havlena 1962). According to Helby, these events are older than the conventional top of the Carboniferous in the non-marine sequences of Europe, which in turn is somewhat older than the Carboniferous - Permian boundary recognized in American and Russian marine sequences. These climatic changes seem to have been more rapid than those subsequent to glaciation, but their synchroneity is now as doubtful as the base of the PCR, which is probably older than previously thought (Irving and Pullaiah 1976). Nevertheless, for various reasons Waterhouse (1976) agreed with placing the boundary at the base of the Seaham Formation, and believed that it approximates the Carboniferous - Permian boundary elsewhere, even more closely than Helby maintained.

Marine shale containing a "*Trigonotreta campbelli*" assemblage, including *Eurydesma*, overlies the fluvioglacial Seaham Formation, 150 m stratigraphically above the *Botrychiopsis* locality at Hut Hill, near Lochinvar in the Hunter Valley (figure 21.3B; Browne and Dun 1924, Osborne 1949, Runnegar 1967). Osborne found the oldest drift leaf of *Gangamopteris* in marine rocks of this area, associated with the gastropod *Peruvispira* about 390 m above the base of the marine transgression. This is probably locality UNEL973 of the University of New England Geology Department register. This locality contains *Peruvispira* and lies between faunas of the "*Trigonotreta campbelli*" and *Martiniopsis elongata* brachiopod assemblages (G. McClung pers. comm. 1976). *Gangamopteris* leaves have also been collected with *M. elongata* faunas in railway cuttings near Lochinvar (UNEF14740 from UNEL915; UNEF14741 from UNEL914) and with *M. koninckі* faunas from the top of the road cutting 4 km west along the New England Highway from Lochinvar (UNEF14730 from UNEL972). In the upper Pebbley Beach Formation forming the first headland north of Pebbly Beach, on the south coast (UNEL1662; B. McCarthy pers. comm. 1976), tidal flat deposits thought to be coeval with the *Martiniopsis ovata* brachiopod assemblage contain abundant pyritized logs and drift leaves of *Gangamopteris* (figures 21.3H, I, J). At this locality, *Gangamopteris* apparently dominated forests on the shore of a marine bay protected from heavy surf.

Dulhunty and Packham (1962) reported *Gangamopteris* leaves in Early Permian rocks of the Mudgee district. I have collected compressed logs and large asymmetric leaves of *Gangamopteris cyclopteroides* Feistmantel 1879 (UNEF15094) from pebbly sandstone cropping out beside the Lue road 10 km north of Rylstone (UNEL1591). These occurrences probably represent an inland dispersal of the *Gangamopteris* taiga during Early Permian time.

Gangamopteris was apparently the dominant plant forming the Garretts seam (David 1907, p.79), at a time when the *Martiniopsis branxtonensis* brachiopod assemblage populated shallow marine silts. While this assemblage was replaced by the *M. ovata*, *M. plana*, and then *M. brevis* assemblages, *Gangamopteris* retained its significance in the Greta (Dun 1898), Clyde, and Yarrunga Coal Measures (Gostin and Herbert 1973, p.56). Some of these coals may have been allochthonous and marine influenced, as they have a high pyrite content (David 1907, p.117; Mackowsky 1975; Read and Cook 1970) and the Greta coals, at least, have a high boron content (Swaine 1966). The Greta coals probably formed in the interdistributary and delta plain swamps of active marine deltas building southwards. The Yarrunga and Clyde coals, on the other hand, probably accumulated in, or adjacent to, relatively more stable coastal lagoons and estuaries.

GLOSSOPTERIS DECIDUOUS SWAMP FORESTS

(Early to Late Permian)

The transition between Early Permian *Gangamopteris* taiga and Late Permian *Glossopteris*-dominated deciduous swamp forests was slow and gradational. Thus it is difficult to date intermediate megafossil floras, despite the distinctness of the end members. This, presently poor, biostratigraphic resolution is disappointing in view of the large number of palynological assemblages (and subassemblages) associated with *Gangamopteris* and *Glossopteris* (figure 21.2). In earliest Permian time the prevailing permafrost climate probably prevented *Glossopteris* from entering the Sydney Basin, because the large aerenchyma chambers in its roots (*Vertebraria*) would be split open by contained ice if they froze. *Glossopteris*-dominated swamp forests slowly gained ascendancy over the *Gangamopteris* taiga with warming of the climate. In the cool temperature climate of the Late Permian, *Glossopteris* had largely displaced *Gangamopteris* over broad freshwater lowlands. It is possible that later Permian *Gangamopteris* formed purer stands in elevated (and, less likely, in coastal) refugia, where the environment was more like Early Permian conditions. These palaeoecological changes were probably concurrent with the evolution of *Glossopteris* from a gangamopterid stock by the gradual development of sclerenchyma around the central zone of anastomosing veins (Gould and Delevoryas 1977). Intermediate leaves with impersistent midribs can be difficult to identify, and I would prefer to identify them with *Gangamopteris*, as have Chandra (1974) and Rigby (1967).

As in India (Sarbadhikari 1974) and South Africa (Plumstead 1969), these changes are also reflected in floristic differences between the Early and Late Permian coal measures in the Sydney Basin. The flora of the Early Permian coal measures is dominated by *Gangamopteris* leaves, which are usually larger (*Ga. cyclopteroides*) than those in the Late Permian coal measures (*Ga. clarkeana*). The flora of the Late Permian coal measures is dominated by *Glossopteris*, most commonly lanceolate fine-meshed types, such as *Gl. communis*, *Gl. indica*, and *Gl. linearis* (identifications after Chandra 1974). The glossopterid fossil root, *Vertebraria*, so common in seat earths of the Late Permian coal measures, has never to my knowledge been found in the Early Permian coal measures (see also David 1907, p.320; Plumstead 1969). Among the equisetaleans, "*Umbellaphyllites*" and *Lelstotheca* are more common in the Early Permian coal measures, whereas *Phyllotheca* is more abundant in the Late Permian coal measures.

Palynological correlations of Balme (1969) and the marine biostratigraphy of Runnegar and McClung (1975) and Waterhouse (1976) indicate that *Glossopteris*-dominated swamp forests began to differentiate during the Early Permian, matured by the Late Permian, but were almost extinguished some time before the deposition of alluvium containing "*Thinnfeldia*" *callipteroides*, shortly before the Permian - Triassic boundary (figure 21.2). Mature *Glossopteris*-dominated swamp forests were certainly well established over the coastal plains of eastern Australia at a time between, and shortly after, the eruption of the Gerringong Volcanics of the south coast, dated at 246 to 260 m.y. (Raam 1969, Runnegar et al. in prep.), and a tuff in the Gyranda Formation of Queensland, dated at 239 m.y. (Green and Webb 1974).

There is abundant evidence that the *Glossopteris* taphoflora of the Late Permian coal measures was derived from a deciduous swamp forest containing plants of various height and habit. Gould (1975) proposed that *Glossopteris* was a large tree with gymnospermous wood (*Araucarioxylon*) and roots with large aerenchyma chambers (*Vertebraria*, figure 21.5L, m). This last feature was probably a respiratory adaptation to waterlogged soils. *Glossopteris* leaves are only rarely found attached to short shoots, either in close spirals or thick axes (Etheridge 1894b), or in well-spaced spirals or verticills on more slender axes (Pant and Singh 1974). More commonly, enormous numbers of isolated *Glossopteris* leaves are found on individual bedding planes, probably as a result of autumn leaf fall (Plumstead 1958). In a specimen of varved shale from "Mudgee" (UNEF14734), *Glossopteris* leaves are concentrated in the lower part of the fine fraction, following the coarser silty layer of the spring thaw. Gunn and Walcott (1962) figured a similar specimen from Antarctica. Other, less prominent, trees in this forest were *Noeggerathiopsis*, *Gangamopteris*, and conifers. Fossil stumps and logs of various size and branching pattern are sometimes found at the top of the coal seams (figure 21.4; Clarke 1885, David 1907, Rigby 1964b). Some of these were 40 m high before branching and have as many as 120 growth rings. Dense growths of pteridophytes formed an undergrowth and colonized intervening marshes. Thick clayey palaeosols and pedoliths are also found in the coal measures (Loughnan 1971, 1975; Branagan and Johnson 1970). A mature forest community is also indicated by a diverse insect fauna of at least 144 species (Riek 1968). These would have required abundant fresh and decaying vegetation for food, standing water for the development of larval stages, and a variety of niches for the different adult life styles. Insect eaten leaves (*Phagophytichnus* of Häntzschel 1975) are also found (Holmes 1974, pl.7, fig. 7).

The increased diversity of the megafossil flora and large fossil logs in the Late Permian coal measures indicates that the climate was considerably warmer than when the *Gangamopteris* taiga first penetrated the region. Varved torbanite and shale, and growth rings in fossil logs and marine shellfish, indicate a marked seasonal rhythm. Rigby (1971) and Gould (1972) considered that the Permian climate had not improved beyond cool temperate, even as far north as the Bowen Basin of Queensland, where they gathered their evidence. A very cool climate is suggested by the few specimens and small size of vertebrate fossils found in the Late Permian coal measures of the Sydney Basin compared with other parts of Gondwanaland, such as South Africa (Barry 1975). Despite over a century of coal mining in the Sydney Basin, only two fish (Feistmantel 1890, Mitchell 1924) and two amphibians (Watson 1956) have been recorded.

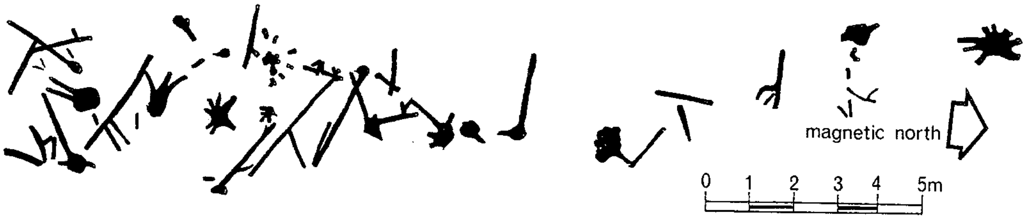


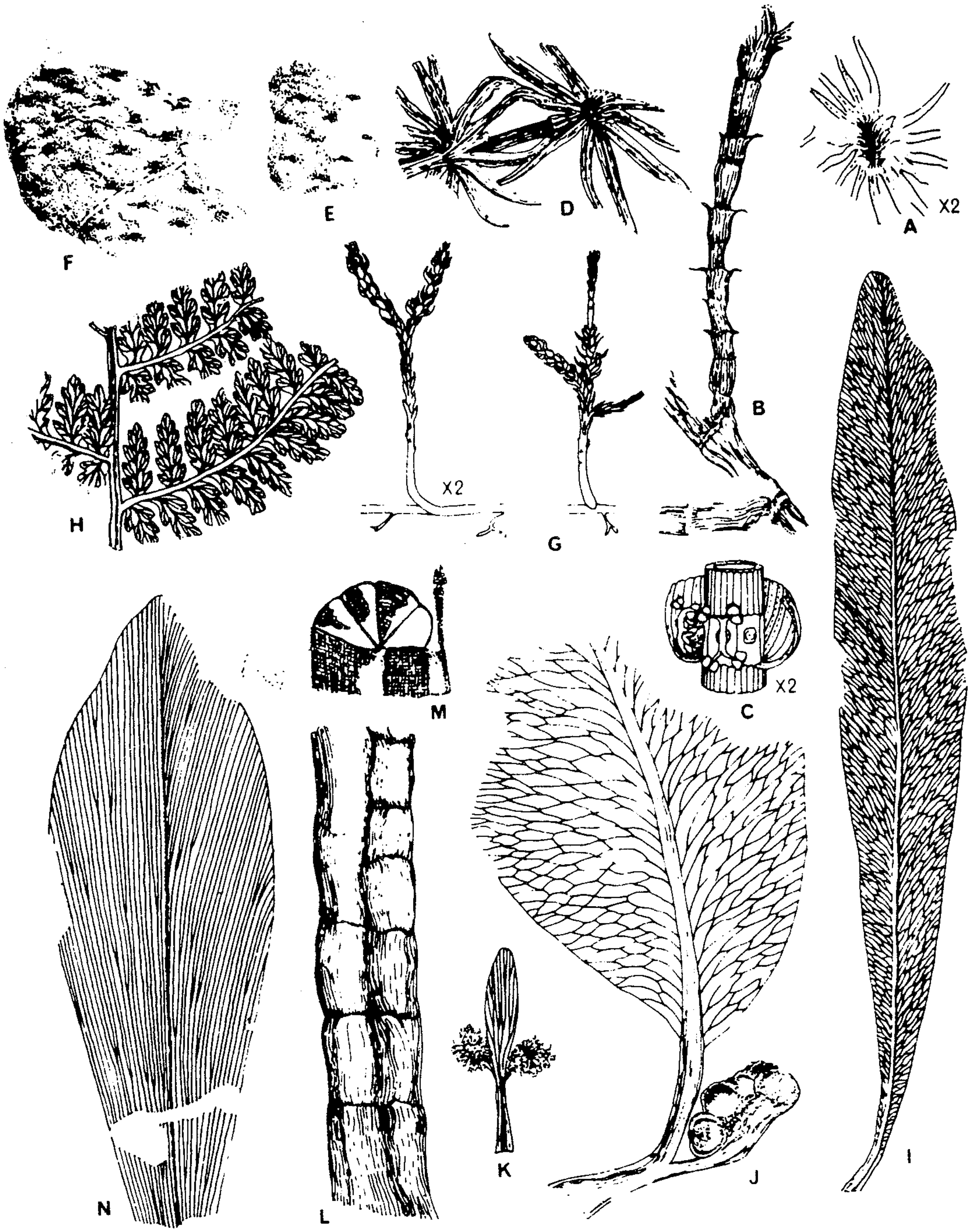
Figure 21.4. Plan of fossil logs and stumps on the top of the Lower Pilot Coal exposed on the rock platform near Swansea (after David 1907).

Moderate boron concentrations in coal (Swaine 1966), pyrite, and an impoverished marine fauna (Booker 1960), indicate that brackish lagoonal conditions were widespread just above the base of the Late Permian coal measures. However, low boron content, fluvial cycles, and palaeosols (Swaine 1966, Duff 1967, Johnson and Cook 1973, Branagan and Johnson 1970) in most of the Late Permian coal measures indicate that *Glossopteris*-dominated communities forested completely freshwater environments on the coastal plain.

The main leaf types produced in these swamp forests are usually identified with the form genera *Glossopteris, Gangamopteris,* and *Noeggerathiopsis* (figures 21.3H, I, J; 21.5I, N). It is also likely that *Blechnoxylon* known from western outliers of the Sydney Basin (Etheridge 1899), and *Palaeovittaria* from the Gunnedah Basin to the northwest (Carey 1935), have been overlooked in fossil plant collections from the central Sydney Basin. Even so, there is less generic and specific variety of leaf impressions in Permian rocks of the Sydney Basin than in other areas of Gondwanaland, such as India (Surange 1975). Relatively reliable identifications of leaves from the Sydney Basin are given by Feistmantel (1890), Etheridge (1903a, b, 1904), Dun (1898), Walkom (1928b), Rigby (1964a, c, 1967), and Packham (1969).

A comparison of glossopterid leaves with those of the modern genus *Eucalyptus* suggests that diffuse venation may give a physiological advantage in severely cold climate. *Eucalyptus* has as prominent a place in the modern Australian flora as *Glossopteris* did in Permian time. The variety of leaf shapes and venations found in *Eucalyptus* (Penfold and Willis 1961, figs 3-5) are analogous to most species of the megafossil form general *Glossopteris, Gangamopteris,* and *Belemnopteris.* An irregular longitudinal venation (as in *Gangamopteris*), rather than the more usual midrib (as in *Glossopteris*), is found only in the Series Longitudinales of the Section Renantherae of *Eucalyptus.* These are all snow gums : frost resistant, medium sized, poor timber trees of high altitudes.

Although many glossopterid fructifications have been found in the Sydney Basin (M.E. White pers. comm. 1976), few have been described or identified. Among these, the following are probably true glossopterid fructifications: scale fronds and sporangium-like organs of Arber (1905); "*Austroglossa*" (figure 21.5J), *Dictyopteridium,* "*Isodictyopteridium*", and *Eretmonia* (figure 21.5K) of Holmes (1974); and *Scutum,* "*Cistella*", and "*Hirsutum*" of Rigby (1961, 1964c). Isolated seeds (Walkom 1928b, Millan 1969) could be related to glossopterid or *Noeggerathiopsis* leaves, or even be derived from other seed plants, such as pteridosperms or conifers. *Eretmonia* is generally regarded as a glossopterid microsporophyll (Surange and Maheshwari 1970). The remaining (ovulate) structures could all be referred to the genera *Scutum, Dictyopteridium,* and *Plumsteadia* (this last has priority over *Gonophylloides* as a replacement for the pre-occupied *Cistella* according to Rigby 1963, 1969d; Maheshwari 1968). However, on the evidence of beautifully preserved petrifactions from Queensland, Gould and Delevoryas (1977) have convincingly argued that these three genera may be different levels from the compression of one


F
E
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type of fleshy megasporophyll, borne in the axils of sterile *Glossopteris* leaves and bearing seeds on their strongly recurved abaxial surfaces.

Both *Gangamopteris* and *Noeggerathiopsis* were probably trees, as fossil logs are also found at levels where their leaves dominate the fossil flora. *Noeggerathiopsis* has been interpreted as a cordaitalean, because it is externally very similar, if not identical, to *Cordaites*. This relationship cannot be proved as no cordaitalean fructifications have been found in Gondwanaland (Surange 1974). The more common occurrence of *Noeggerathiopsis* and *Gangamopteris* in whorls (Dana 1849, Etheridge 1918, Walkom 1921, Rigby 1967), may partly be because they were evergreen. The fructification *Arberia* (Rigby 1972a) has been loosely attributed to *Noeggerathiopsis* and *Gangamopteris* and also interpreted as as a modifed cordaitalean inflorescence (by Schopf 1976). However, the organization of *Arberia* is more like a reduced pinnate frond of pteridosperm derivation than a fertile cordaitalean shoot. The name *Cordaicladus adamsii* (Feistmantel) Rigby 1969b for stems with broad leaf scars, found near Newcastle, imples cordaitalean affinities, but Etheridge (1903a) recorded leaves of *Glossopteris ampla* Dana 1849 attached to similar axes.

Specialized aquatic communities within the swamp forests were formed by algae, equisetaleans, and lycopods. Blooms of botryococcoid unicellular algae (described as "*Pila*" and "*Rienschia*" in Arber 1905), sometimes formed thick waxy deposits (subsequently diagenetically altered to torbanite) in stagnant ponds where spring runoff from high land marginal to the coastal plain accumulated along its western edge (Dulhunty 1944).

The most common equisetaleans of the Early Permian coal measures are remains superficially similar to *Annularia* of the Euramerican Carboniferous, such as *Lelstotheca robusta* (Feistmantel)

Figure 21.5. Permian plant fossils.
A-C, *Phyllotheca australis* Brongniart 1828, from Newcastle, A, leaf sheath (after Townrow 1956) twice natural size, B, portion of a branching axis (after Feistmantel 1890), C, cone, *Gondwanostachys australis* Meyen 1969 (after Townrow 1955) twice natural size.
D, *Lelstotheca robusta* (Feistmantel) Maheshwari 1972, from Newcastle (after Rigby 1966a).
E-F, *Cyclodendron leslii* (Seward) Krausel 1928 from near Tingha (UNEL1577), E, apical portion of axis (UNEF15013), F, cracking older portion of axis (UNEF15020).
G, *Selaginella harrisiana* Townrow 1968, from Victoria Pass (reconstruction after Townrow 1968) twice natural size.
H, "*Neomariopteris*" *lobifolia* (Morris) Maithy 1974, from "Mulubimba" (the aboriginal name for Newcastle) (after Morris 1845).
I, *Glossopteris linearis* McCoy 1847, from Bowenfels (after Feistmantel 1890).
J-K, glossopterid reproductive structures from Cooyal (after Holmes 1974), J, "*Austroglossa*" *walkomii* Holmes 1974 attached to *Glossopteris conspicua* Feistmantel 1880, K, *Eretmonia cooyalensis* Holmes 1974.
L-M, *Vertebraria indica* Royle 1833, the root of *Glossopteris*, from Newcastle (after Feistmantel 1890), L, natural radial section, M, natural cross and radial section.
N, *Noeggerathiopsis spatulata* (Dana) Maithy 1965a from Bowenfels (after Feistmantel 1890). All figures natural size unless otherwise indicated.

Maheshwari 1972 (figure 21.5D, Rigby 1966a) and "*Umbellaphyllites ivinii*" (Walkom) Rigby 1966b (discussed by Pant and Nautiyal 1967, p.61). In the Late Permian coal measures, *Phyllotheca* is more common, with at least four species (Townrow 1956, Arber 1905): *Phyllotheca australis* Brongniart 1828 (figures 21.5A, B), *P. indica* Bunbury 1861, *P. "sahnii"* Saksena 1952 (discussed by Pant and Nautiyal 1967) and *P. deliquescens* (Goeppert) Schmalhausen 1879. The cone of *Phyllotheca australis* (figure 21.5C, transferred to *Gondwanostachys* by Meyen 1969) indicates that these, and several other species of *Phyllotheca* from Gondwanaland, formed an aberrant provincial group of the Phyllothecaceae, probably sharing a common archaeocalamitacean ancestor with *Lelstotheca* and *"Umbellaphyllites"* (Townrow 1956, Boureau 1964).

Among the lycopods, *Selaginella harrisiana* is locally abundant in a road cutting through the Late Permian coal measures at Victoria Pass (figure 21.5G, Townrow 1968). Rigby (1964c) recorded *Cyclodendron leslii* from the Illawarra Coal Measures, but has omitted this occurrence in a later review (Rigby 1972b). It is likely that further material will be discovered in the future as *Cyclodendron leslii* (Seward) Krausel 1928 (figures 21.5E, F, identified according to the specific concept of Chaloner and Boureau 1967) has recently been discovered near Tingha, on the New England Tableland of New South Wales (Kimber 1975).

Sphenopterid fern fronds (figure 21.5H) are sometimes found with *Glossopteris* leaves. They also formed monodominant stands, judging from a small collection in the Australian Museum labelled "Appletree Creek, Jerrys Plains". Maithy (1974) has transferred several species of this style of frond to the genus *Neomariopteris*, but this kind of structure remains to be demonstrated for the fragmentary remains from the Sydney Basin. These were probably, at least in part, osmundalean ferns (Gould 1970). *"Sphenopteris" grandis* Dun 1898 is based on a most unusual specimen for *Sphenopteris*. It is more like *"Rhacopteris" chubutiana*, which I have contrasted with *"Otopteris" argentinica* on page 391.

Near the western margin of the Sydney Basin, the *Glossopteris* flora of the Late Permian coal measures exhibits a conspicuous conifer component. *Walkomiella australis* (Feistmantel) Florin (figure 21.8B, C) has been found near Ulan (AMF46259), Ilford (AMF43462), Cobbora (AMF29981), Bowenfels (AMF35658, 35786), and Gulgong (AMF6828, 6302). It is likely that a coniferous forest was widespread on the emergent Lachlan Fold Belt and other non-depositional areas beyond the Sydney Basin coastal plain.

Some fructifications from near Adamstown and East Maitland have been compared with *Arberia* (Rigby 1972a) and "antarcticoid fertiligers" (Schopf 1976), but are perhaps closest to *Rigbya arberioides* (Lacey et al. 1974). The botanical affinities of these apparently ovulate fructifications are presently uncertain.

UPLIFT AND ALLUVIUM WITH *"THINNFELDIA" CALLIPTEROIDES*
(latest Permian)

Even as the Late Permian coal measures were accumulating, the northern margin of the Sydney Basin was locally folded and uplifted (Branagan and Johnson 1970). These movements culminated in the uplift and erosion of the entire Sydney Basin. Peat swamps were drained and *Glossopteris* was thus banished from the Sydney Basin. The time of low water table is not represented by rocks in the Sydney Basin. By the latest Permian, land and sea were returning to a similar level. The alluvium which could then accumulate (basal Narrabeen Group) contained a new and distinctive assemblage of palynomorphs (the *Protohaploxypinus reticulatus* Assemblage of Helby 1973) and of leaves, dominated by *"Thinnfeldia" callipteroides* Carpentier 1935 (figure 21.6).

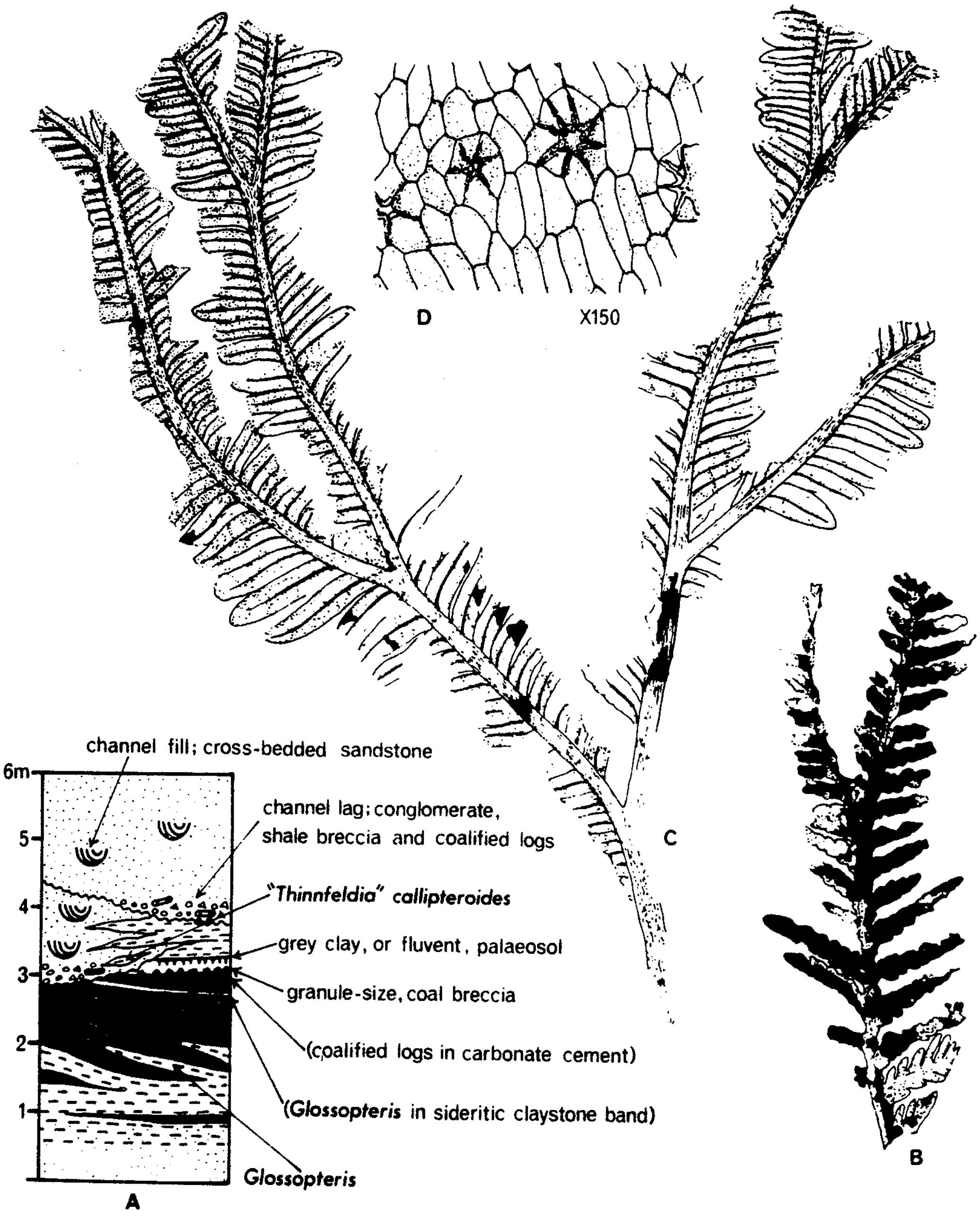
Whereas there is a major unconformity between the basal Narrabeen Group and older Permian rocks in the Hunter Valley, the disconformity between the Late Permian coal measures and the basal Narrabeen Group in the Southern Coalfield has only been discovered by detailed mapping of coal plies in the uppermost seam (Shibaoka and Bennett 1975). *Glossopteris* and *Vertebraria* may be found right up to the abrupt boundary between coal measures and alluvium. I have collected *Glossopteris* in a sphaerosideritic clay palaeosol within 20 cm of the top of the Bulli Coal in Darkes Forest mine (UNEF14736 from UNEL1567) and in siltstone intercalations near the base of the Bulli Coal near the old Coal Cliff jetty (UNEF1435 from UNEL1575). *Glossopteris* has also been collected from shale of the uppermost Illawarra Coal Measures in the Birthday shaft near Sydney (figure 21.8) (Dun 1911, Stuntz 1975).

Alluvium appears to have spread throughout the Sydney Basin from an uplifted area to the north. A misleading impression of sandy braided streams is conveyed by maps of the rock types forming the roof of the Bulli Coal (figure 21.7 and Diessel et al. 1967, fig. 2). The alluvium was more likely deposited by high-sinuosity, low-energy streams meandering over a flat coastal plain. Coalescing and anastomosing sandstone shoestrings were probably formed by channel avulsion. Broader sandstone bodies were formed by the lateral and downstream migration of meander bends. This is suggested by the strong curvature on the narrower sandstone shoestrings, the scroll bars and levees of interbedded sandstone and shale, and the large areas roofed by blocky grey clay (fluvent) palaeosols (identified from Stace et al. 1968, Buol et al. 1973). Large fossil logs are sometimes found in riffle bar gravel and intraformational breccia at the base of the fluvial channels, but I have not seen any in the other lithologies. Nor have I found any recognizable plant remains in the organic horizon of the grey clay palaeosols other than carbonized roots. However, lee pond shale interbedded with scroll bar sandstone commonly contains a well-preserved fossil plant assemblage dominated by *"Thinnfeldia" callipteroides*. This assemblage includes some admixture of equisetaleans, filicaleans, and isoetaleans, which probably lived around and within these ponds. Associated conifer remains, which dominate other localities near this stratigraphic level, probably represent the stable floodplain forest which overtopped the "*T.*" *callipteroides* scrub on scroll bars and levees.

The Permian - Triassic boundary has traditionally been placed at the top of the last economic coal seam in the Sydney Basin (David 1950). However, Balme (1969) has correlated palynomorphs of the *Lunatisporites pellucidus* Assemblage with similar assemblages from earliest Triassic marine rocks in Western Australia and Pakistan. Thus the international Permian - Triassic boundary as reaffirmed by Nakazawa et al. (1975), lies within the Scarborough Sandstone and Munmorah Conglomerate of the Sydney Basin, where this palynological assemblage first appears (figure 21.2). This is a good deal higher than the horizon containing abundant "*Thinnfeldia*" *callipteroides*. A Permian age of the "*T.*" *callipteroides* assemblage is also supported by the almost identical fossil flora from the plant-bearing shale (bed 3) of the Sakamena Group in Madagascar, which underlies shale and sandstone (bed 4) containing *Glossopteris* and further shale (bed 5) containing a Gyronitan marine fauna (Anderson and Anderson 1970). The Gyronitan corresponds to the upper Griesbachian and Dienerian of Tozer (1971).

"*Thinnfeldia*" *callipteroides* (figures 21.6B, C, D) is known from the Sydney Basin largely by an incidental identification of Townrow (1966b). It is quite unlike "*Thinnfeldia*" (now included within *Pachypteris* by Doludenko 1971) or *Dicroidium* as understood by Gothan (1912) and Frenguelli (1943). Its multiple forked rachis is most like some Northern Hemisphere species of *Callipteris*. The pinnae of "*Thinnfeldia*" *callipteroides* may be short and semicircular, long and narrow, or even lobed and pinnate. Townrow (1966b) identified *Lepidopteris* from the "*T.*" *callipteroides* assemblage, but I regard his fragments as "*T.*" *callipteroides* with lobed pinnae (as in figure 21.6B) until a demonstrably unforked frond of the characteristic *Lepidopteris* shape is found at this level. Townrow's cuticle preparations, which I have examined, are not sufficiently distinctive to support separation from "*T.*" *callipteroides*.

Figure 21.6. Leaves, cuticle, and stratigraphic setting of "*Thinnfeldia*" *callipteroides* Carpentier 1935.
A, geological relationship between Bulli Coal of the Illawarra Coal Measures and the overlying Coal Cliff Sandstone of the basal Narrabeen Group, based largely on the area around old Coal Cliff jetty with some observations (in parentheses) from Darkes Forest mine.
B-D, "*Thinnfeldia*" *callipteroides*, B, C, leaves from Oakdale Colliery, B, UNEF14738 from "old south" (UNEL1570), C, UNEF14739 from "crib room" (UNEL1571), D, cuticle, 150 times natural size from Coxs Gap (MMF13684). Plant drawings natural size.


D
X150
channel fill; cross-bedded sandstone
6m
5
4
3
2
1
channel lag; conglomerate, shale breccia and coalified logs
C
"Thinnfeldia" callipteroides
grey clay, or fluvent, palaeosol
granule-size, coal breccia
(coalified logs in carbonate cement)
(Glossopteris in sideritic claystone band)
Glossopteris
A
B

"Thinnfeldia" callipteroides probably belonged to the pteridosperm stock which gave rise to *Dicroidium*, most likely through intermediate forms similar to *"Dicroidium" gopadense* from Nidpur in India (Bose and Srivastava 1971). The successive cuticles of *"Thinnfeldia" callipteroides, "Dicroidium" gopadense,* other Nidpur *Dicroidium* leaves, *Dicroidium zuberi* (described as *Hoegia* by Townrow 1957), and *D. odontopteroides* exemplify a general evolutionary trend from thick cuticles with haplocheilic stomata (as in figure 21.6D) during the Late Permian to thinner cuticles with irregular subsidiary cells (or "pseudosyndetocheilic" stomata, as in figure 21.12C) during the Middle and Late Triassic. Multiple forked, but otherwise *Dicroidium*-like, leaves are a rare associate of younger *Dicroidium* floras (*Tetraptilon* of Frenguelli 1950).

"Thinnfeldia" callipteroides has been found immediately above the Late Permian coal measures at many localities from the south coast to near Muswellbrook: Bulli Colliery (figure 21.7A, UNEF14731 from UNEL1572), Bellambi Colliery (AMF27431), old Coal Cliff jetty (UNEF14742 from UNEL1581), north Coal Cliff beach (Townrow 1966b, fig. 1B, Burragorang Valley (AMF4562-4563), Nattai Colliery (MMF16482-16484), Oakdale Colliery (figures 21.6B, C, 21.7B), and the eastern end of Coxs Gap road tunnel into the Goulburn Valley, west of Muswellbrook (figure 21.6D; MMF13691). It has also been collected from Hamilton, near Newcastle (AMF26114), south of Frazer Park beach, near Swansea (UNEF15096), and in the Birthday shaft, near Sydney (figure 21.8A; as *Alethopteris* of Dun 1908). The higher examples of this last record may be contrasted with reports (R. Helby pers. comm.) of *Dicroidium zuberi* at similar stratigraphic horizons in the west and north. None of these isolated remains have been studied, so that it is presently uncertain whether pteridosperm floras of the middle Narrabeen Group were like those dominated by *"Thinnfeldia" callipteroides, Dicroidium zuberi,* or an intermediate type of broadleaf vegetation like that found near Nidpur, India (as discussed by Retallack 1977c).

Common associates of *"Thinnfeldia" callipteroides* are equisetalean pith casts (UNEF13976 from UNEL1570), *Schizoneura gondwanensis* Feistmantel 1876 (Etheridge 1893a, 1903b, Rigby 1969a), large *Isoetes*-like leaflet groups (MMF16455-16461), sterile cladophleboid fern fronds (UNEF13977 from UNEL1572), and conifer shoots, including *Voltziopsis africana* Seward 1934 (figure 21.8H) and undescribed remains (figure 21.8D).

Several authors (including Townrow 1966b) have recorded rare *Glossopteris* leaves from the *"Thinnfeldia" callipteroides* assemblage. There is some evidence, discussed later, that a single conservative lineage of glossopterid plants survived until the Middle Triassic in swampy areas of Gondwanaland. However, along with others who have searched diligently for *Glossopteris* in the basal Narrabeen Group (Harper 1915, p.63), I can find no substantial evidence of it. Small, naturally macerated leaf fragments found at Coxs Gap may show a clear venation of polygonal meshes (MMF13666). These could be fragments of a *Chiropteris*-like leaf or weathered fragments of *Glossopteris* resorted from the underlying coal measures. In

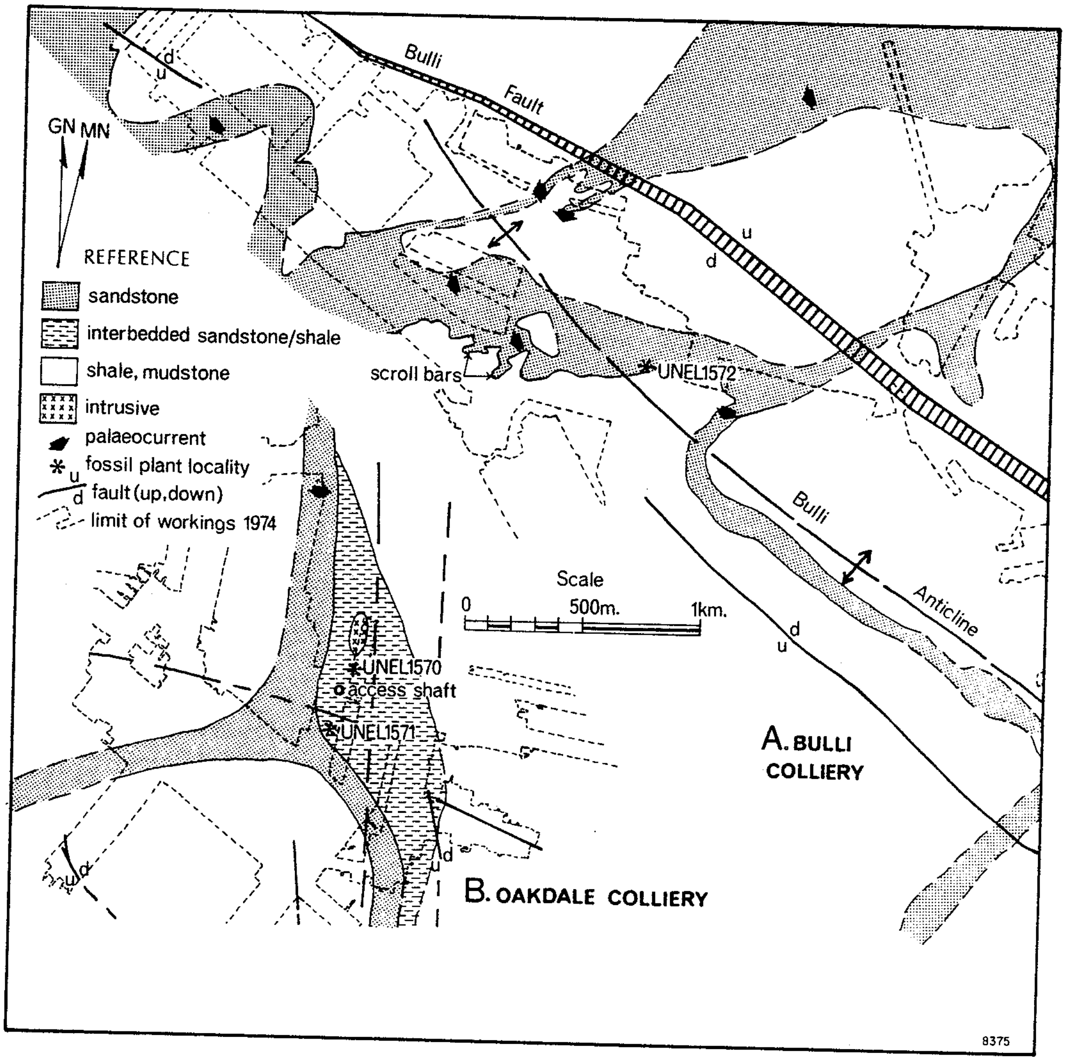


Figure 21.7. Lithologies forming the roof of the Bulli Coal in Bulli and Oakdale Collieries, Southern Coalfield, New South Wales.

several deep bores (David and Pittman 1894) and the Birthday shaft (figure 21.8A), near Sydney, the uppermost coal seam is overlain by shale, without "*Thinnfeldia*" *callipteroides*, but containing *Glossopteris*, *Schizoneura*, *Taeniopteris*, and a group of leaves most probably allied to *Ginkgophytopsis*(?) *kidstonii* of Høeg's (1967) Palaeophyllales (Dun 1911). Some workers (such as Helby 1969b) have interpreted this occurrence as another late survival of *Glossopteris*. However, from recent borehole correlations, Stuntz (1975), has suggested that the uppermost coal seam below Sydney is stratigraphically higher than the highest seam in the Southern Coalfield, and that the shale containing *Glossopteris* and *Schizoneura* is probably an uneroded remnant of higher coal measure sediment, older than the alluvium-bearing "*Thinnfeldia*" *callipteroides*.

THE RISE OF CONIFEROUS FORESTS
(latest Permian to mid-Scythian)

Very few megafossil plants have been found in the predominantly sandy sediments deposited between the time when broadleaf floras were successively dominated by "*Thinnfeldia*" *callipteroides* and *Dicroidium zuberi*. The few available plant megafossils, spores, and pollen (the upper *Protohaploxypinus reticulatus*, *Lunatisporites pellucidus*, and *Protohaploxypinus samoilovichii* Assemblages of Helby 1973) suggest that the vast floodplain was extensively forested by conifers. Filicaleans, equisetaleans, and lycopods locally fringed standing water crowded with conchostracans (such as those described by Etheridge 1888).

At that time quartz - lithic sandstone and conglomerate were deposited by streams draining the northern and western Sydney Basin and an eastern volcanic ridge. At times the streams flowed into large coastal lagoons intermittently open to the sea, allowing the occasional penetration of acritarchs, foraminifera, sponge spicules, and holothurian sclerites (see Mayne et al. 1974, p.207). This period of high water table probably corresponded to the global marine transgression which culminated in the Smithian (McTavish and Dickins 1974), during which the only reliably dated Triassic marine fauna penetrated eastern Australia (Runnegar 1969b). At times, and in places of more stable water table, the partly volcanogenic alluvium was oxidized in floodplain soils. These have been preserved as red, mottled, and drab palaeosols, with carbonaceous fossil roots and soil peds (described as "coal pipes" and "jointy claystone" by Dun 1908). In places these soil materials were redeposited as bedded claystone pedoliths (Retallack 1977a, p.390).

This poorly fossiliferous interval includes the Scarborough and lower Bulgo Sandstones. These units and their plant megafossils are best known from the sea cliffs south of Sydney (Ward 1972b) and from the second Cremorne bore (Pittman 1894, Etheridge 1893b, 1894a) and the Birthday shaft (figure 21.8A), both near Sydney.

Filicaleans and equisetaleans have been recorded by Dun (1908) and Pittman (1894) as "*Sphenopteris*", "*Phyllotheca*", and "*Equisetum*". Despite the prominence of lycopod spores in palynological samples (Helby 1973), only one lycopod specimen, loosely identified as "*Stigmaria*", has been noted from the Moore Park bore (Cox 1881).

Voltziopsis, the best known conifer of this interval, is apparently restricted to latest Permian and Scythian rocks. *Voltziopsis wolganensis* (figure 21.8E, F) is locally abundant in the basal Narrabeen Group of the Sydney Basin, for example, at the eastern end of Coxs Gap road tunnel (MMF13666) and near Newnes (Townrow 1967b). Both this species and *V. africana* Seward 1934 (figure 21.8H) are found in the basal Narrabeen Group and the latest Permian (bed 3) of the Sakamena Group in Madagascar (Anderson and Anderson 1970). The youngest occurrence of *Voltziopsis* is the abundant *V. angusta* (figure 21.8G) in the lower Newport Formation at Bungan Head (UNEF13856-13863 from UNEL1417). This florule is transitional between conifer- and *Dicroidium*-dominated broadleaf vegetation.

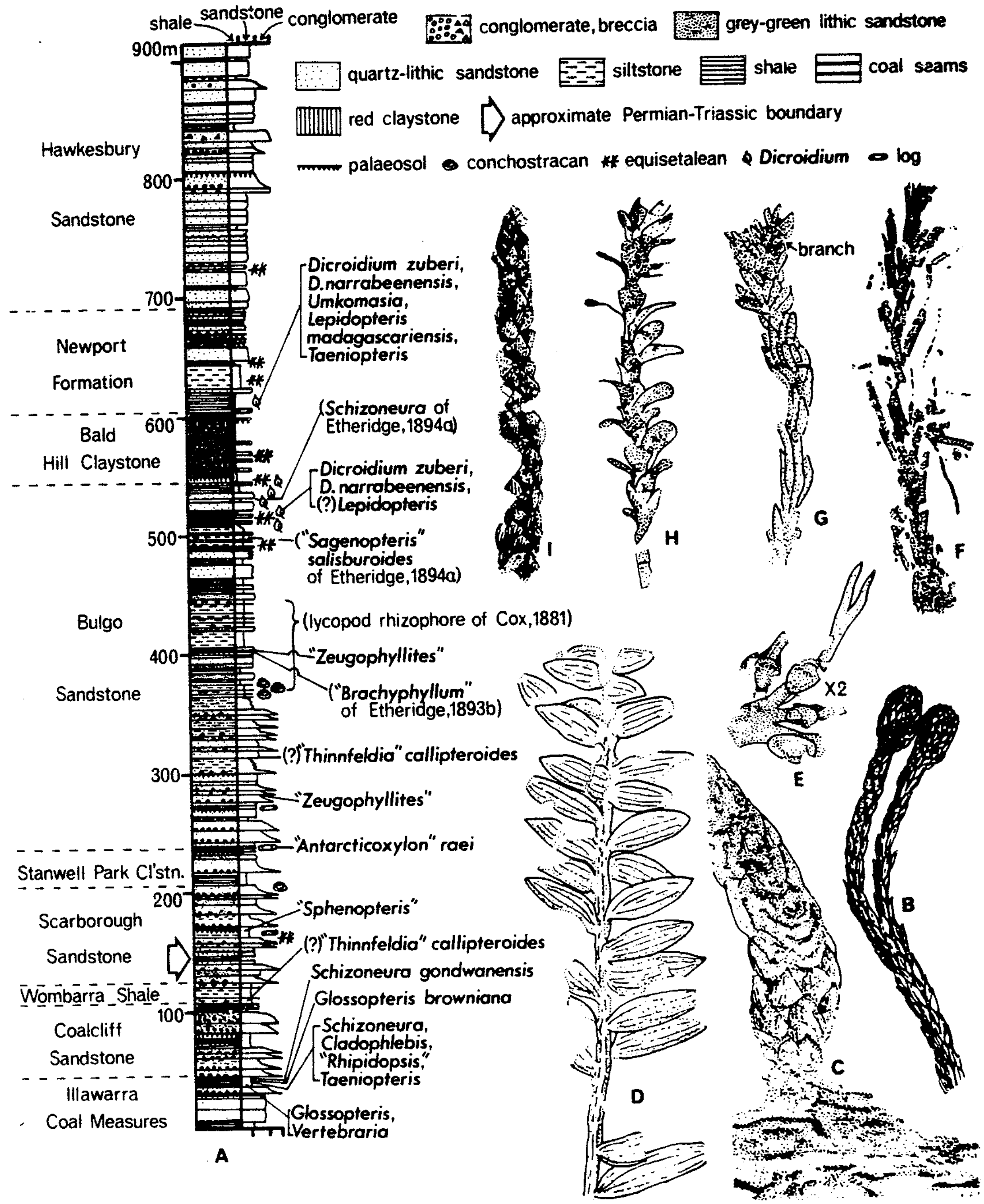
An additional common type of conifer shoot is here called "*Brachyphyllum*" s.l. (figure 21.8I). These are generally similar to *Walkomiella australis* (figure 21.8B, C) but have broader, almost mucronate leaves. They have been found at Thelma Head, south of Garie beach (figure 21.8I; UNEF14737 from UNEL1567), at 90 m in ELECOM Wyong DDH 4 (AMF51456), at 540 m in the second Cremorne bore (Etheridge 1893b), and at Turimetta Head (Helby and Martin 1965, fig. 6).

There are also several conifer remains which Etheridge (1892) and Dun (1908) have loosely identified as "*Podozamites*" and "*Zeugophyllites*" (figure 21.8D). Some of these (such as MMF3084 from Bulli) reached such a size, that were it not for their cuticle, interveinal striae, and leaves arranged in a well-spaced spiral, they could be confused with *Schizoneura gondwanensis*.

Baker (1931) described a coniferous log ("*Antarcticoxylon*" *raei*), 6 m long, with a calculated diameter of 76 mm, from the base of the Bulgo Sandstone in the Birthday shaft. According to Walton (1956), this poorly preserved specimen is more likely a *Dadoxylon*. Fossil logs up to 3 m long and 83 mm in original diameter are scattered over the rock platform formed in the Bulgo Sandstone, near Figure of Eight Pools, south of Burning Palms, Royal National Park. Burges (1935) described coniferous wood, apparently from the lower part of the Terrigal Formation, south of Terrigal (unit A of McDonnell 1974, article 10). This is stratigraphically equivalent to the upper Bulgo Sandstone on the South Coast (Mayne et al. 1974, fig. 43).

DICROIDIUM ZUBERI AND SANDY STREAMS OF THE WESTERN MARGIN
(late Scythian)

During the Scythian a distinctive broadleaf flora dominated by *Dicroidium zuberi*, gained ascendancy over the coniferous forests where it was favoured by a siliceous sandy substrate. *Dicroidium*


shale
sandstone
conglomerate
conglomerate, breccia
grey-green lithic sandstone
quartz-lithic sandstone
siltstone
shale
coal seams
red claystone
approximate Permian-Triassic boundary
palaeosol
conchostracan
equisetalean
Dicroidium
log
900m
800
700
600
500
400
300
200
100
Hawkesbury
Sandstone
Newport
Formation
Bald
Hill Claystone
Bulgo
Sandstone
Stanwell Park Cl'stn.
Scarborough
Sandstone
Wombarra Shale
Coalcliff
Sandstone
Illawarra
Coal Measures
A
Dicroidium zuberi,
D. narrabeenensis,
Umkomasia,
Lepidopteris
madagascariensis,
Taeniopteris
(Schizoneura of
Etheridge, 1894a)
Dicroidium zuberi,
D. narrabeenensis,
(?) Lepidopteris
("Sagenopteris"
salisburoides
of Etheridge, 1894a)
(lycopod rhizophore of Cox, 1881)
"Zeugophyllites"
("Brachyphyllum"
of Etheridge, 1893b)
(?) "Thinnfeldia" callipteroides
"Zeugophyllites"
"Antarcticoxylon" raei
"Sphenopteris"
(?) "Thinnfeldia" callipteroides
Schizoneura gondwanensis
Glossopteris browniana
Schizoneura,
Cladophlebis,
"Rhipidopsis,"
Taeniopteris
Glossopteris,
Vertebraria
I
H
branch
G
F
X2
E
B
C
D

first gained control of the far western and northern Sydney Basin. As the water table began to fall and rivers reworked the floodplain to a greater mineralogical maturity (Ward 1972a), the *Dicroidium* flora displaced the coniferous forests over the entire Sydney Basin.

The best evidence for the easterly invasion of the *Dicroidium* flora is the distribution of palynological assemblages (Helby 1973, p.151). Unfortunately I have not been able to see the specimens, but Helby (pers. comm. 1977) reports *Dicroidium zuberi* from very low stratigraphic horizons in the west and north, such as the Caley Formation in the Wolgan Valley and the Tuggerah Formation at 252.4 and 255.5 m in Elecom Ourimbah DDH 5. These are stratigraphically equivalent to the Wombarra Claystone and Stanwell Park Claystone in the southern and central Sydney Basin, where megafossil floras dominated by *Dicroidium zuberi* are not known below the upper Bulgo Sandstone. Easterly invasion can also be, less convincingly, argued from Frenguelli's (1944a) ideas on the phylogeny of varieties of *Dicroidium zuberi* (his species of "*Zuberia*"). The leaves of *Dicroidium zuberi* from Mount Piddington on the western margin of the Sydney Basin are of a more primitive variety (*D. zuberi* var. *papillatum* (Townrow) Retallack 1977c) than those at a similar stratigraphic horizon on the coast near Garie and Terrigal (*D. zuberi* var. *feistmantelii* (Johnston) Retallack 1977c).

The fossil flora dominated by *Dicroidium zuberi* is widespread in late Scythian to early Anisian rocks of Gondwanaland. It is associated with tetrapods of the *Cynognathus* zone in the upper Beaufort Beds of South Africa (Du Toit 1927, Anderson and Anderson 1970). In the Sydney Basin it locally includes *Pleuromeia longicaulis* (figures 21.11E, F), its supposed cone (*Cylostrobus sydneyensis*, figure 21.11D, and distinctive microspores (*Aratrisporites*). *Pleuromeia* is a useful biostratigraphic indicator of late Scythian to early Anisian age (Retallack 1975). A specimen of *Dicroidium zuberi* var. *feistmantelii* (Johnston) Retallack 1977c, similar to those from the

Figure 21.8. Late Permian and Early Triassic conifer fossils and stratigraphy.
A, geological section of the Birthday shaft, Balmain, near Sydney, showing the distribution of plant fossils (interpreted from Dun 1908, 1911, 1912; Baker 1931; Townrow 1966b) with additions from the second Cremorne and Moore Park bores (in parentheses).
B, C, *Walkomiella australis* (Feistmantel) Florin 1944, from Bowenfels (after Feistmantel 1890), B, shoot with terminal cones, C, shoot branching from a woody axis.
D, unidentified conifer from "Woonona Park" (after Townrow 1967b).
E-F, *Voltziopsis wolganensis* Townrow 1967b from Newnes, E, seed cone unit, twice natural size, F, portion of a foliage shoot.
G, *V. angusta* (Walkom) Townrow 1967b from Turrimetta Head.
H, *V. africana* Seward 1934, unknown locality in Southern Coalfield.
I, "*Brachyphyllum*" s.l, (UNEF14737) from Thelma Head (UNEF1567).
Plant drawings natural size unless otherwise specified.

coastal Sydney Basin, has also been found as a drift leaf in Smithian to Middle Anisian marine rocks near Wairaki Hut, in the Taringatura Hills of New Zealand (OU3960). The first appearance of *Dicroidium zuberi*, and to a lesser extent its dominance of broadleaf vegetation, form a useful biostratigraphic horizon in Gondwanaland. However, *D. zuberi* persisted until the Norian in younger broadleaf floras characterized by *D. odontopteroides* (Azcárate and Fasola 1970, Archangelsky 1968). The reproductive structures of *D. zuberi* found at Mount Piddington (figures 21.9D, E, F) and also in the lowest Bald Hill Claystone, Newport and Terrigal Formations of the Sydney Basin, have not yet been found in these younger broadleaf floras.

Balme and Helby (1973) have suggested that the apparently greater diversity of the *Dicroidium zuberi* flora, compared with floras from the lower Narrabeen Group, represented a long term recovery of the terrestrial ecosystem from the destruction of the complex *Glossopteris*-dominated communities by marine transgression succeeded by continental emergence. Palynological assemblages remain the best evidence, but the megafossil floras supply some arguments both for and against the idea. It is possible that the rapid expansion of *Pleuromeia* along the seashores of the world was due to opportunism in a decimated biosphere (Retallack 1975). Furthermore, the *Dicroidium zuberi* localities of the Sydney Basin can be arranged in a sequence of increasingly diverse floras up-section: firstly, Mount Piddington (UNEL1467); secondly, the lower Bald Hill Claystone north of Garie beach (UNEL1566) and the Terrigal Formation south of Terrigal (UNEL1466); and thirdly, the Newport Formation in the sea cliffs north of Sydney. On the other hand, the early Scythian coniferous forests may have had a low species diversity for purely intrinsic reasons, similar to analogous modern vegetation (described by Strahler 1966, p.348). Furthermore, the conifer and older *Dicroidium zuberi* localities have not been collected as extensively as the younger *Dicroidium zuberi* localities.

The best known localities for *Dicroidium zuberi* near the western margin of the Sydney Basin are Mount Piddington (figure 21.9) and the laminite marker horizon of the upper Burralow Formation at Mount Hay (Goldbery 1972a, pl.13, fig. 2). These two localities are stratigraphically equivalent to the coastal Bald Hill Claystone and upper Newport Formation respectively (Goldbery and Holland 1973).

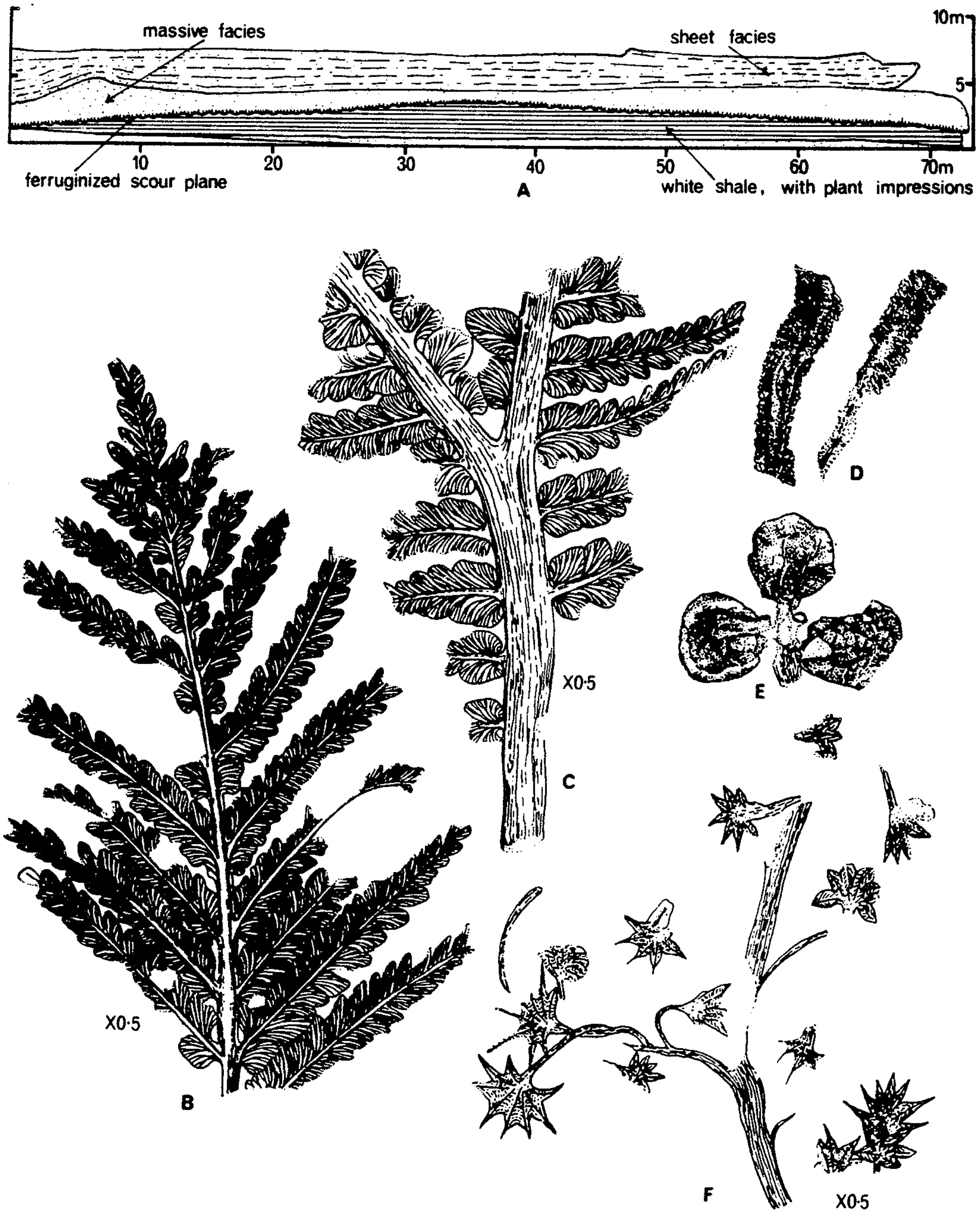
Near the carpark and picnic area at Mount Piddington a bed of white shale (figure 21.9, UNEL1467), contains abundant leaf impressions of *Dicroidium zuberi*. Feistmantel's (1878, pls 9-11; 1890, pls 23-25) beautiful sketches of these leaves (redrawn in figures 21.9B, C) have been designated holotypes for several of the taxa which Archangelsky (1968) synonymized with *Dicroidium zuberi*. These include "*Thinnfeldia feistmanteli*" (Walkom 1932), "*Zuberia Feistmanteli*" (Frenguelli 1944a), and both species of "*Hoegia*" (Townrow 1957).

The seed and pollen organs of *Dicroidium zuberi*, also found at Mount Piddington, are larger than usual, but otherwise typical of the pteridosperm family Corystospermaceae. The megasporophyll (figures 21.9E, F) has more cupule lobes, but is otherwise similar to the one found with *Dicroidium zuberi* by Frenguelli (1944a), and is probably a new species of *Umkomasia* (of Thomas 1933). The cupules may form a fleshy verrucose cover to seeds terminating pinnately arranged branches (figure 21.9E), but dehisced cupules clearly show five or six pointed lobes (figure 21.9F). Walkom (1925, 1932) compared isolated dehisced cupules of this type with *Williamsonia* and *Phyllotheca robusta*. The microsporophyll (figure 21.9D) is identical to "*Pterorrachis*" *barrealensis*. As Townrow (1962) pointed out, Frenguelli (1942b, 1944a) was mistaken about its structure, which is more like *Pteruchus* (of Thomas 1933). However, I do not agree with Townrow (1962) that "*Pterorrachis*" *barrealensis* should be synonymized with *Pteruchus dubius*, as it is sufficiently distinctive to be a separate species.

The only other definite plant remains found in the white shale at Mount Piddington are fertile fronds of the marattiaceous fern *Asterotheca* (AMF56876). Tenison-Woods (1884) also recorded "*Macrotaeniopteris wianamattae*", "*Gleichenia dubia*", and "*Podozamites*" sp. from here, but I have not been able to find any such specimens in museums or at Mount Piddington.

The white shale is part of the Wentworth Falls Claystone Member of the Banks Wall Sandstone, Grose Sub-Group, upper Narrabeen Group (Bembrick and Holland 1972). Although petrographically distinct, in general appearance the Grose Sub-Group (including its massive and sheet facies, figure 21.9A) is similar to the Hawkesbury Sandstone (as interpreted by Conaghan and Jones 1975). Similarly, it was probably deposited by large streams which were braided at low stage. The white shale is probably a pedolith derived from the upper horizon of a Triassic soil developed on a more exposed part of the drainage basin. Diffuse light-pink mottling and rare fossil roots in the shale indicate limited Triassic soil formation as a clayey alluvial (fluvent) palaeosol (identified from Stace et al. 1968 and Buol et al. 1973).

In coastal exposures, *Dicroidium zuberi* becomes prominent some distance below the Bald Hill Claystone (67 m in the Birthday shaft, figure 21.8A). A grey-green siltstone forming the base of the Skillion, south of Terrigal (UNEL1466), in unit A of the lower Terrigal Formation (stratigraphically equivalent to the upper Bulgo Sandstone), contains *Dicroidium zuberi* var. *feistmantelii* (Johnston) Retallack 1977c) (UNEF13978, most abundant), *D. lancifolium* var. *lancifolium* (Morris) Gothan 1912 (UNEF13979), and "*Pterorrachis*" *barrealensis* (UNEF13980). Grey shale in the lowest Bald Hill Claystone north of Garie beach (UNEL1566, photographed by Ward 1972a, pl.24, fig. 3) contains *Dicroidium zuberi* var. *feistmantelii* (UNEF13981, most abundant), *D. dubium* var. *australe* (Jacob and Jacob) Retallack 1977c (UNEF13982), *D. lancifolium* var. *lancifolium* (UNEF13983), *Umkomasia* sp. with six-lobed dehisced cupules (UNEF13984), *Lepidopteris madagascariensis* Carpentier 1935 (UNEF13985), *Taeniopteris* sp. (UNEF13986), and equisetalean stems (UNEF13987).


massive facies
sheet facies
10m
5
10
20
30
40
50
60
70m
ferruginized scour plane
A
white shale, with plant impressions
X0·5
C
D
E
X0·5
B
F
X0·5

The *Dicroidium zuberi* flora occurs at a similar stratigraphic horizon to palynomorphs of the *Aratrisporites tenuispinosus* Assemblage (Helby 1973). Megafossil plant remains from rocks corresponding to the lower zonule of this assemblage have been found in the second Cremorne bore and Birthday shaft (figure 21.8A), at Terrigal (UNEL1466), and possibly at Mount Piddington (UNEL1467). Rocks containing the upper zonule of this assemblage include all the *Dicroidium zuberi* localities stratigraphically above and including the locality north of Garie beach (UNEL1566). The megafossil flora found with the lower zonule does not appear to have been as diverse as that with the upper zonule assemblage, but neither has it been as intensely collected.

THE CONIFER'S LAST STAND

(late Scythian to early Anisian)

The Bald Hill Claystone forms a prominent stratigraphic marker in the upper Narrabeen Group. Red claystone and volcanogenic sandstone were spread westward over the southern and central Sydney Basin during an extended period of low water table (Ward 1972a, Goldbery and Holland 1973). At Long Reef the Bald Hill Claystone contains eight closely superimposed grey-brown podzolic (ferrod) palaeosols, representing an accumulated depositional hiatus of at least 16,000 years (Retallack 1977b). No fossil leaves have been found within the red claystone. The presence of conifer pollen (*Lunatisporites* and *Protohaploxypinus*) similar to that produced by the coniferous forests of the middle Narrabeen Group, rather than *Dicroidium* pollen (*Alisporites* of de Jersey 1962, *Falcisporites* of Helby 1973, and *Pteruchipollenites* of Balme 1964), suggests that these soils were forested by conifers. It is likely that coniferous forest remained the dominant vegetation of an eastern volcanic ridge, while *Dicroidium* spread over the entire onshore Sydney Basin. When this volcanic ridge became prominent as a source of sediment during a period of low water table, the conifers made a last advance over the area around Sydney.

The mainly podzolic palaeosols in Triassic rocks of the Sydney (Retallack 1977a, b) and Bowen Basins (Jensen 1975) are compatible with a cool temperate climate. The increased diversity and types of insects, fish, amphibians, vegetation, and palaeosols in the Triassic compared with the Permian, indicate a less severe seasonal climate.

Figure 21.9. *Dicroidium zuberi* (Szajnocha) Archangelsky 1968, and its fructifications from Mount Piddington.
A, geological sketch of the plant-bearing shale (UNEL1467) in the road cutting northwest of the picnic area on Mount Piddington.
B, C, leaves of *Dicroidium zuberi*, half natural size (after Feistmantel 1890).
D, "*Pterorrachis*" *barrealensis* Frenguelli 1942b (UNEF13904).
E, F, *Umkomasia* sp. E, terminal seed-bearing cupules (MMF3106); F, dehisched cuples, half natural size.
Plant drawings natural size unless otherwise specified.

Some authors (Loughnan et al. 1964, Dickins 1973) believed that the Triassic redbeds formed in a tropical climate. However, the latitude of Sydney during the deposition of these redbeds (Bald Hill Claystone) was about 75°S (estimated from the palaeomagnetic pole of McElhinny 1973). Moreover, there are also redbeds in Permian sequences of the Sydney Basin (Loughnan 1975, Bowman 1970) which by all other indications were formed in a cool temperate to frigid climate. In all these cases the red colour is probably due to the pedological oxidation of a parent material ultimately derived from basic volcanics.

The coniferous forests were finally extinguished by sedimentological and ecological responses to a slowly rising water table. They were never to be seen again in the onshore Sydney Basin once the eastern volcanic ridge had completely waned as a source of sediment. Humic gley (fibrist) palaeosols in the uppermost Bald Hill Claystone and lowermost Garie Formation were probably forested by a mixed *Dicroidium - Voltziopsis* swamp woodland (Retallack 1977b). The organic horizon and sediments adjacent to one of these palaeosols at Turimetta Head (figure 21.10) contains these plant megafossils and coalified logs. Equisetaleans (*Neocalamites*) can be found in their position of growth in the uppermost A horizon and lowermost organic horizon of this palaeosol. These plants probably represent a preliminary stage in the hydrosere which reclaimed land from extensive lakes and lagoons for the swamp woodland climax. Eventually, this vegetation could no longer cope with the rising waters, and the palaeosols and characteristic shore-face pedoliths of the Garie Formation were overlain by widespread lagoonal shale of the lower Newport Formation (Bunny and Herbert 1971).

DELTA-TOP *DICROIDIUM* HEATHS AND *PLEUROMEIA* LAGOONAL BAY MEADOWS
(late Scythian to early Anisian)

At the peak of a cycle of high water table following redbed formation, much of the central Sydney Basin was inundated by a lobate lagoonal system, intermittently open to the sea. This was slowly filled by sediment from the "Burralow deltas" to the west and the "Gosford deltas" to the north (Conolly 1969).

One lobe of the "Gosford delta" is preserved in the sea cliffs between Long Reef and Palm Beach, north of Sydney. Active deltaic distributary channels flowed through the present Turimetta Head (figure 21.10), whereas further north around Avalon there were interdistributary bays and delta plains (Retallack 1975).

The base of the delta is most conveniently mapped from a horizon of lycopod fossils. *Pleuromeia longicaulis* (figure 21.11E, F) grew as monodominant thickets in a partly waterlogged alluvial soil (aquent) fringing an interdistributary bay, now preserved in the sea cliffs north of Avalon beach. Its floating cones (*Cylostrobus sydneyensis*) and fleshy elongate leaves (*Sigillariophyllum*) were scattered over a large area of prodelta shale to the south (Retallack 1975).

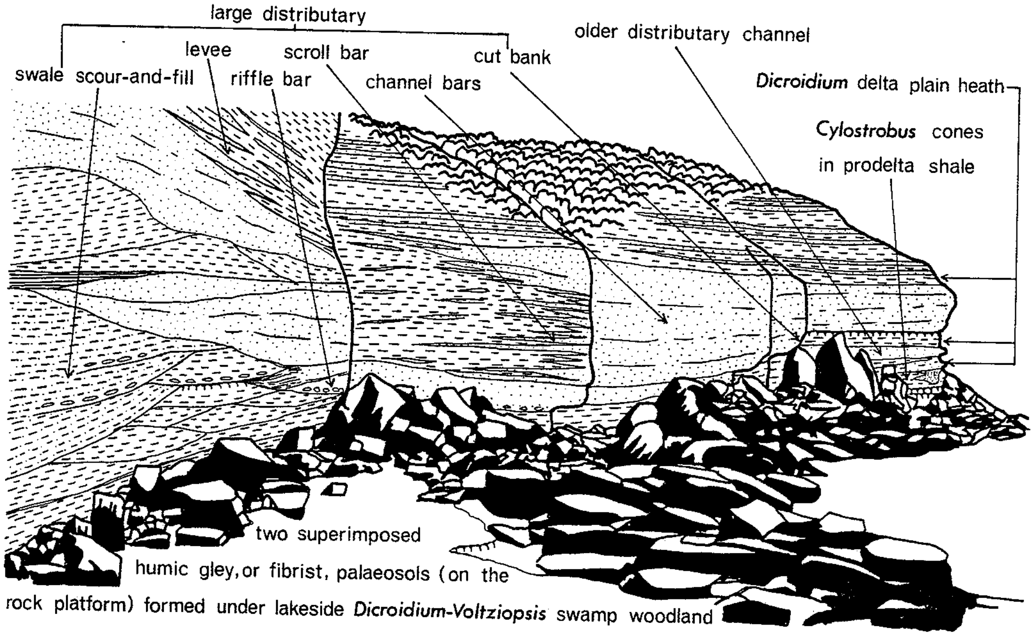
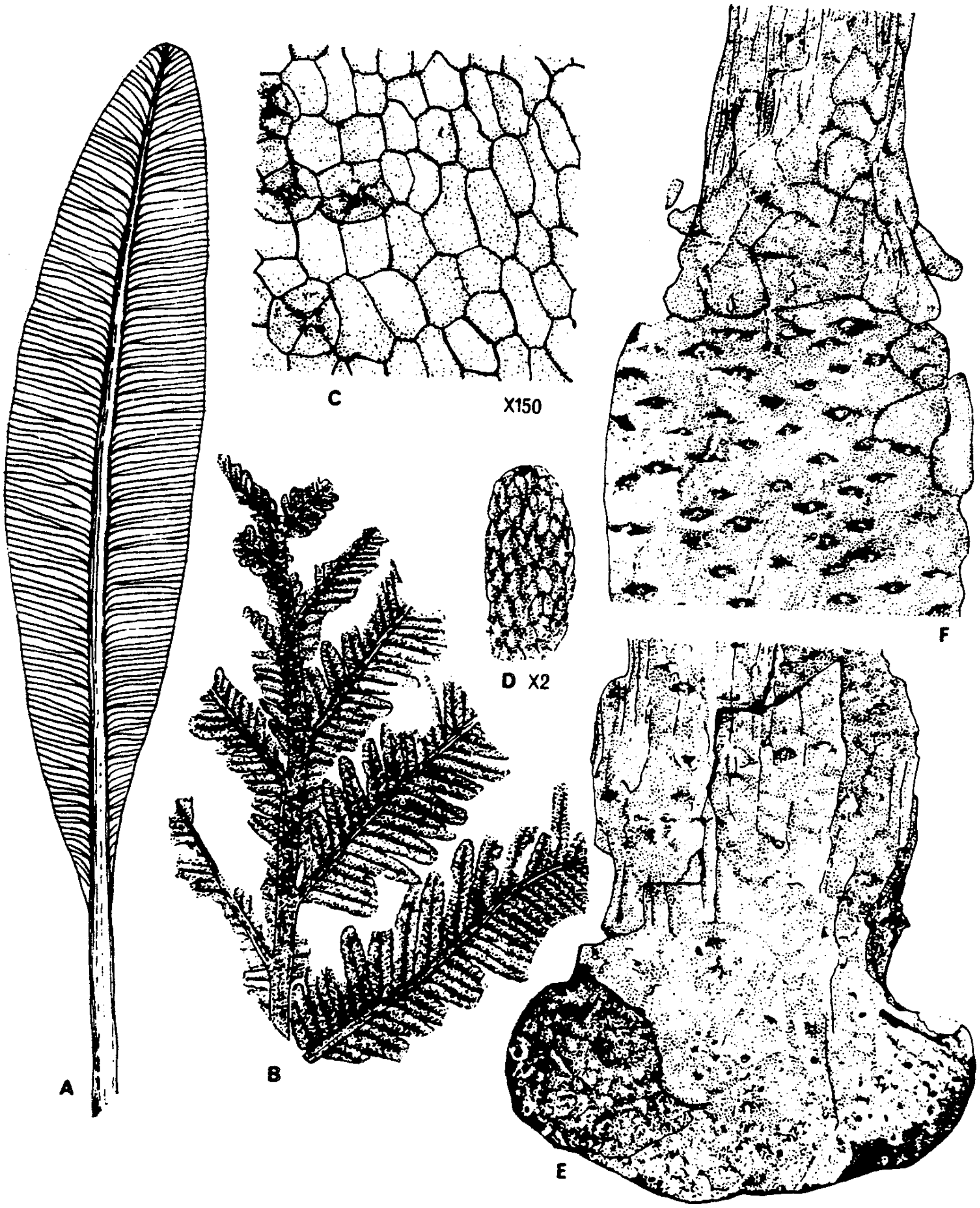


Figure 21.10. Simplified geological sketch of the southeastern wall of Turimetta Head from the southern end of the rock platform, showing the palaeoenvironmental interpretations of Retallack (1975, 1977a, b). Lithological symbols as for figure 21.8.

The delta plain was vegetated mostly by *Dicroidium zuberi*, judging from the abundance of its leathery leaf remains. This vegetation was probably a heath association here, although there are reasonable arguments that *D. zuberi* formed forests elsewhere (Archangelsky 1968). North of Sydney the *Dicroidium zuberi* flora grew on thin (about 0.5 m thick), sandy surfaced gleyed podzolic (aquod) palaeosols, a soil commonly supporting heath today. Egg cup podzols, cradle knolls, and radiating root systems in the A horizon of these palaeosols are all less than 0.5 m in diameter. Coalified logs found in association with these palaeosols are all less than 110 mm wide. Finally the *Dicroidium* leaves are unusually thick and tough, compared with the same species, associated with the same fructifications, at Mount Piddington, where the impressions show the veins more clearly.

The *Dicroidium* flora from the lower Newport Formation in the sea cliffs north of Sydney has been discussed by many authors, most notably Walkom (1925), Burges (1935), Jacob and Jacob (1950), Helby and Martin (1965), Townrow (1966b, 1967b), and Retallack (1973, 1975). The most conspicuous fossils are *Dicroidium* leaves, mainly *D. zuberi* var. *feistmantelii* (Johnston) Retallack 1977c (Walkom 1925, pl. 24, figure 7, pl.25, figures 1, 2). Some *Dicroidium* leaves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with more elongate pinnules than is usual for *D. zuberi* (UNEF13944, 15092 are referred to *Dicroidium brownii* (Seward) Retallack 1977c (based on *"Odontopteris" brownii* Seward 1908). These are probably transitional forms from leaves of the *"Thinnfeldia" callipteroides* complex. Other species of *Dicroidium* in the flora are *D. dubium* var. *australe* (Jacob and Jacob) Retallack 1977c (Walkom 1925, pl.26, fig. 4, pl.27, figs 3, 6; Jacob and Jacob 1950, figs 20-27), *D. lancifolium* var. *lancifolium* (Morris) Gothan 1912 (Walkom 1925, pl.25, fig. 3, pl.26, figs 1-3, pl.27, fig. 2; Jacob and Jacob 1950, figs 4-6), *D. narrabeenense* var. *bursellii* (Lacey) Retallack 1977c (Jacob and Jacob 1950, figs 7-9), *D. narrabeenense* var. *narrabeenense* (Dun in Walkom) Jacob and Jacob 1950 (Walkom 1925, pl.27, fig. 1, pl.28; Jacob and Jacob 1950, figs 10-12), *D. pinnis-distantibus* (Kurtz) Frenguelli 1944b (Walkom 1925, pl.27, fig. 5) and *D. townrovii* Retallack 1977c (Walkom 1925, pl.24, fig. 8). The pinnatifid and unipinnate leaves illustrate intermediate stages in the evolutionary trend towards *Dicroidium odontopteroides*, which appeared no earlier than the Late Anisian. All the *Dicroidium* leaves from the Newport Formation had thick, tough cuticles with varying proportions of haplocheilic, "pseudosyndetocheilic", and intermediate stomata, the former being more common on bipinnate leaves. The same corystosperm fructifications as are found at Mount Piddington (figure 21.9) are also widely associated with *Dicroidium zuberi* in these sea cliffs. Although he did not recognize them as such, Walkom (1925) figured both the microsporophyll (pl.31, fig. 10) and megasporophyll (pl.29, figs 7-9, pl.31, figs 6, 11).

Other elements of the flora are isoetaleans (UNEF13824, 13825, from UNEL1457); *Pleuromeia longicaulis* (figure 21.11E, F) and its supposed cone *Cylostrobus sydneyensis* (figure 21.11D); further arborescent lycopods (UNEF13820 from UNEL1465); the equisetaleans, *Neocalamites* (Walkom 1925, pl.24, figs 1-3) and *Schizoneura* (UNEF13795 from UNEL1383); the sterile fern frond, *Cladophlebis* (Walkom 1925, pl.24, fig. 5); the *Gleichenia*-like *"Todites" narrabeenensis* Burges 1935; the fertile marattiaceous fern *Asterotheca* (UNEF13838 from UNEL1383); the pteridosperms, *Lepidopteris madagascariensis* (figures 21.11B, C; Townrow 1966b) and the *Pachydermophyllum*-like *"Odontopteris" dubiae* Burges 1935; possible cycadophytes referred to several species of *Taeniopteris* (Walkom 1925, text fig. 1, pl.29, figs 2, 3); the conifer *Voltziopsis angusta* (Walkom) Townrow 1967b; and some leaves

Figure 21.11. Fossil plants from the Newport Formation.
A, *Taeniopteris lentriculiformis* (Etheridge) Walkom 1917 from Gosford (after Etheridge 1894c).
B, C, *Lepidopteris madagascariensis* Carpentier 1935, B, leaf, from Bungan Head (UNEF13853 from UNEL1417), C, cuticle, from Mona Vale (UNEL1418), 150 times natural size (UNEF13961).
D, *Cylostrobus sydneyensis* (Walkom) Helby and Martin 1965, from Turimetta Head, twice natural size (after Helby and Martin 1965).
E, F, *Pleuromeia longicaulis* (Burges) Retallack 1975, E, base of stem with rhizophore, F. stem apex with attached leaves. Plant drawings natural size unless otherwise specified.

of uncertain taxonomic position, *"Rhipidopsis" narrabeenensis* Walkom 1925 (also described by Burges 1935). These last superficially appear to be fan-shaped apetiolate leaves, as in *Rhipidopsis*, but are in fact wedge-shaped leaves with anastomosing venation, arranged in a close spiral around a slender axis. They are most similar to leaves of Høeg's (1967) Palaeophyllales, particularly the South African Permian specimens Høeg calls *Ginkgophytopsis* (?) *kidstonii*.

TAENIOPTERIS LENTRICULIFORMIS COASTAL SCRUB
(Anisian)

A *Dicroidium zuberi* flora dominated by *Taeniopteris lentriculiformis* (figure 21.11A), delineates a remarkably persistent horizon in the uppermost Newport and Terrigal Formations of the eastern Sydney Basin and in Anisian (later Malakhovian to Etalian) marine rocks of the Murihiku Supergroup in New Zealand. At this level most of the Sydney Basin was a broad coastal plain drained by braided and meandering streams (McDonnell 1974). *Taeniopteris lentriculiformis* has not been found in stratigraphically equivalent formations of the western Sydney Basin. It seems to have dominated a freshwater coastal association. In New Zealand at least it was displaced during Ladinian (Kaihikuan) time by *Linguifolium* coastal woodlands, as at Mount Potts (Arber 1917). The acme of *Taeniopteris lentriculiformis* followed by its subtle, possibly evolutionary, replacement by *Linguifolium* in a similar habitat, is a useful biostratigraphic marker.

At North Avalon, *Taeniopteris lentriculiformis* appears to have grown in thick (1.7 m) grey clay (fluvent) soils developed on levees (Retallack 1977b). Here it has been found attached to, and associated with, slender branched axes (UNEF13893, 13894 from UNEL1393), suggesting that it was a many branched, diffuse shrub. Several specimens of *T. lentriculiformis* were also found in the fish-bearing shale lens of the Gosford railway ballast quarry (Etheridge 1894d, David 1890). *Taeniopteris lentriculiformis* is the most abundant fossil in the shale lens north of Harbord beach (Dunstan 1894, Etheridge 1894c).

In the Blue Mountains the stratigraphic equivalent of these eastern localities is the laminite marker horizon of the Burralow Formation. The only fossils known from that unit are the fertile marattiaceous fern, *Rienitsia spathulata* Walkom 1932, from Clarence Siding and *Dicroidium zuberi* from Mount Hay (Goldbery 1972a).

Drift fragments of *T. lentriculiformis* are prominent within a restricted interval of marine rocks in the Murihiku Supergroup, Southland, New Zealand. Marine biostratigraphic control is best in the Wairuna Peak Beds, east of Gore (Wood 1956). I have identified *T. lentriculiformis* from several localities in this area; S170/f525 (NZGSB26.1) lying between two probably Malakhovian (Smithian to Middle Anisian according to Waterhouse 1973a) faunas; S170/f560 (NZGSB31.31) lying between probably Malakhovian and Etalian

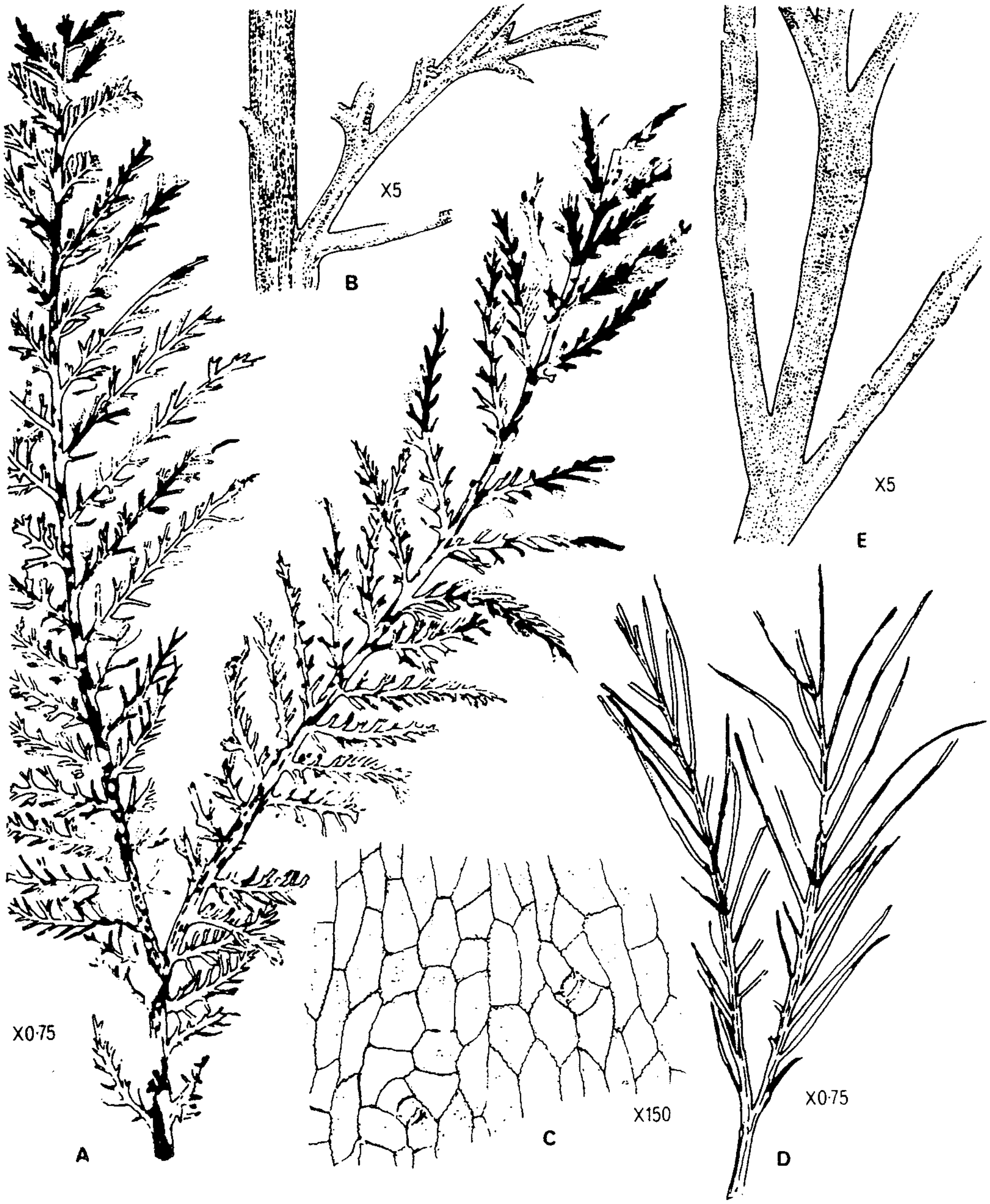
(Late Anisian) faunas; and S170/f606 (NZGSB191.6) and S170/f635 (NZGSB194.2) both along strike from Etalian faunas. This indicates an Anisian age for floras dominated by *T. lentriculiformis*.

XYLOPTERIS, SANDY SOILS AND BRAIDED STREAMS
(Anisian)

Conaghan and Jones (1975) and Conaghan (article 12) have suggested that much of the Hawkesbury Sandstone was deposited during the falling stage of floods in large, low sinuosity streams, which were braided at low stage. These powerful streams, at a time of stable water table, reworked and destroyed most of the palaeosols, fossiliferous shale, and other evidence of the ancient flora. The broad sandy floodplain was forested by a modified *Dicroidium zuberi* flora. This was characterized by the addition of xerophytic pteridosperms of the genus *Xylopteris*. It probably produced palynomorphs of the lower part of the lower zonule of the *Aratrisporites parvispinosus* Assemblage of Helby (1973). A comparison between these pteridosperm floras and the *Sphenopteridium* and *"Otopteris" argentinica* floras of the Late Carboniferous, suggests that only after all this time had the ecosystem in the Sydney Basin returned to cool temperate broadleaf forests analogous with the pre-glacial vegetation.

Fossils are rare in the sandstone. Etheridge (1890) described a large sandstone pith cast of the base of an equisetalean. Impressions of coalified logs commonly show a rectangular boxwork pattern after the original coal cleat. Von Mueller (1879) mistakenly identified one of these as a chambered leaf of an aquatic angiosperm, which he called *"Ottelia praeterita"*.

Plant fossils are sometimes found in shale lenses of the Hawkesbury Sandstone. The Brookvale shale lens is best known because of its abundant fossil fish, as well as amphibians, unionid bivalves, crustaceans, insects, trace fossils, and the enigmatic *Spirangium* (Dun 1913, Webby 1970, Mayne et al. 1974). The megafossil plant assemblage from Brookvale is best described as a modified *Dicroidium zuberi* flora. Typical *D. zuberi* (AMF14769) is present together with a wide range of intermediate *Dicroidium* fronds showing progressively narrower pinnules (such as *D. townrovii* Retallack 1977c, incorrectly identified with *Dicroidium superbum* by Townrow 1957) to normal fronds of the genus *Xylopteris* (figure 21.12). Because of their generally similar cuticles, some authors (Archangelsky 1968, Anderson and Anderson 1970) included *Xylopteris* within *Dicroidium*. However, slight cuticular differences (Townrow 1962) and the narrow, often lignified, leaf segments of *Xylopteris* are sufficiently distinctive for a separate genus. All these differences may indicate a xerophytic adaptation to the water stress and lower nutrient status of sandier soils. Xerophytic adaptations are also common in modern plants growing in nutrient poor, sandy soils weathered directly from the Hawkesbury Sandstone (Beadle et al. 1972).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Xylopteris leaves from Brookvale are the oldest occurrence of the genus in Gondwanaland, and considerably modify ideas on its phylogeny. Jones and de Jersey (1947) considered that the orderly and gradual appearance of *Xylopteris elongata, X. spinifolia,* and then *X. tripinnata* through 1200 m of Late Triassic coal measures represented an evolutionary lineage. However, Brookvale *Xylopteris* leaves suggest that the postulated evolutionary lineage of Jones and de Jersey (derived from narrow pinnuled *Dicroidium lancifolium* var. *lineatum* (Tenison - Woods) Retallack 1977c such as SUGD13013 from Brookvale) is equally as likely as the opposite sequence (derived from Brookvale leaves of *Dicroidium townrovii* Retallack 1977c. Even a simultaneous polyphyletic origin from various *Dicroidium* leaves, at various times and places of drier conditions, is likely. The successive appearance of the various species of *Xylopteris* in the Ipswich Coal Measures is more likely due to changing environmental conditions than evolution there.

Other megafossil plants from Brookvale include the liverwort, *Marchantites cyathoides* Townrow 1959; the equisetalean, *Phyllotheca brookvalensis* Townrow 1956; the marattiaceous ferns, *Rienitsia spathulata* Walkom 1932 (AMF15111) and *Asterotheca* sp. (Townrow 1957, AMF46201); a large fertile coniopterid frond (SUGD13034); sterile fern fronds, *Cladophlebis* (AMF46210); the pteridosperm, *Lepidopteris "stormbergensis"* (Townrow 1966b); and leaves of uncertain systematic position, probably conspecific with *"Anthrophyopsis" grandis* Walkom 1928a (AMF35947) and *"Chiropteris" lacerata* Arber 1917 (SUGD13040). *"Chiropteris"* was another plant similar to *?Ginkgophytopis kidstonii* (Seward) Høeg 1967. Triassic *Glossopteris*-like leaves, such as *"Anthrophyopsis"*, are discussed below. The specimens (AMF39397, SUGD13036) from Brookvale, which Townrow (1967a, fig. 1A) identified with *Rissikia apiculata* shoots from the Molteno Formation of South Africa, are more likely fossil roots. They are weakly cutinized, with slender spirally arranged rootlets arising at right angles from the main axis. The Molteno shoots of *R. apiculata* have more strongly cutinized and closely spaced leaves, at a more acute angle to the axis.

DICROIDIUM ZUBERI FRINGING A FRESHWATER COASTAL LAGOON (late Anisian)

According to the interpretation of the Wianamatta Group proposed by Herbert (article 13), the channelled sandy floodplain (Hawkesbury Sandstone) was overlain either transitionally (Mittagong Formation) or directly by widespread lagoonal shale (Ashfield Shale).

Figure 21.12. *Xylopteris* leaves and cuticle from the Brookvale shale lens of the Hawkesbury Sandstone.
A-C, *Xylopteris tripinnata* (Jones and de Jersey) Frenguelli 1943 (AMF18590), A, leaf, three quarters natural size, B, detail of the tenth inside pinna base of the left branch, five times natural size, C, cuticle, 150 times natural size.
D, E, *X. elongata* (Carruthers) Schopf 1973 (AMF18581), D, leaf, three quarters natural size, E, detail near the apex of the right branch, five times natural size.

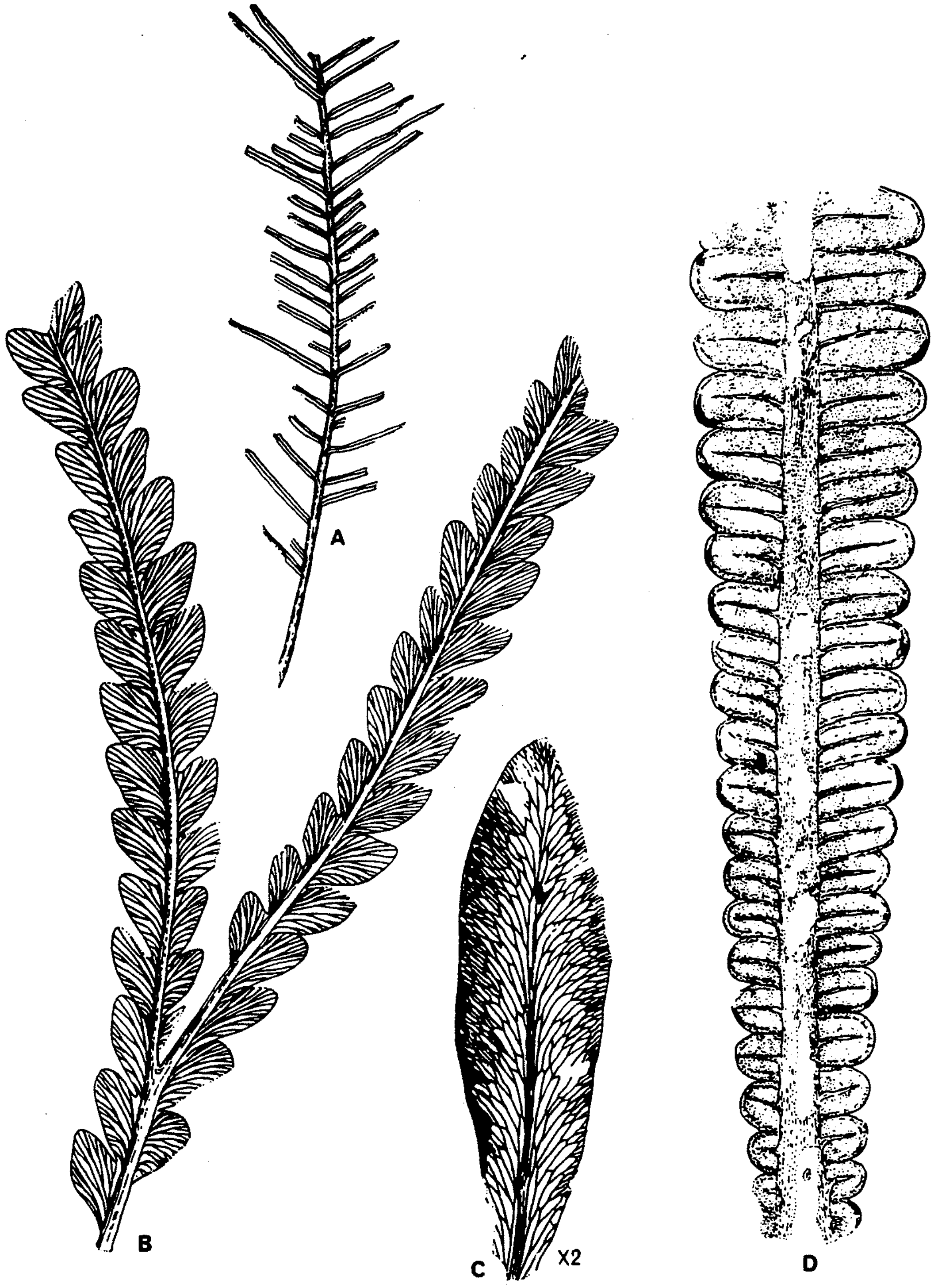
The lower part of the Ashfield Shale has yielded a *Dicroidium zuberi* flora which probably supplied palynomorphs of the upper part of the lower zonule of the *Aratrisporites parvispinosus* Assemblages of Helby (1973).

The "Ashfield lagoon" was almost certainly freshwater at this level. Phreatoicoid crustaceans (Nicholls 1943) and a 2.25 m long articulated labyrinthodont skeleton (Watson 1958) have been found at this level in the brick pits at St Peters, near Sydney. Modern and fossil relatives of these animals are characteristically non-marine. The St Peters quarries are also notable for fossil insects (Tillyard 1916) and a fish fauna of two distinct assemblages: a nearshore (grey shale) assemblage of small fish of Mesozoic appearance and a deeper water (dark sideritic shale) assemblage of larger fish of a Palaeozoic appearance (Woodward 1908). The ferruginized unionid coquina sometimes found on top of the Hawkesbury Sandstone (Etheridge 1888) probably represents a shoreline coquina, such as is commonly seen around modern lakes and dams.

Fossil leaves are scarce in the St Peters quarries, but include several well-preserved, perhaps flotsam, leaves of the fertile marattiaceous fern *Asterotheca* (AMF29774); the pteridosperms, *Dicroidium zuberi* (AMF1540) and *"Cycadopteris" scolopendrina* (as in figure 21.13D; AMF25645); the possible cycadophyte *Taeniopteris wianamattae* (Feistmantel) Walkom 1917 (AMF4490); and the probable ginkgoaleans, *Ginkgoites simmondsii* (Shirley) Florin 1936 (figured by Seward 1919, fig. 648; and by Ratte 1887, as *"Jeanpaulia palmata"*) and *?Phoenicopsis elongatus* (Morris) Seward 1919 (AMF4489). The genus *"Cycadopteris"* was distinguished by its prominent recurved leaf margin, but is now included within *Pachypteris* (Boureau and Doubinger 1975).

An Australian Museum collection from Wooloomooloo Bay is probably from the Mittagong Formation or basal Ashfield Shale. It includes equisetaleans, *Phyllotheca brookvalensis* Townrow 1956 (AMF4524); sterile fern fronds, *Cladophlebis* (AMF4598); and the pteridosperms, *Dicroidium zuberi* (AMF4597), *Xylopteris elongata* (AMF4523, AMF4514), and *Lepidopteris "stormbergensis"* (Townrow 1966b; AMF4599).

Figure 21.13. Fossil plants from the Wianamatta Group.
A, *Rissikia "media"* (Tenison-Woods) Townrow 1967a, from Clarkes Hill (after McCoy 1847).
B, *Dicroidium odontopteroides* var. *moltenense* Retallack 1977c, from Clarkes Hill (after Feistmantel 1890).
C, *Glossopteris moribunda* Johnston 1887, from Glenlee railway cutting (AMF25325).
D, *"Cycadopteris" scolopendrina* Ratte 1887, from St Peters (after Ratte 1887). All figures natural size.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DICROIDIUM ODONTOPTEROIDES ON A FRESHWATER COASTAL PLAIN
(late Anisian to Ladinian)

The upper part of the Wianamatta Group, above the Ashfield Shale, was deposited in a variety of coastal plain environments (Herbert article 13). Limited marine influence of the upper Ashfield Shale and Minchinbury Sandstone is indicated by glauconite and acritarchs (Mayne et al. 1974). Supposed foraminifera and ostracodes from the Minchinbury Sandstone (Chapman 1909, Lovering 1953) have been reinterpreted as simple and septarian glauconite pellets (Love and Bembrick 1963). The freshwater coastal plain sediments of the overlying Bringelly Shale evidently supported a *Dicroidium* flora. This seems to have been ecologically similar to the preceding *Dicrodium zuberi* flora, but was characterized by new and biostratigraphically important plants, such as *Dicroidium odontopteroides* and *Rissikia "media"* (figure 21.13).

Floras characterized by *Dicroidium odontopteroides* are widespread in Gondwanaland. They probably produced palynomorphs of the upper zonule of the *Aratrisporites parvispinosus* Assemblage of Helby (1973) in the Sydney Basin and the *Duplexisporites problematicus* Assemblage of de Jersey (1975) in southeastern Queensland. Retallack et al. (1977) discussed the detailed correlation of a similar megafossil flora with Aniso-Ladinian floras throughout Gondwanaland. Similar floras are best dated in coal measures underlying Ladinian (Kaihikuan) marine rocks in Tank Gully near Mount Potts, New Zealand (NZGS collections; Arber 1917) and in the Nymboida Coal Measures, both stratigraphically above and below a basalt flow, which has been isotopically dated at 211 m.y. (Retallack et al. 1977).

The supposed "Rhaeto-Liassic" floras of Tasmania, which Townrow (1964) suggested may demonstrate a cool temperate climate, are more likely Anisian to Rhaetian in age (Anderson and Anderson 1970). The climate of Australia was probably becoming warmer at much the same rate as it had since the Early Permian, and does not appear to have become warm temperate until the Jurassic (Bowen 1961).

John Townrow (*in* Love and Bembrick 1963) has identified *Dicroidium "obtusifolium"* (Johnston) Townrow 1966a and equisetalean stems from "a dark red siltstone with coarse bands of reddish sandstone" which "appear whitish due to finely disseminated plant material". These sediments occur immediately above the Minchinbury Sandstone at Cranebrook (GR 708343 Windsor 1:63,360). *Dicroidium "obtusifolium"* is regarded as a variety of *D. odontopteroides* because only "9 out of 10 leaves in a population are definitely identifiable" (Townrow 1966a, p.131). This is the oldest occurrence of a leaf of this kind in the Sydney Basin. I have never seen a definite specimen from older rocks, and assume that records of *Dicroidium odontopteroides* from lower stratigraphic levels (e.g., by Balme and Helby 1973; McElroy 1969, p.400; Dun 1908) were based on outdated specific concepts, such as that of Townrow (1957, which included *Dicroidium lancifolium*) or were misidentified fragments of *"Thinnfeldia" callipteroides* or *Dicroidium zuberi*.

The coastal plain sediments of the Bringelly Shale contain abundant plant megafossils on certain horizons. Some of these figured by McCoy (1847) and Feistmantel (1878, 1890) from Clarkes Hill, near Cobbitty. John Mitchell also collected further material, now in the Australian Museum, from a similar stratigraphic horizon in the Razorback Range. This flora includes the likely gleicheniaceous fern *"Odontopteris microphylla"* McCoy 1847 (very similar to *Gleichenites gleichenoides* (Oldham and Morris) Seward and Sahni 1920); the pteridosperms, *Dicroidium odontopteroides* var. *moltenense* Retallack 1977c (figure 21.13B), *D. dubium* var. *dubium* (Feistmantel) Gothan 1912 (Feistmantel 1890, pl.26, fig. 3), and *D. zuberi;* and the conifer *Rissikia "media"* (figure 21.13A). McCoy's (1847) specimen of *"Pecopteris" tenuifolia* should be re-examined carefully to see whether it is indeed a senior synonym of *Rissikia "media"*. *Dicroidium zuberi* at this level is generally smaller than in older rocks of the Sydney Basin, and includes varieties *feistmantelii* (Johnston) Retallack 1977c (Feistmantel 1890, pl.26, fig. 3) and *sahnii* (Seward) Retallack 1977c (AMF48164 from the Razorback Range).

At the turn of the century, John Mitchell also collected a diverse megafossil flora (now in the Australian Museum) from a railway cutting near Glenlee, at a stratigraphic horizon about 20 m above the base of the Bringelly Shale (C. Herbert pers. comm. 1976). Among his more interesting finds were some leaves indistinguishable from the type, which I have seen, of *Glossopteris moribunda* Johnston 1887, from the Triassic of Tasmania (figure 21.13C). Many authors have found similar leaves with *Dicroidium* floras (Srivastava 1969, 1971, Du Toit 1927, Plumstead 1969, Anderson and Anderson 1970, Walkom 1928a, Flint and Gould 1975, Hill et al. 1965). These leaves form a relatively conservative group with many characters in common : a midrib tapering to a single vein at the apex; undulose or irregularly lobed margins; slight asymmetry; a laterally curved midrib; secondary venation arising from the midrib at an acute angle; and more numerous, narrower vein meshes towards the leaf margin. All these features and others discussed by Thomas (1952) indicate that it is a *Glossopteris* leaf, rather than *Sagenopteris*, *Anthrophyopsis*, or *Mexiglossa* (as understood by Frenguelli 1941, Doludenko and Svanidze 1970, Harris 1932, Delevoryas and Person 1975). The available evidence suggests that a single conservative lineage of glossopterid plants survived into the Middle Triassic in Gondwanaland.

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