K-AR DATED PALYNOFLORAS IN TASMANIA 1: EARLY OLIGOCENE, *PROTEACIDITES TUBERCULATUS* ZONE SEDIMENTS, WILMOT DAM, NORTHWESTERN TASMANIA

by M.K. Macphail & R.S. Hill

(with two tables, five plates, three text-figures and an appendix)

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https://doi.org/10.26749/rstpp.128.1 ISSN 0080-4703. Department of Geography, University of Newcastle, Newcastle, New South Wales, Australia 2308 (MKM); Department of Plant Science, University of Tasmania, GPO Box 252C, Hobart, Tasmania, Australia 7001 (RSH).

Tertiary lake sediments at Wilmot Dam, northwestern Tasmania, are dated as Lower *Proteacidites tuberculatus* Zone, based on the palynological zonation developed for the Gippsland Basin in eastern Bass Strait. The age limits of Early–Middle Oligocene for this zone are in excellent agreement with a K/Ar date of 26.7 Ma for basalts capping this deposit. Three new species are described: *Tricolpites stylidioides*, *Mutisiapollis patersonii* and *Periporopollenites hexaporus*. The first two appear to be the earliest records to date of Stylidiaceae and *Mutisia* (Asteraceae: tribe Mutisieae) respectively.
Key Words: palynofloras, Oligocene, Stylidiaceae, *Mutisia*, Trimeniaceae, Tasmania.

INTRODUCTION

The palynological zonation scheme developed for the Gippsland Basin by Stover & Partridge (1973) has become widely used to date sediments elsewhere in Australia — to the extent that the individual zones, such as the Oligocene–late Early Miocene *Proteacidites tuberculatus* Zone, have become informal Stage names for the Australian Tertiary.

The criteria defining the zone boundaries, however, have had to be adapted from region to region to take account of known or suspected diachronism in the times of first appearance and extinction of zone "index" species. With few exceptions, this reflects variation in environmental forcing factors operating on the local to regional scale (see Macphail *et al.* 1994).

Widespread Tertiary volcanism has allowed a number of palynofloras in eastern Australia to be independently dated using Potassium/Argon (K/Ar), although in most situations this provides only a maximum or minimum age limit (e.g. Owen 1988, Pickett *et al.* 1990, Taylor *et al.* 1990, Macphail *et al.* 1991). Sutherland & Wellman (1986) have reviewed K/Ar dated volcanic rocks in Tasmania. This paper is the first in a series using a K/Ar dated palynoflora to assess the reliability of the Stover & Partridge Gippsland Basin zonation as a method for dating non-marine sediments in Tasmania.

The sequence we analyse comes from the Wilmot Dam site in the Moina area of northwestern Tasmania (fig. 1). Here K/Ar dating confirms not only the *P. tuberculatus* Zone date for a buried channel deposit but also provides independent age control on glaciation of the adjacent upper Forth Valley during the late Paleogene (Macphail *et al.* 1993a). Three new fossil pollen species are described: *Tricolpites stylidioides, Mutisiapollis patersonii* and *Periporopollenites hexaporus* (appendix 1). Three other palynomorphs that may prove to be useful for identifying *P. tuberculatus* Zone palynofloras in Tasmania are illustrated: *Tetrapollis campbellbrownii*, *Pesavis* sp. cf. *P. tagluensis* and a distinctive but undescribed fungal fruiting body (pl. 1, M–P, see page 7).

GEOLOGICAL SETTING

Moina is located in an area of low, rugged interfluve ridges between the northwestern escarpment of the Central Plateau and Black Bluff Range. The region is geologically complex due to (1) partial stripping of subhorizontal Jurassic dolerites, exposing the underlying strongly folded and faulted pre-Carboniferous basements rocks, and (2) infilling of the incised drainage lines with basalt during the late Tertiary (Rawlings 1967). The latter is responsible for the preservation of Tertiary deposits at Wilmot Dam, located on the Wilmot River just below the junction of the Lea and Isis Rivers (fig. 1).

Here, Tertiary fluvio-lacustrine sediments accumulated in and spilt over from a trough bounded by sets of NNW- and WNW-trending faults within the Ordovician Gordon Limestone and Moina Sandstone basement (fig. 1). Drilling by the Hydro-Electric Commission of Tasmania (HEC) suggests that movement along these faults created a system of lakes in which some 62 m of gravel, sands and clays accumulated during the Tertiary. Lacustrine sedimentation was followed by volcanic activity which buried the area under basaltic breccia and basalt flows (Paterson 1967, Rawlings 1967).

SAMPLES

The samples analysed in this study come from HEC drill hole 4558 drilled in 1965 by the HEC, close to the western margin of the trough where c. 26 m of Tertiary sediments underlie c. 20 m of volcanics (fig. 2).

Two samples of basalt were submitted to K. Henley, Amdel Ltd, South Australia: 43 ft (13.1 m) [TSC58500], a porphyritic olivine basalt with small (1–1.5 mm) phenocrysts of olivine and plagioclase in a holocrystalline groundmass of plagioclase, pyroxene and Fe/Ti oxides; and 63 ft (19.2 m) [TSC58501], a rock similar to the above, except that much of the groundmass consisted of partly

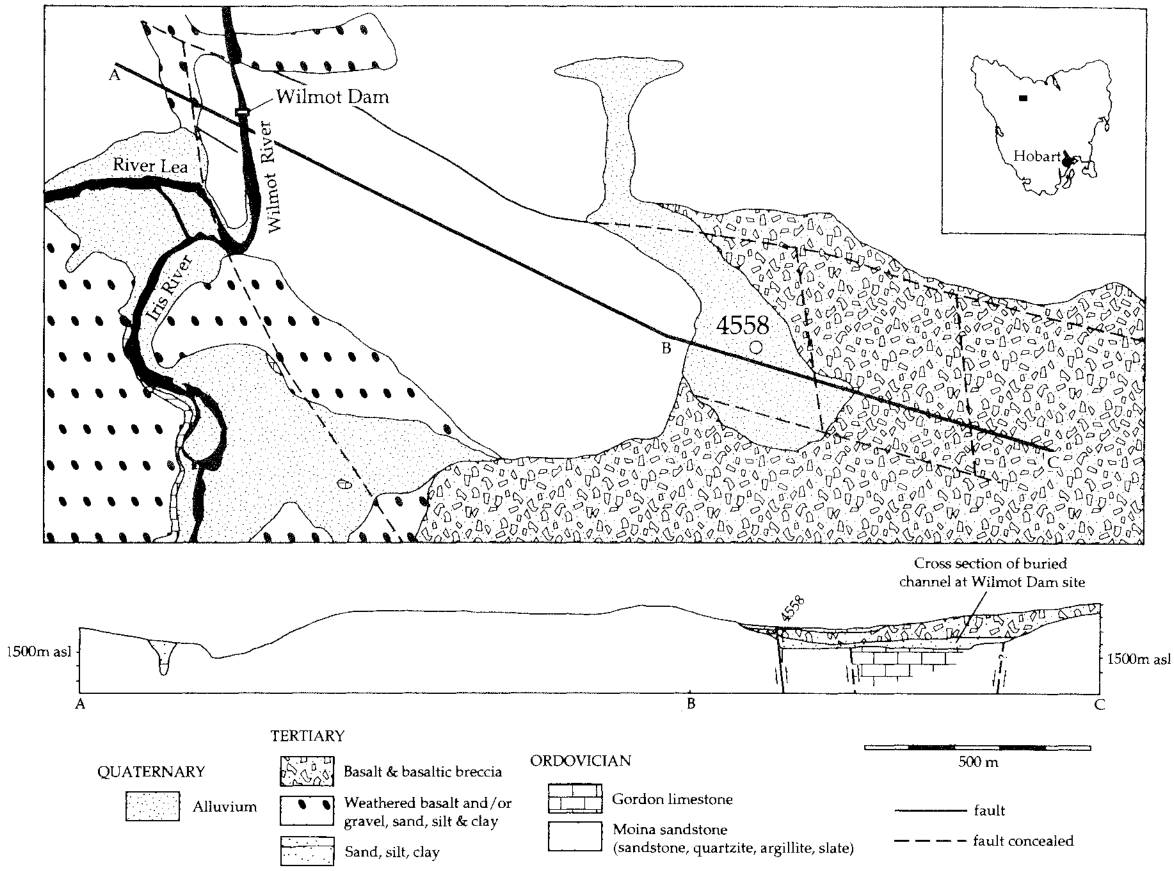

FIG. 1 — Simplified geology of the Wilmot Dam site (after Paterson 1967).

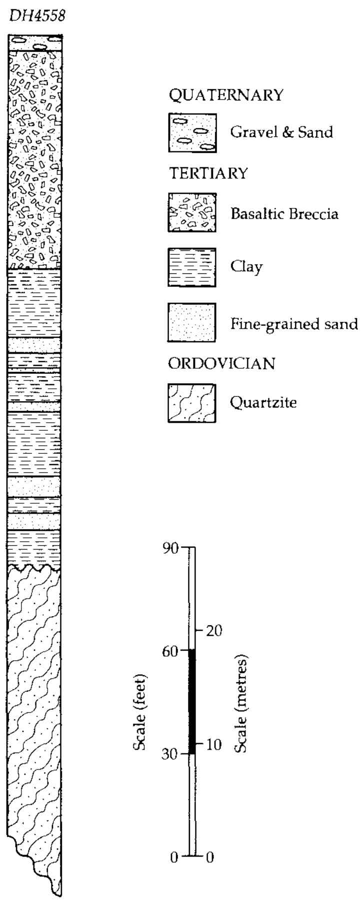

FIG. 2 — Lithostratigraphy of DH 4558 (after Paterson 1967).

devitrified glass. Only the former was considered suitable for K/Ar dating.

Two samples were processed for fossil palynomorphs by K. Weiss, Laola Pty Ltd, Perth: 70 ft (21.3 m), which yielded abundant, well-preserved fossil spores, pollen and cysts of a freshwater dinoflagellate, and 77.5 ft (23.6 m), which yielded moderate numbers of less well-preserved spores and pollen. Age diagnostic and a representative selection of other species are illustrated in plates 1–5: new species are described in appendix 1.

AGE DETERMINATIONS

Potassium/Argon

Apart from patches of a yellow, weakly anisotropic alteration product making up less than 3–5% of the groundmass, the basalt sample at 13.1 m was assessed as fresh and, therefore, able to be dated with an acceptable level of reliability by K/Ar (Amdel Report G6809/93).

Potassium and argon analyses and calculated age are given in table 1. The date of 26.7 Ma approximates to the Middle/Late Oligocene, based on currently accepted boundaries of 35.4 Ma and 23.3 Ma for the Epoch as a whole (Harland *et al.* 1990).

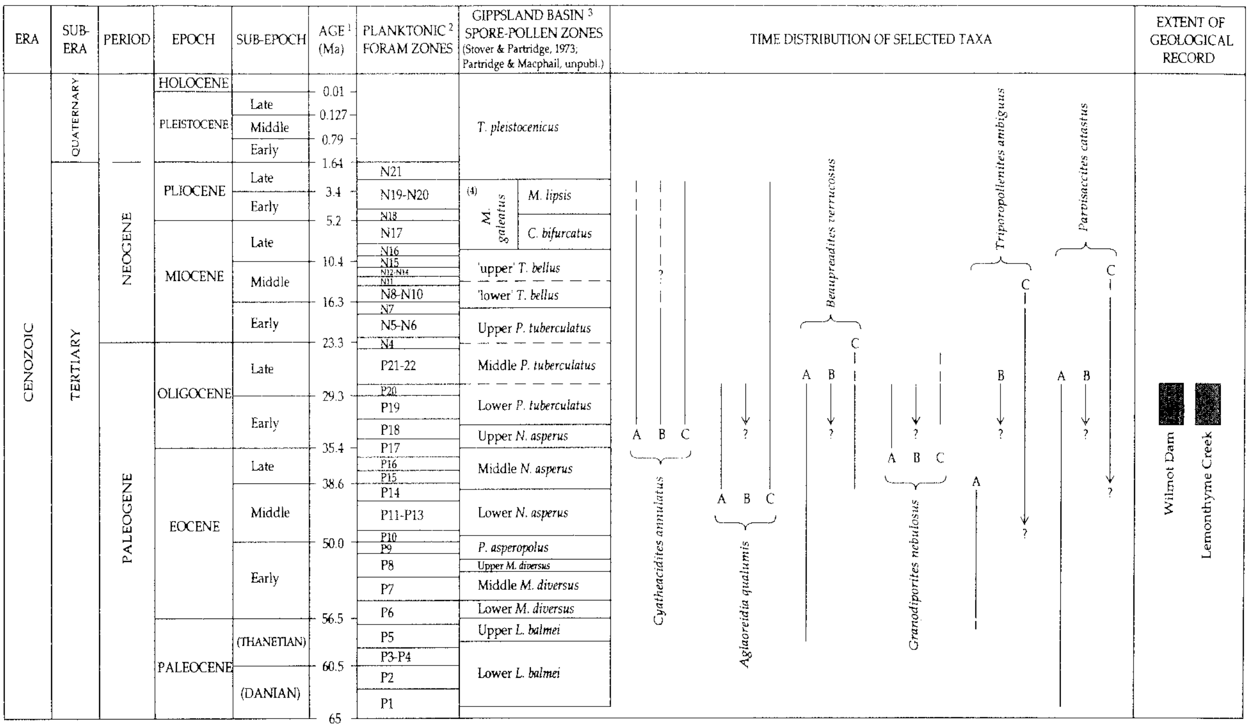

FIG. 3 — Time distribution of age-diagnostic taxa in (A) Gippsland Basin, (B) northwestern Tasmania and (C) Murray Basin, southeastern Australia, shown against the Cenozoic time scale of Harland et al. *(1990). 1, 2 = calibration of Stage boundaries and correlation of planktonic foraminiferal biozones based on Harland* et al. *(1990). 3 = correlation of Gippsland Basin palynological zones against planktonic foraminiferal biozones prepared by A.D. Partridge (8th May 1993). 4 = Murray Basin (Macphail & Truswell, pers. obs.).*

Palynostratigraphy

The stratigraphic distribution of fossil spores and pollen in samples at 21.3 m and 23.6 m is given in table 2. The time distributions of key taxa are shown in figure 3.

Occurrences of *Cyatheacidites annulatus* in both samples provide a reliable lower age limit of Early Oligocene, *Proteacidites tuberculatus* Zone age for sediments near the top of the lacustrine infill (Stover & Partridge 1973). The upper age limit is Lower *P. tuberculatus* Zone, based on multiple occurrences of *Aglaoreidia qualumis, Beaupreaidites verrucosus, Granodiporites nebulosus, Triporopollenites ambiguus* and *Parvisaccites catastus* (pl. 1, A–L).

Species which first appear in the Gippsland Basin within the Early Miocene, Upper *P. tuberculatus* Zone, e.g. *Acacia-pollenites myriosporites*, and overlying late Early–Late Miocene, *Triporopollenites bellus* Zone, e.g. *Canthiumidites* (al. *Triporopollenites*) *bellus, Symplocoipollenites austellus* and *Rugulatisporites cowrensis*, are absent.

TABLE 1
K/Ar analyses

Sample	%K	$^{40}Ar^*$ ($\times 10^{-11}$moles/g)	$^{40}Ar^*/^{40}Ar_{total}$	Age†
13.1 m	0.7348	3.4618	0.634	26.7 ± 0.3

* Denotes radiogenic ^{40}Ar.
† Age in Ma with error limits given for the analytical uncertainty at one standard deviation.

DISCUSSION

The lake sediments are older than the dated basalt and, therefore, all or part of the Lower *P. tuberculatus* Zone in northwestern Tasmania is older than 26.7 Ma.

As for other sites in northwestern Tasmania (Hill & Macphail 1983, Macphail *et al.* 1991), the Wilmot Dam palynofloras include a number of species whose time ranges do not overlap in the Gippsland Basin. Examples are: (1) *Chenopodipollis chenopodiaceoides* and (21.3 m) *Foveo-triletes lacunosus*, two of the species whose first appearance defines the lower boundary of the Middle *P. tuberculatus* Zone, and (2) *Tricolpites simatus* and (23.6 m) *Triporo-pollenites ambiguus*, species which range no higher than the Late Eocene, Middle *Nothofagidites asperus* Zone.

TABLE 2
Stratigraphic distribution of fossil spores and pollen at Wilmot Dam and Lemonthyme Creek

Fossil species	Wilmot Dam DDH 4558	Lemonthyme DDH 5825		Modern analogue
	21.3 m	23.6 m	20.1–45.3 m	
(a) Algae				
Pseudoschizea circula	-	+	+	indet. soil? algae
Saeptodinium sp.	1	-	3	Freshwater dinoflagellate
(b) Fungi				
Pesavis cf. *tagluensis*	-	+	+	indet. fungus
Unidentified sporae dispersae	-	-	+	indet. fungus
(c) Ferns & Fern Allies				
Baculatisporites disconformis	+	+	2	Liverworts
Bryosporis anisopolaris	-	-	+	Mosses
Cyatheacidites annulatus	+	+	+	*Lophosoria quadrapinnata*
Cyathidites australis	+	+	1	ground ferns
Cyathidites paleospora	+	+	-	Cyatheaceae
Cyathidites splendens	+	-	+	*Acrostichum*?
Dictyophyllidites arcuatus	+	-	-	Gleicheniaceae
Foveotriletes balteus	+	+	+	Lycopodiaceae
Foveotriletes lacunosus	+	-	-	*Lycopodium varium*-type
Foveotriletes palaequetrus	+	-	+	*Lycopodium australium*-type
Gleicheniidites spp.	+	-	+	Gleicheniaceae
Herkosporites elliotii	+	-		*Lycopodium deuterodensum*-type
Ischyosporites-Triletes complex	10	15	+	indet. lycopsids
Laevigatosporites spp.	2	2	1	Blechnaceae?
Latrobosporites crassus	+	-	+	indet. lycopsid
Latrobosporites marginis	+	+	+	*Lycopodium laterale*-type
Matonisporites ornamentalis	+	+	1	Dicksoniaceae
Osmundacites sp.	-	+	-	Osmundaceae?
Peromonolites densus	-	-	+	Blechnaceae?
P. vellosus	+	-	-	Blechnaceae?
Polypodiisporites histiopteroides	-	+	-	*Histiopteris*
Reticuloidaesporites spp.	+	3	+	indet. fern
Retitriletes australoclavatidites	+	+	+	Lycopodiaceae
Rugulatisporites mallatus	-	-	+	*Culcita dubia*-type
Stereisporites australis	+	+	1	*Sphagnum*
Verrucosisporites cristatus	+	+	+	indet. lycopsid?
Verrucosisporites kopukuensis	+	+	+	indet. lycopsid?
(d) Gymnosperms				
Araucariacites australis	2	5	1	Araucariaceae
Cupressaceae-Taxodiaceae	6	3	1	Cupressaceae-Taxodiaceae
Dacrycarpites australiensis	+	3	2	*Dacrycarpus*
Dilwynites granulatus	+	+	+	Araucariaceae
Lygistepollenites florinii	2	+	1	*Dacrydium* Group B spp.
Microalatidites paleogenicus	1	+	+	*Phyllocladus*
Microcachrydites antarcticus	+	+	1	*Microcachrys*
Parvisaccites catastus	+	+	-	*Dacrydium bidwillii*-type
Phyllocladidites mawsonii	8	10	17	*Lagarostrobos franklinii*
Podocarpidites spp.	6	12	12	*Podocarpus/Dacrydium*
Podosporites erugatus	+	-	+	*Microstrobos*
P. parvus	2	1	3	*Microcachrys*?
P. microsaccatus	-	+	-	indet. Podocarpaceae
Trichotomosulcites subgranulosus	-	+	-	indet. Podocarpaceae
(e) Angiosperms				
Aglaoreidia qualumis	+	+	-	Sparganiaceae/Typhaceae
Banksieaeidites elongatus	-	+	-	*Banksia*
Beaupreaidites elegansiformis	+	+	+	*Beauprea*
B. verrucosus	+	+	+	*Beauprea*
Chenopodipollis chenopodiaceoides	+	+	+	Chenopodiaceae
Clavatipollenites glarius	-	-	+	*Ascarina*
Cupanieidites orthoteichus	+	-	+	Sapindaceae (Cupanieae)
Cyperaceaepollis neogenicus	+	+	-	Cyperaceae
Dodonaea triquetra-type	+	+	-	*Dodonaea triquetra*
Droseraceae	+	-	+	Droseraceae
Dryadopollenites retequetrus	+	-	-	indet. angiosperm
Ericipites crassiexinus	-	+	-	Ericales
E. scabratus	+	3	+	Ericales
Gothanipollis cf. *bassensis*	+	+	+	Loranthaceae
G. cf. *gothanii*	+	+	+	Loranthaceae

cont.

Fossil species	Wilmot Dam DDH 4558	Lemonthyme DDH 5825		Modern analogue
	21.3 m	23.6 m	20.1–45.3 m	
G. perplexus	-	-	+	Loranthaceae
Granodiporites nebulosus	+	+	+	*Embothrium*
Gyropollis psilatus	-	-	+	Gyrostemonaceae
Haloragacidites harrisii-Casuarinidites cainozoicus	1	4	3	Casuarinaceae
Ilexpollenites anguloclavatus	-	+	+	*Ilex*
Liliacidites lanceolatus	+	+	+	Liliaceae
Malvacipollis spinyspora	+	+	+	*Micrantheum*
M. subtilis	+	+	+	*Austrobuxus*
Margocolporites cf. *scaboratus*	+	-	-	indet. angiosperm
Milfordia homeopunctatus	+	-	-	Restionaceae
M. hypolaenioides	+	+	-	Restionaceae
Mutisiapollis patersonii	+	+	+	*Mutisia*
Myrtaceidites parvus-mesonesus	1	+	+	Myrtaceae (not *Eucalyptus*)
Nothofagidites asperus	1	+	3	*Nothofagus* (*Lophozonia*)
N. brachyspinulosus	5	5	4	*Nothofagus* (*Fuscospora*)
N. deminutus-vansteenisii	+	+	2	*Nothofagus* (*Brasssopora*)
N. emarcidus-heterus	37	24	29	*Nothofagus* (*Brassospora*)
N. falcatus	+	+	+	*Nothofagus* (*Brassospora*)
N. flemingii	2	1	6	*Nothofagus* (*Nothofagus*)
N. goniatus	-	-	+	*Nothofagus* (*Lophozonia*?)
Palaeocoprosmadites zelandiae	-	+	-	*Coprosma/Opercularia*
pentacolporate sp.	+	+	-	Meliaceae?
Periporopollenites demarcatus	+	-	+	Trimeniaceae?
P. hexaporus	+	+	+	Trimeniaceae?
P. vesicus	1	+	+	Trimeniaceae?
Polyorificites oblatus	+	-	+	indet. angiosperm
Proteacidites adenanthoides	-	-	+	*Adenanthos*?
P. annularis	-	-	+	*Xylomelum*
P. obscurus	+	+	+	*Agastachys*-type
P. latrobensis	+	-	+	indet. Proteaceae
P. pseudomoides	+	-	+	indet. Proteaceae
P. reticuloscabratus	-	-	+	*Gevuina/Hicksbeachia*
P. scaboratus	+	+	+	*Macadamia*-type
Proteacidites spp.	3	4	3	Proteaceae
Pseudowinterapollis cranwellae	+	-	+	*Tasmannia*
Quintiniapollis psilatispora	+	-	+	*Quintinia*
Retistephanocolpites sp. aff. *Callitriche*	-	+	-	Callitichaceae
Rhoipites sp. cf. *Muehlenbeckia*	+	+	-	*Muehlenbeckia*
Sapotaceoidaepollenites latizonatus	+	+	+	Sapotaceae
S. rotundus	-	-	+	Sapotaceae
Sparganiaceaepollenites sphericus	+	+	-	Sparganiaceae
Stephanocolpites oblatus	+	+	-	*Haloragodendron*
S. sphericus	-	-	+	indet.
Striasyncolpites laxus	-	-	+	Menyanthaceae
Tetracolporites palynius	+	+	-	*Ixerba*?
Tricolpites reticulatus	+	-	+	*Gunnera*
T. simatus	+	+	+	Loranthaceae
T. stylidioides	+	+	+	Stylidiaceae
T. trioblatus	+	+	+	Scrophulariaceae
Tricolpites spp.	+	+	+	indet. angiosperms
Tricolporites cf. *adelaidensis*	+	+	+	indet. angiosperm
Tricolporites leuros	-	-	+	indet. angiosperm
T. microreticulatus	+	+	-	indet. angiosperm
T. paenestriatus	+	-	-	indet. angiosperm
Tricolporites spp.	3	+	3	indet. angiosperms
Tetrapollis campbellbrownii	+	-	-	Haloragaceae?
Triporopollenites ambiguus	-	+	+	*Telopea* — type
T. sp. cf. *T. chnosus*	+	+	+	indet. Proteaceae
Pollen sum	492	355	393	

Relative abundance values expressed as a percentage of the total identifiable pollen and spore count (excluding algae, fungi and liverworts). Percentages less than 1% are given as +.

This almost certainly reflects differences in topography, local climate and depositional environment between the deeply incised, moderate to high plateaux, characteristic of northwestern Tasmania, and the Gippsland Basin, which was a low-lying coastal plain, backed by extensive freshwater peat swamps in the Latrobe Valley Depression (Sluiter & Kershaw 1982, Holdgate & Sluiter 1991) and, as now, open to the Tasman Sea to the southeast.

Nevertheless, the palynological age determination of Lower *P. tuberculatus* Zone is in excellent agreement with both the K/Ar date of 26.7 Ma and Stover & Partridge's conclusion (1973: 243–244) that the top of the Middle *P. tuberculatus* Zone approximates to the Oligocene–Miocene boundary. We conclude, therefore, that the criteria proposed by Stover & Partridge (1973) are a reliable method for dating strata of Oligocene, *P. tuberculatus* Zone age in Tasmania. Some uncertainty still exists regarding strata of Early Miocene, *P. tuberculatus* Zone age, since the earliest record to date of any index species of the overlying *T. bellus* Zone is Late Pliocene — *Symplocoipollenites austellus* at Linda Valley, western Tasmania (Macphail *et al.*, in prep.).

The Wilmot Dam palynofloras are virtually identical in composition to fossil assemblages recovered from a 34 m thick sequence of laminated clays and silts overlying a tillite at Lemonthyme Creek in the adjoining Forth Valley (Paterson *et al.* 1967). Age-diagnostic species common to both deposits include *Cyatheacidites annulatus, Beaupreaidites verrucosus, Granodiporites nebulosus, Parvisaccites catastus* and *Triporopollenites ambiguus* (table 2).

Reinforcing the impression that the deposits are coeval are occurrences of two new species (appendix 1) that appear to be restricted to *P. tuberculatus* Zone palynofloras in Tasmania: *Periporopollenites hexaporus* and *Mutisiapollis patersonii.* Other distinctive shared taxa include Droseraceae and *Tricolpites stylidioides* (pls 1, 2).

Basalts associated with the Lemonthyme deposit are unsuitable for K/Ar dating and, based on spore-pollen evidence alone, Macphail *et al.* (1993a) concluded that the tillite was most probably Early Oligocene and highly unlikely to be younger than Late Oligocene. This makes the (local) glaciation responsible for deposition of the tillite the oldest recorded to date, outside of Antarctica during the Cenozoic. The Early–Middle Oligocene date for the Wilmot Dam palynosequence supports and strengthens this conclusion.

The latest Eocene–earliest Oligocene is widely seen as a critical period in the history of Cenozoic global cooling, and a significant number of tree and shrub taxa that had been typical of Eocene megatherm–mesotherm rainforest in the Bass Strait region did not survive into Oligocene time (Macphail *et al.* 1994). Nevertheless, it is equally clear from sites such as Wilmot Dam and Lemonthyme Creek that the Tasmanian flora continued to be enriched by new species, either through continued differentiation of the original Gondwanic stock in Australia or through long-distance dispersal, probably via Antarctica.

It is tempting to speculate that the former (autochthonous) group includes *Periporopollenites hexaporus,* possibly derived from the same Trimeniaceaen stock as *P. demarcatus,* which first apppears in southeastern Australia during the Maastrichtian. The first appearance of *Mutisiapollis patersonii* and *Tricolpites stylidioides* are more likely to be due to long-distance dispersal via Antarctica for two reasons. Firstly, both taxa include modern representatives in South America (Mabberley 1989). Secondly, palaeogeographic evidence (Veevers *et al.* 1991) shows that, during the Early Oligocene, Tasmania was a mountainous peninsula at about latitude 55°–63°, separated from Antarctica by the circum-Antarctic Ocean. Both appear to be the oldest fossil records to date of these taxa (compare Muller 1981).

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PLATE 1

Age-diagnostic taxa. All photomicrographs ×1250 unless otherwise stated. Scale bar A = 25 µm; scale bar B = 50 µm.

Cyatheacidites annulatus *Cookson, 1947, × 788. (A) Lemonthyme DH 5825 at 31.1 m,* P. tuberculatus *Zone; (B) Lemonthyme DH 5802 at 46 m,* P. tuberculatus *Zone; (C) Lemonthyme DH 5825 at 30.8 m,* P. tuberculatus *Zone; (D) Lemonthyme DH 5825 at 24.7 m,* P. tuberculatus *Zone.*

Parvisaccites catastus *Stover & Partridge, 1973. (E) Wilmot Dam DH 4558 at 21.3 m,* P. tuberculatus *Zone.*

Granodiporites nebulosus *Stover & Partridge, 1973. (F) Wilmot Dam DH 4558 at 23.6 m,* P. tuberculatus *Zone; (G) as above, phase contrast showing scattered granulae.*

Triporopollenites ambiguus *Stover & Partridge, 1973. (H) Lemonthyme DH 5825 at 45.3 m,* P. tuberculatus *Zone.*

Beaupreaidites verrucosus *Cookson, 1950. (I) Wilmot Dam DH 4558 at 23.6 m,* P. tuberculatus *Zone; (J) Lemonthyme DH 5825 at 30.1 m,* P. tuberculatus *Zone phase contrast; (K) Lemonthyme DH 5825 at 39.9 m,* P. tuberculatus *Zone phase contrast.*

Aglaoreidia qualumis *Stover & Partridge, 1973. (L) Wilmot Dam DH 4558 at 23.6 m,* P. tuberculatus *Zone.*

Tetrapollis campbellbrownii *Macphail & Truswell, 1993. (M) Wilmot Dam DH 4558 at 21.3 m,* P. tuberculatus *Zone; (N) as above, phase contrast showing grooved nexine around pores.*

Pesavis *sp. cf.* P. tagluensis *(Elsik & Jansonius, 1974); × 788; (O) Lemonthyme DH 5825 at 29.3 m,* P. tuberculatus *Zone; unidentified Fungi Sporae Dispersae; × 788; (P) Lemonthyme DH 5825 at 31.1 m,* P. tuberculatus *Zone.*

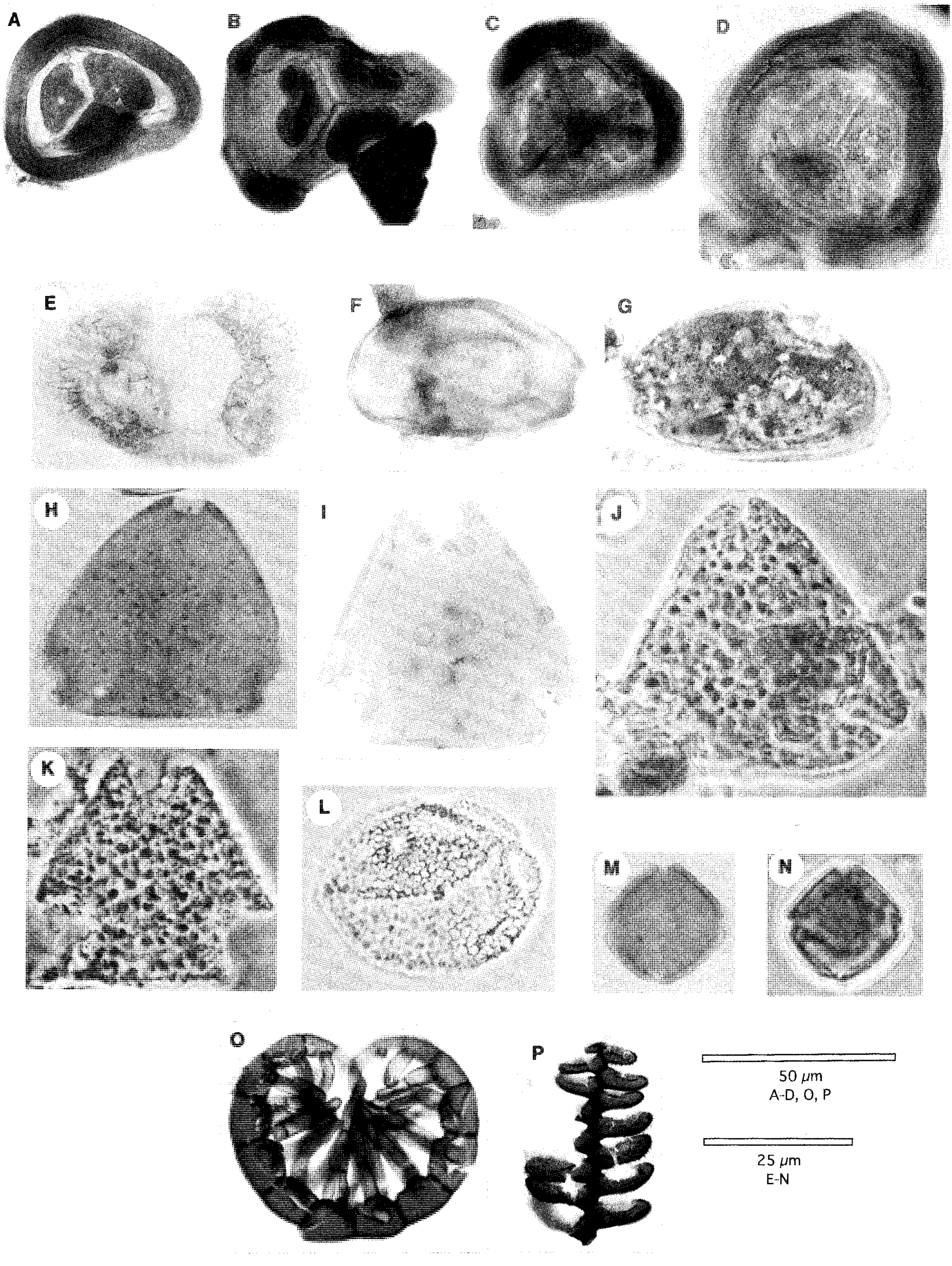

PLATE 1

REFERENCES

ELSIK, W.C. & JANSONIUS, J., 1974: New genera of Paleogene fungal spores. *Can. J. Bot.* 52: 953–958.

ERDTMAN, G., 1966: *POLLEN MORPHOLOGY AND PLANT TAXONOMY: ANGIOSPERMS.* Hafner Publishing Co., New York: 553pp.

HARLAND, W.B. & FIVE CO-AUTHORS, 1990: *A GEOLOGIC TIME SCALE 1989.* Cambridge University Press, Cambridge: 263 pp.

HEUSSER, C.J., 1971: *POLLEN AND SPORES OF CHILE.* University of Arizona Press, Tucson: 167 pp.

HILL, R.S. & MACPHAIL, M.K., 1983: Reconstruction of the Oligocene vegetation at Pioneer, north-east Tasmania. *Alcheringa* 7: 281–289.

HOLDGATE, G.R. & SLUITER, I.R., 1991: Oligocene–Miocene marine incursions in the Latrobe Valley depression, onshore Gippsland Basin: evidence, facies relationships and chronology. *Geol. Soc. Aust. Spec. Publ.* 18: 137–157.

MABBERLY, D.J., 1989: *THE PLANT BOOK.* Cambridge University Press, Cambridge: 706 pp.

MACPHAIL, M.K. & TRUSWELL, E.M., 1993: Appendix 1. Taxonomic, phytogeographic and biostratigraphic notes on selected species. *AGSO J. Aust. Geol. Geophys.* 14: 61–63.

MACPHAIL, M.K., HILL, R.S., FORSYTH, S.M. & WELLS, P.M., 1991: A Late Oligocene–Early Miocene cool climate flora in Tasmania. *Alcheringa* 15: 87–106.

MACPHAIL, M.K. , COLHOUN, E.A., KIERNAN, K. & HANNAN, D., 1993a: Glacial climates in the Antarctic region during the Late Paleogene: evidence from northwest Tasmania, Australia. *Geology* 21: 145–148.

MACPHAIL, M.K., JORDAN, G.J. & HILL, R.S., 1993b: Key periods in the evolution of the Cenozoic flora and vegetation of Tasmania 1: the Early–Middle Pleistocene. *Aust. J. Bot.* 41: 673–707.

MACPHAIL, M.K., FITZSIMONS, S. & COLHOUN, E.A., in prep.: Key periods in the evolution of the Cenozoic flora and vegetation of Tasmania 2: the Late Pliocene.

MACPHAIL, M.K., ALLEY, N., TRUSWELL, E.M. & SLUITER, I.R. 1994: Early Tertiary vegetation: evidence from spores and pollen. *In* Hill, R.S. (Ed.): *HISTORY OF THE AUSTRALIAN VEGETATION: CRETACEOUS TO RECENT.* Cambridge University Press, Cambridge: 189–261.

MULLER, J., 1981: Fossil pollen records of extant angiosperms. *Bot. Rev.* 47: 1–142.

OWEN, J.A.K., 1988: Miocene palynomorph assemblages from Kiandra, New South Wales. *Alcheringa* 12: 269–297.

PARTRIDGE, A.D., 1978: Palynology of the Late Tertiary sequence at Site 356, Leg 40, Deep Sea Drilling Project. *Initial Rep. Deep Sea Drilling Proj.* 40: 953–961.

PATERSON, S.J., 1967: Tertiary deep lead deposits in the Moina area. *Pap. Proc. R. Soc. Tasm.* 101: 251–260.

PATERSON, S.J., DUIGAN, S.L. & JOPLIN, G.A., 1967: Notes on the Pleistocene deposits at Lemonthyme Creek in the Forth Valley. *Pap. Proc. R. Soc. Tasm.* 101: 221–225.

PICKETT, J.W. & FIVE CO-AUTHORS, 1990: A stratigraphic evaluation of Ettinhausen's New England Tertiary plant localities. *Aust. J. Earth Sci.* 37: 293–303.

RAWLINGS, G.E., 1967: Sub-basaltic sediments and metasediments of the Mersey–Forth area. *Pap. Proc. R. Soc. Tasm.* 101: 267–270.

SKVARLA, J.J., TURNER, B.L., PATEL, V.C. & TOMB, A.S., 1977: Pollen morphology in the Compositae and morphologically related families. *In* Heywood, V.H., Harbourne, J.B. & Turner, B.L. (Eds): *THE BIOLOGY AND CHEMISTRY OF THE COMPOSITAE.* Academic Press, London: 141–241.

SLUITER, I.R. & KERSHAW, A.P., 1982: The nature of Late Tertiary vegetation in Australia. *Alcheringa* 6: 211–222.

STIX, E., 1960: Pollenmorphologische untersuchungen and Compositae. *Grana palynol.* 2: 41–114.

STOVER, L.E. & PARTRIDGE, A.D., 1973: Tertiary and Late Cretaceous spores and pollen from the Gippsland Basin, southeastern Australia. *Proc. R. Soc. Vict.* 85: 237–286.

SUTHERLAND, F.L. & WELLMAN, P., 1986: Potassium–Argon ages of Tertiary volcanic rocks, Tasmania. *Pap. Proc. R. Soc. Tasm.* 120: 77–86.

TAYLOR, G., TRUSWELL, E.M., MCQUEEN, K.G. & BROWN, M.C., 1990: Early-Tertiary palaeogeography, landform evolution and palaeoclimates of the Southern Monaro, N.S.W., Australia. *Palaeogeogr., Palaeoclimatol. Palaeoecol.* 78: 109–134.

THOMPSON, P.W. & PFLUG, H., 1953: Pollen und sporen des mitteleuropäischen Tertiärs. *Palaentol. graphica* Abt B, 94: 1–138.

TRUSWELL, E.M. & MARCHANT, N.G., 1986: Early Tertiary pollen of probable Droseracean affinity from Central Australia. *Spec. Pap. Palaeontol.* 35: 163–178.

VEEVERS, J.J., POWELL, C.MCA. & ROOTS, S.R., 1991: Review of seafloor spreading around Australia. 1. Synthesis of patterns of spreading. *Aust. J. Earth Sci.* 38: 373–389.

(accepted 1 June 1993)

PLATE 2

New species. All photomicrographs ×1250 unless otherwise stated. Scale bar A = 25 µm; scale bar B = 50 µm.

Tricolpites stylidioides *n. sp. (A–D) Holotype at three focal planes; equatorial view; figure 4 phase contrast — Lemonthyme DH 5825 at 36.6 m,* P. tuberculatus *Zone; (E) paratype; polar view of unusually small specimen — Lemonthyme DH 5825 at 36.6 m,* P. tuberculatus *Zone; (F) paratype; equatorial view — Lemonthyme DH 5825 at 31.1 m,* P. tuberculatus *Zone; (G) specimen showing mesocolpial thickening of nexine — Lemonthyme DH 5825 at 31.1 m,* P. tuberculatus *Zone; (H) specimen showing irregular margins of colpi — Wilmot Dam DH 4558 at 23.6 m,* P. tuberculatus *Zone; (I) specimen showing strongly thickened nexine at poles — Lemonthyme DH 5825 at 31.1 m,* P. tuberculatus *Zone; (J) unusually large oblate specimen (crushed) — Lemonthyme DH 5802 at 46 m,* P. tuberculatus *Zone.*

Mutisiapollis patersonii *n. sp. (K–N) Holotype at three focal planes; equatorial view; figure 14 phase contrast — Lemonthyme DH 5825 at 30.8 m,* P. tuberculatus *Zone; (O–P) oblique polar view; figure 14 phase contrast showing puncto-reticulate tectum — Lemonthyme DH 5825 at 36.6 m,* P. tuberculatus *Zone; (Q–R) equatorial view at two focal planes of a grain showing an undulating, micro-echinate tectum in which the puncta have joined to form fossulae; (S) equatorial view of small specimen with unusually well-developed micro-echinate sculpture — Lemonthyme DH 5825 at 33.5 m,* P. tuberculatus *Zone; (T) Wilmot Dam DH 4558 at 21.3 m,* P. tuberculatus *Zone; (U) Lemonthyme DH 5825 at 39.9 m,* P. tuberculatus *Zone.*

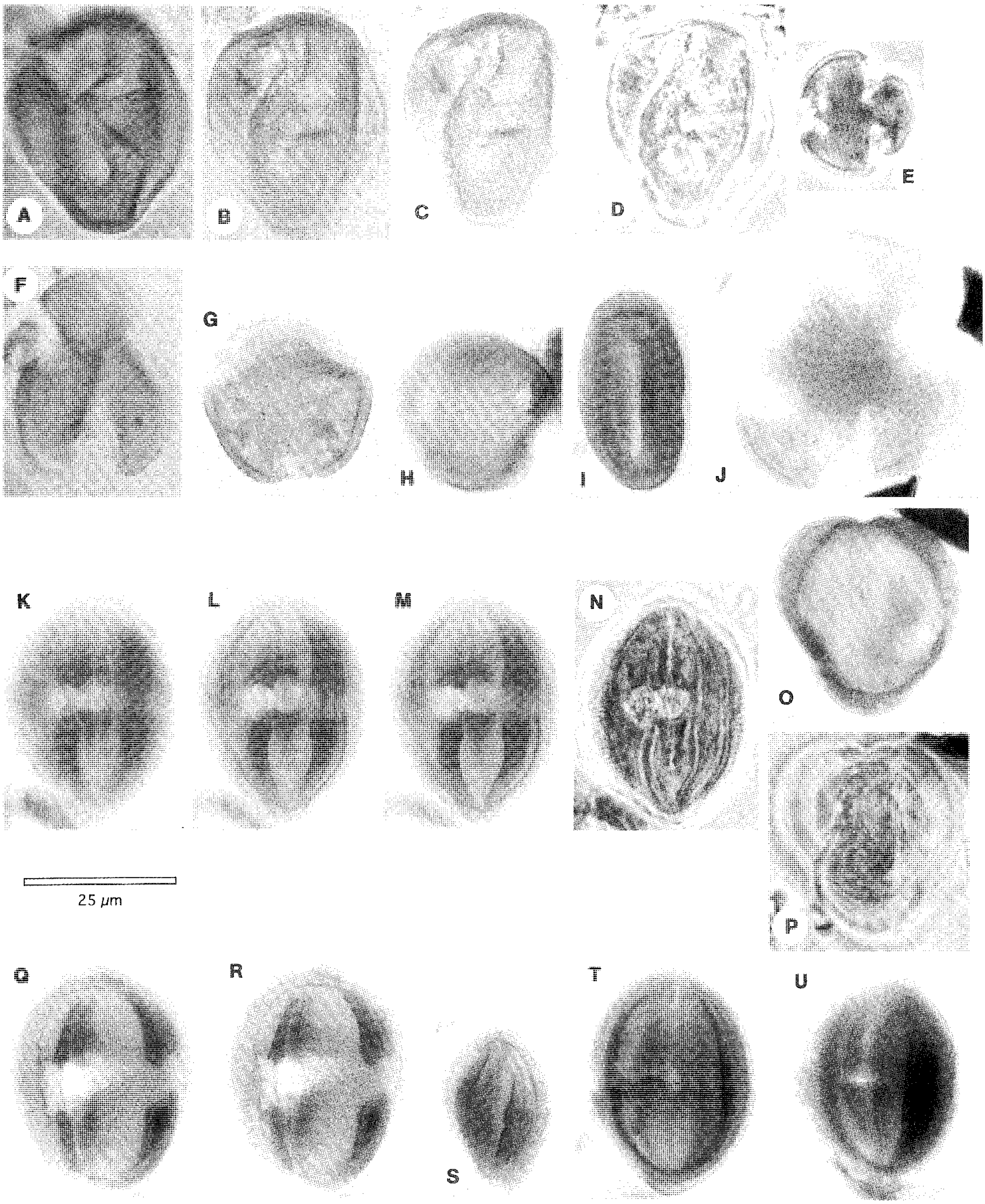

PLATE 2

APPENDIX 1

Although the Wilmot Dam and Lemonthyme Creek palynofloras are dominated by long-ranging taxa, chiefly *Nothofagus* and Podocarpaceae, they include a number of rare to uncommon types that, to date, have only been recorded in Tasmania, e.g. *Mutisiapollis patersonii* n.sp. and *Periporopollenites hexaporus* n.sp. Others are the oldest records anywhere, e.g. *Tricolpites stylidioides* n. sp., or significantly extend the known geographic range of the taxon, e.g. *Tetrapollis campbellbrownii* Macphail & Truswell, 1993.

NEW SPECIES

Tricolpate Pollen

GENUS *Tricolpites* Cookson, 1947 ex Couper, 1953

TYPE SPECIES *Tricolpites reticulatus* Cookson, 1947 (subsequent designation by Couper, 1953)

Tricolpites stylidioides n.sp. (pl. 2, A–J)

HOLOTYPE. Slide SB W-001, stored in the Department of Plant Science, University of Tasmania. England Finder co-ordinates R43(2). Paratypes at O40(4), R45(1), T37(0), T43(2), U41(0) and W67(0) on the same slide.

TYPE LOCALITY. HEC drillhole 5825, Lemonthyme Creek (41°37'S,146°09'E), at 136.0 ft (41.45 m), Early Oligocene.

DERIVATION OF NAME. From the presumed botanical affinity with the Stylidiaceae.

DIAGNOSIS. Monad, isopolar, radiosymmetric, stephanocolpate, apertures three, less frequently four, elongate, usually gaping with ragged margins, subprolate–suboblate, usually distorted (compressed oval), crushed grains oblate; amb subcircular; exine 1–1.5 µm at equator increasing to 3 µm at pole, nexine markedly thicker than sexine, thickening across poles, intectate, apiculate, apiculae short and narrow, < 0.5 µm high, scattered at regular intervals c. 1 µm apart.

DIMENSIONS. Polar diameter 25–(28)–40 µm, eight specimens measured; equatorial diameter 20–(31)–45 µm, ten specimens measured.

BOTANICAL AFFINITY. *Forstera/Phyllachne* (Stylidiaceae).

KNOWN DISTRIBUTION. Tasmania — Early Oligocene to present; Gippsland Basin — earliest Oligocene to terminal Pliocene; central–west Murray Basin — Oligocene to Late Miocene.

DISCUSSION. The type closely resembles pollen of the Stylidiaceae, in particular *Fostera* Linn. f., a very small genus of perennial herbs now confined to montane–subalpine habitats in Tasmania, New Zealand and Fuegia. Tetracolpate, suboblate specimens approximate to the type produced by *Phyllachne* J.R. et G. Forst. The only widespread lowland member of the family in Australia, *Stylidium graminifolium* Swartz, produces strongly oblate pollen with five to six gaping colpi with rounded apices, a type not recorded earlier than Late Pliocene sediments in Tasmania.

Specimens from northwestern Tasmania are the oldest fossil pollen record of the family to date. The presence of *Tricolpites stylidioides* in laminated claystones and siltstones within and overlying the tillite at Lemonthyme Creek (Macphail *et al.* 1993) firmly links the establishment of the family in Tasmania with Cenozoic global cooling.

Tricolporate Pollen

GENUS *Mutisiapollis* n.gen.

TYPE SPECIES *Mutisiapollis patersonii* n.sp.

DERIVATION OF NAME. From the presumed botanical affinity with *Mutisia* L.f. (Asteraceae tribe Mutisieae).

DIAGNOSIS. Monad, isopolar, radiosymmetric; tricolporate, colpi long, endocolpi lalongate; subprolate–prolate, amb subcircular; exine >4 µm thick at equator, sexine clearly stratified with a basal layer of thick columellae separated by an internal tectal layer from an outer layer of short, fine columellae, tectum undulate, puncto-reticulate, microechinate.

DISCUSSION. *Mutisia* is a moderate-sized genus of shrubs and lianes, more or less confined to the Andes in South America. Its pollen is said to be distinct from that produced by other genera within the tribe Mutisieae (Stix 1960) although transmission electron microscopy (Skvarla *et al.* 1977) has established that the pollen type falls within the Anthemoid pattern, also found within the tribes Anthemideae and Cynareae.

We are unaware whether fossil *Mutisia*-type pollen has been described from pre-Quaternary sediments in South America but note that Partridge (1978) referred a species of *Tubulifloridites* with well-developed echini, recovered from Late Tertiary sediments at DSDP Site 365 off the west coast of Africa, to *Mutisia* or *Echinops* (Cynareae) .

Mutisiapollis patersonii n.sp., *non* Partridge, 1978, Fig. 12 (pl. 2, K–U)

DERIVATION OF NAME. After S.J. Paterson who, as Chief Geologist with the HEC, was responsible for the identification of Tertiary sediments at the Wilmot Dam site.

HOLOTYPE. Slide SB W–002, housed in the Department of Plant Science, University of Tasmania, England Finder co-ordinates S43(4); paratype at M29(2) on the same slide.

TYPE LOCALITY. HEC drillhole 5825, Lemonthyme Creek (41°37'S, 146°09'E), at 101 ft (30.8 m), early Oligocene.

DIAGNOSIS. Monad, isopolar, radiosymmetric; tricolporate, colpi extending to near poles, endocolpi lalongate c. 5 × 7 µm, oval to diamond-shaped, lateral margins often indistinct or ragged; exine 4–7 µm thick at equator decreasing to 2.5–4 µm at poles, nexine thinner than sexine but swelling to c. 3 µm around endocolpi, sexine consisting of a basal layer of thick simplibaculate columellae 1.5–3 µm long, separated by a homogeneous layer from an outer layer of fine columellae <0.8 µm, surface of tectum often undulate in sectional view, appearing scabrate–verrucate in surface view due to subtectum structure, puncto-reticulate, microechinate.

DIMENSIONS Polar diameter 20–(36)–40 µm, nine specimens measured; equatorial diameter 20–(27)–32 µm, eight specimens measured.

DISTRIBUTION Northwestern Tasmania: Early to Middle? Oligocene; not recorded elsewhere to date.

DISCUSSION Apart from variations in size, there is little to distinguish *Mutisiapollis patersonii* from pollen of *Mutisia speciosa* (fig. 62A in Erdtman 1966), *M. decurrens* and *M. spectabilis* (Heusser 1971: 30-31, pl. 23, figs 273, 274). *Echinops* is rambibaculate and lacks the secondary columellate layer in the subtectum (Erdtman 1966, fig. 64). *Polupissusites* Salard-Cheboldaeff emend. Pocknall, 1982 is rambibaculate and characterised by exine which thickens across the poles.

The records of *Mutisiapollis patersonii* are amongst the earliest for any member of the Asteraceae anywhere (see Muller 1981). Its Cenozoic distribution in Tasmania is similar to *Cyatheacidites annulatus,* in that both first appear during the Early Oligocene whilst the modern sources are now confined to South America. A logical explanation is that Antarctica was the centre of origin/ dispersal for both taxa.

Periporate Pollen

GENUS *Periporopollenites* Pflug & Thomson, 1953

TYPE SPECIES *Periporopollenites stigmosus* Potonie, designated by Pflug & Thompson in Thompson & Pflug 1953

Periporopollenites hexaporus n.sp. (pl. 3, A–J)

1991 Unknown species Macphail *et al.*: 96, fig. 5M–O

HOLOTYPE Slide SB W–003, stored in the Department of Plant Science, University of Tasmania: England Finder co-ordinates R47(3); paratype at X46(0) on the same slide.

TYPE LOCALITY HEC drillhole 5825, Lemonthyme Creek (41°37'S, 146°09'E), at 102 ft (31.1 m), Early Oligocene.

DERIVATION OF NAME From the characteristic number of pores.

DIAGNOSIS Monad, apolar, sphaeroidal although often compressed into a cubical to polyhedrol shape; periporate, pores six, rarely 12, large, circular, 4–7 µm, weakly annulate; exine 1.5–2.5 µm thick, sexine twice as thick as nexine, columellae coarse, clavate–gemmate, heads wholly or partially fused to form a thin tectum, puncto-reticulate.

DIMENSION 22–(25)–32 µm, 13 specimens measured.

BOTANICAL AFFINITY Trimeniaceae?

DISTRIBUTION Northwestern Tasmania: Early Oligocene to Late Oligocene/Early Miocene; not recorded elsewhere to date.

DISCUSSION. Stover & Partridge (1973: 272) have used Periporopo*llenites* to accommodate fossil periporate pollen characterised by ten to approximately 32 simple apertures and exine that is clearly stratified and thin, relative to the size of the grain. In spite of the lower number of pores, relatively thick exine and verrucate sculpture, *P. hexaporus* appears to be related to *P. demarcatus* Stover & Partridge, 1973 via intermediate forms (see below). For this reason we prefer to retain the species within *Periporopollenites* rather than accommodate the type in *Parsonsidites* Couper, 1960 (erected to cover psilate to scabrate grains with five or more pores) or *Polyporites* Samoilovich & Mtchedlishvili, 1961(erected to cover grains with five to six pores and pilate exine).

Most populations of *Periporopollenites hexaporus* include specimens characterised by thin pilate columellate, semi-tectate exine (often corroded) and with 10 to 18 (av. 12) pores which may or may not be surrounded by annuli (pl. 3, K–M). Further work is required to assess whether this morphotype warrants species status. At present, we prefer to regard it as an intermediate between hexa*porus* and the *demarcatus-vesicus* complex (pl. 3, N–Q) and suggest that all species are part of the same (Trimeniaceaen?) phylogenetic lineage. If correct, the (to date) restriction of P. he*xaporus* to Tasmania is evidence of local evolution within this family.

OTHER TAXA

Trilete Spores

Cyatheacidites annulatus Cookson, 1947 (pl.1, A–D)

Spores with this morphology are now only found within the monospecific South American tree-fern family Lophosoriaceae.

The fossil taxon has a markedly disjunct time distribution in Australia: *Cyatheacidites tectifera* which first appears in the late Albian and becomes extinct in the Campanian, and *C. annulatus* which first appears in the early Oligocene and becomes extinct during the Pliocene. This almost certainly reflects two separate, ultimately unsuccessful colonisation events. Based on the variations in the morphology of the three raised pads on the proximal surface, several subspecies may have evolved within the C. *annulatus* lineage during the late Tertiary.

Tricolpate Pollen

Gothanipollis perplexus Pocknall & Mildenhall, 1984 (pl. 5, A)
Gothanipollis sp. cf *G. gothanii* Krutzsch, 1959 (pl. 4, B)
Gothanipollis sp. cf *G. bassensis* Stover & Partridge, 1973 (pl. 5, C)
Tricolpites simatus Stover & Partridge, 1973 (pl. 5, D)

Although now extinct in Tasmania, Gotha*nipollis* spp. and *Tricolpites simatus* show that Loranthaceae were part of the regional flora from the late Early Eocene into the Middle Pleistocene (Macphail *et al.* 1993c). Interestingly, the first appearance of Loranthaceae pollen in Tasmania is earlier and extinction of the type later than in the Gippsland Basin (compare Stover & Partridge 1973).

Tricolporate Pollen

Margocolporites sp. cf *Anopterus* (pl. 4, H–I)

This psilate tricolporate type broadly resembles modern *Anopterus* (Escalloniaceae) pollen in having strongly developed margo costae and pronounced endo-cracking of the exine.

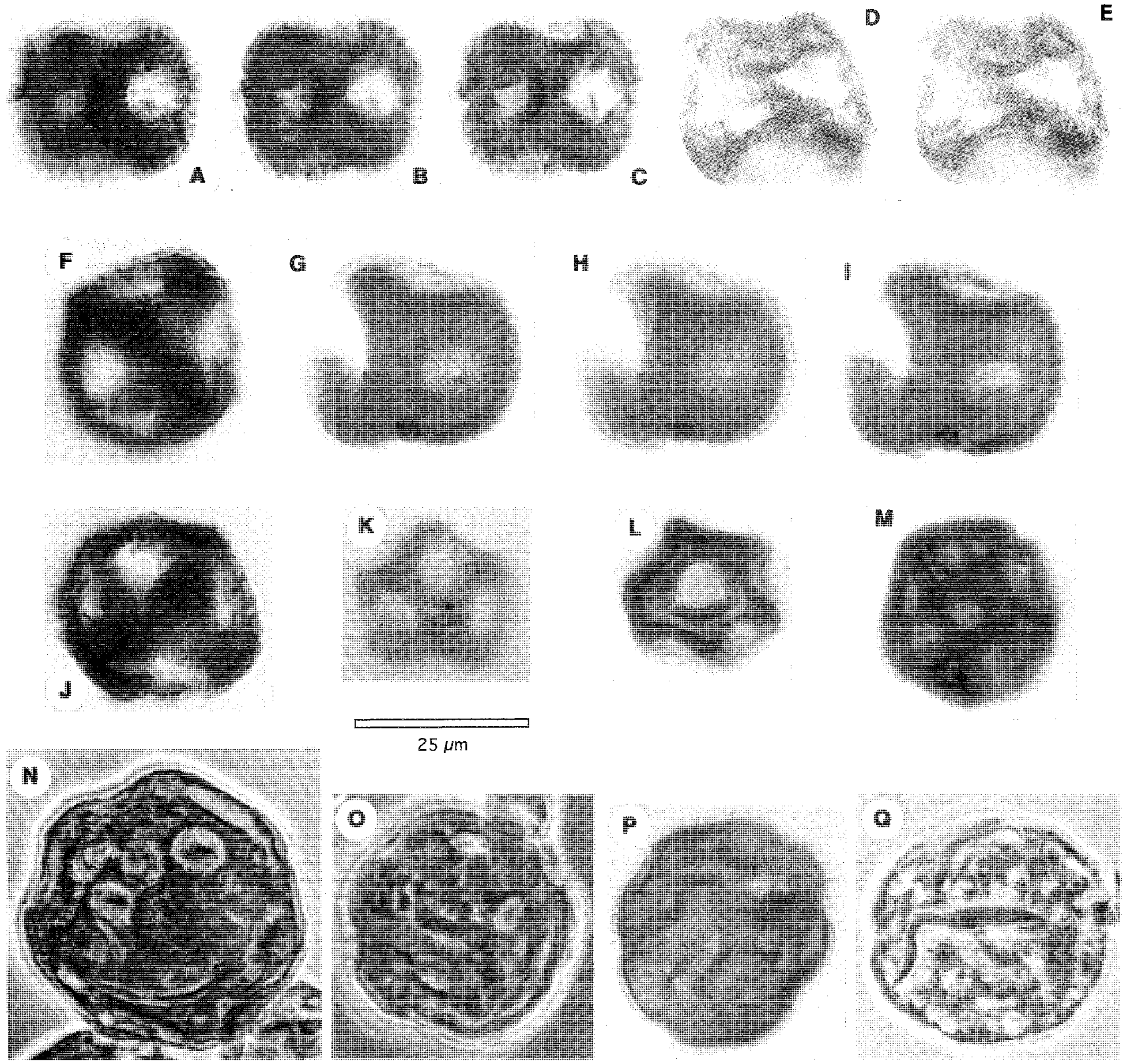

PLATE 3

New species (continued). All photomicrographs ×1250 unless otherwise stated. Scale bar A = 25 μm; scale bar B = 50 μm.

Periporopollenites hexaporus *n. sp. (A–C) Holotype at three focal planes; oblique view — Lemonthyme DH 5802 at 31.1 m,* P. tuberculatus *Zone; (D–E) paratype at two focal planes; oblique view — Lemonthyme DH 5825 at 31.1 m,* P. tuberculatus *Zone; (F) specimen showing strongly developed verrucate ornamentation — Lemonthyme DH 5802 at 46 m,* P. tuberculatus *Zone; (G–I) specimen showing (1) poroid split in nexinous membrane across pore and (2) fusion of clavate columellae to form a verrucate tectum — Wilmot Dam DH 4558 at 23.6 m,* P. tuberculatus *Zone; (J) specimen showing clavate columellae more or less reduced to gemmae; semi-tectate — Lemonthyme DH 5802 at 46 μ,* P. tuberculatus *Zone; (K) specimen intermediate between* P. hexaporus *and* P. demarcatus; *12 pores present; columellae pilate; tectum thin, corroded; annuli absent around pores — Lemonthyme DH 5825 at 36.6 m,* P. tuberculatus *Zone; (L) 10-porate grain with well developed annuli — Wilmot Dam DH 4558 at 23.6 m,* P. tuberculatus *Zone; (M) 18-porate specimen with well-developed annuli — Lemonthyme DH 5802 at 46 m,* P. tuberculatus *Zone.*

Periporopollenites demarcatus *Stover & Partridge, 1973. (N) Crushed, unusually large specimen; note puncto-reticulate tectum; phase contrast — Wilmot Dam DH 4558 at 21.3 m,* P. tuberculatus *Zone; (O) as above; phase contrast — Lemonthyme DH 5825 at 36.6 m,* P. tuberculatus *Zone.*

Periporopollenites vesicus *Stover & Partridge, 1973. (P) Wilmot Dam DH 4558 at 21.3 m,* P. tuberculatus *Zone.*

Periporopollenites *sp. cf.* P. polyoratus *(Couper) Stover & Partridge, 1973. (Q) Lemonthyme DH 5825 at 31.1 m,* P. tuberculatus *Zone.*

Tetraporate Pollen

Tetrapollis campbellbrownii Macphail & Truswell 1993 (pl. 1, H–I)

This species, first described from Oligocene–late Early Miocene sediments in the Murray Basin, is characterised by four (rarely three or five) pores surrounded by channeled nexine: columellae are not visible but the sexine is clearly stratified into two layers, the outermost of which tends to be undulate.

Although difficult to photograph, all features are displayed by the Wilmot Dam specimen. The species is widespread in Oligo–

PLATE 4 (see next page)

Woody taxa. All photomicrographs ×1250 unless otherwise stated. Scale bar A = 25 µm; scale bar B = 50 µm. (A) Microcachrydites antarcticus *Cookson, 1947 — Lemonthyme DH 5825 at 36.6 m,* P. tuberculatus *Zone; (B)* Podosporites erugatus *Mildenhall, 1978 — Lemonthyme DH 5825 at 36.6 m,* P. tuberculatus *Zone; (C)* Nothofagidites flemingii *(Couper) Potonié, 1960 — Lemonthyme DH 5802 at 46 m,* P. tuberculatus *Zone; (D)* Quintiniapollis psilatispora *(Martin) Mildenhall & Pocknall, 1989 — Wilmot Dam DH 4558 at 21.3 m,* P. tuberculatus *Zone; (E)* Sapotaceoidaepollenites latizonatus *(McIntyre) Pocknall & Mildenhall, 1984 — Wilmot Dam DH 4558 at 21.3 m,* P. tuberculatus *Zone; (F–G) pentacolporate sp. Meliaceae[?]; this type differs from five-pored specimens of* Tetracolporites palynius *Stover & Partridge, 1982, in that the nexine is strongly thickened around the pores; polar view — (F) equatorial view; (G) Wilmot Dam DH 4558 at 21.3 m,* P. tuberculatus *Zone; (H)* Margocolporites *sp. cf.* Anopterus *(Escalloniaceae). Polar view; note prominent margo colpae and pronounced endocracks in exine — Lemonthyme DH 5825 at 33.5 m,* P. tuberculatus *Zone; (I) as above; phase contrast — Lemonthyme DH 5825 at 33.5 m,* P. tuberculatus *Zone; (J) as above; equatorial view; it is uncertain whether the crossed longitudinal colpi are characteristic of the type — Lemonthyme DH 5825 at 29.3 m,* P. tuberculatus *Zone; (K)* tetraporate *sp. cf* Tricolporites adelaidensis *Stover & Partridge, 1982; the specimen falls within the size and pore range but it lacks the gaping, short colpi characterising this species;* Tetracolporites spectabilis *Pocknall & Mildenhall is brevicolpate with annulate ora — Lemonthyme DH 5825 at 33.5 m,* P. tuberculatus *Zone; (L–M)* Tricolporites *sp. cf.* Muehlenbeckia *(Polygonaceae); the species is characterized by the finely scabrate sculpture and diamond-shaped lalaongate endocolpi — Wilmot Dam DH 4588 at 23.6 m,* P. tuberculatus *Zone; (N)* Rhoipites (al. Tricolporites) microreticulatus *Harris, 1965 — Wilmot Dam DH 4558 at 23.6 m,* P. tuberculatus *Zone; (O)* Dryadopollis retequetrus *(Stover & Partridge), Pocknall & Mildenhall, 1984; ×788 — Wilmot Dam DH 4558 at 21.3 m,* P. tuberculatus *Zone; (P) cf.* Dryadopollis retequetrus *(Stover & Partridge), Pocknall & Mildenhall, 1984; × 788 — Wilmot Dam DH 4558 at 21.3 m,* P. tuberculatus *Zone; (Q)* Beaupreaidites elegansiformis *Cookson, 1950; phase contrast — Lemonthyme DH 5802 at 46 m,* P. tuberculatus *Zone; (R)* Triporopollenites *sp. cf.* T. chnosus *Stover & Partridge, 1973; ×788 — Wilmot Dam DH 4558 at 21.3 m,* P. tuberculatus *Zone; (S)* Malvacipollis subtilis; *phase contrast — Lemonthyme DH 5825 at 31.1 m,* P. tuberculatus *Zone.*

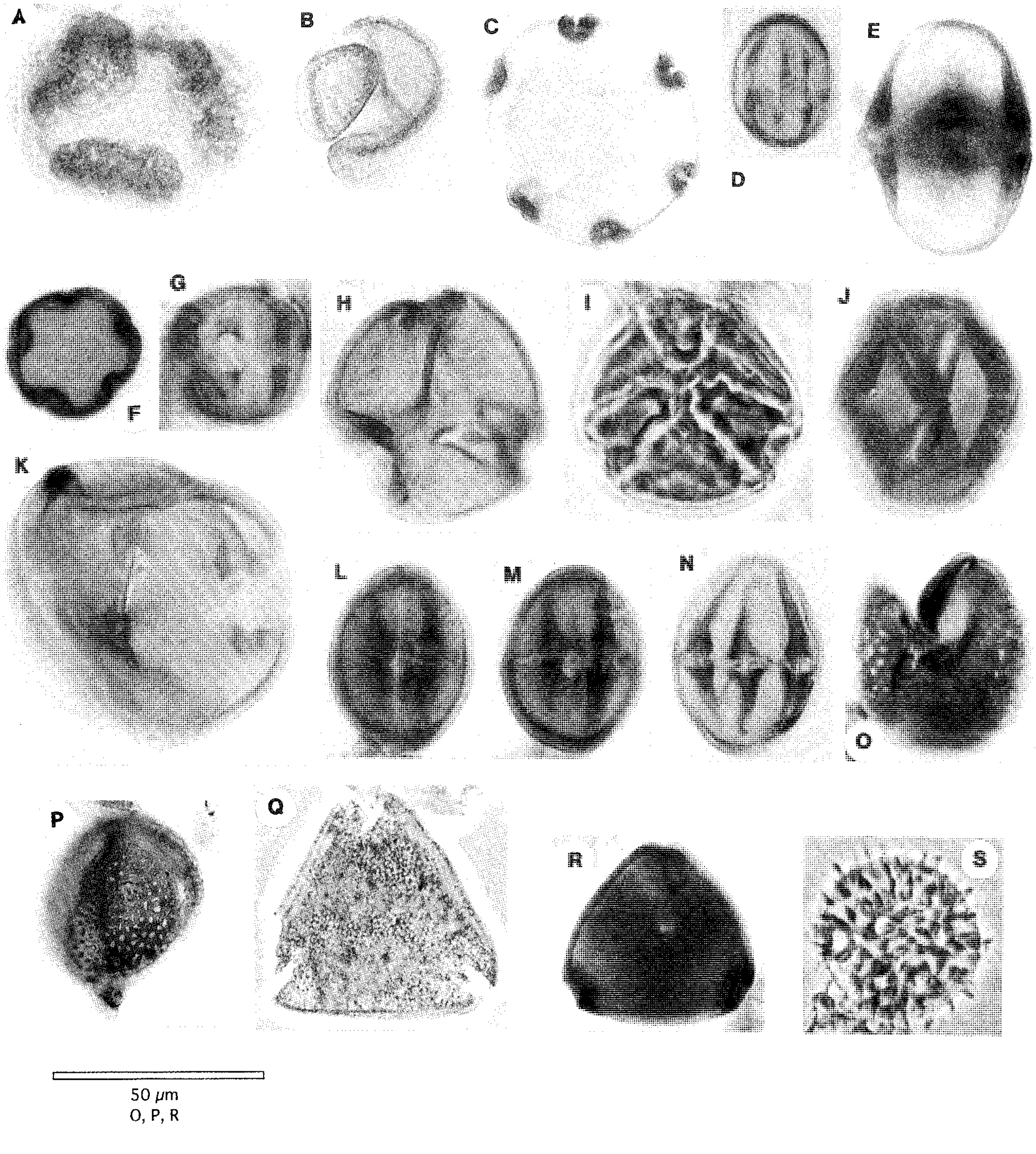

PLATE 4

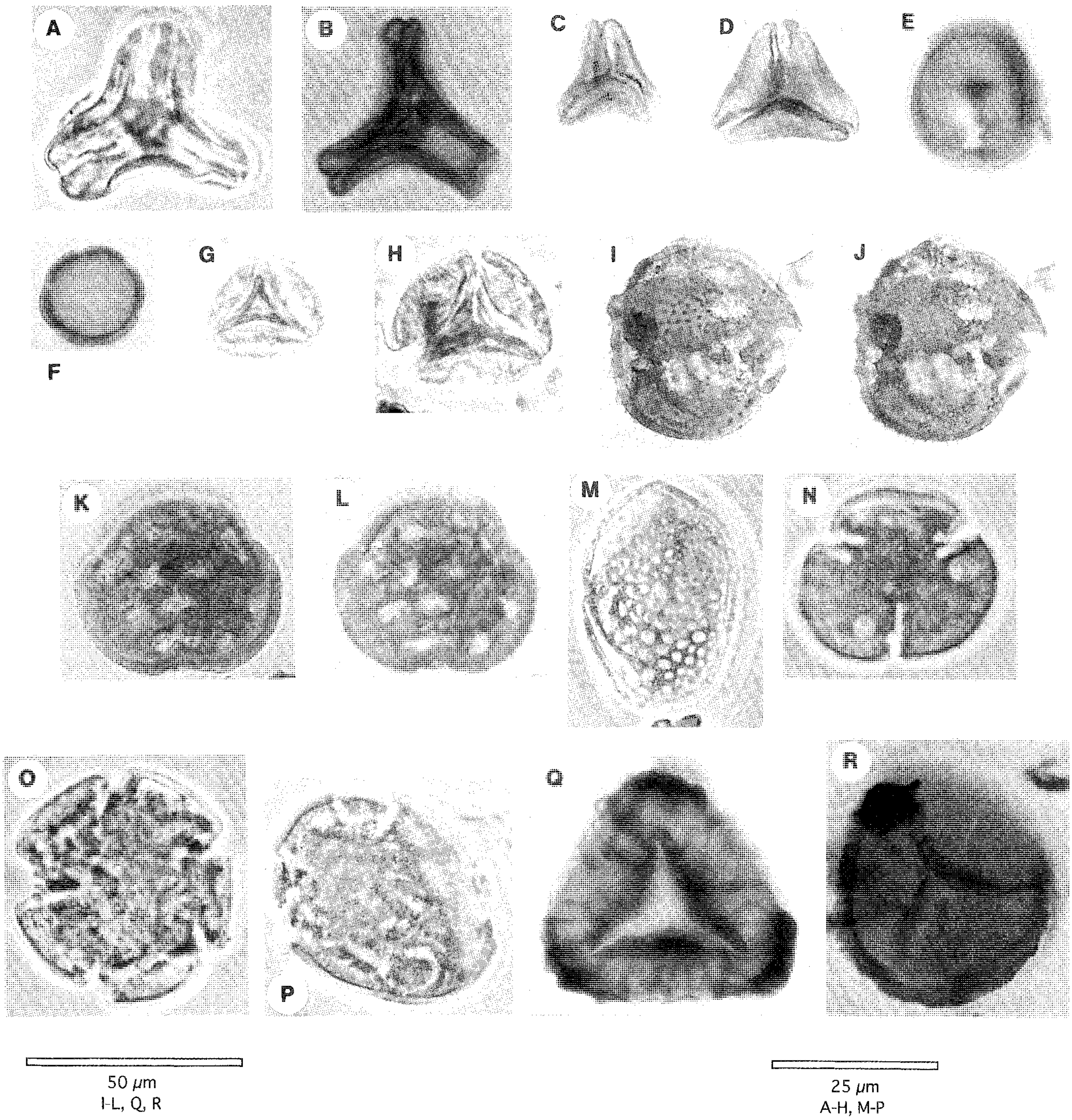

PLATE 5

Climbers, herbs, ferns and fern allies. (A) Gothanipollis perplexus *Pocknall & Mildenhall, 1984 — Lemonthyme DH 5825 at 39.9 m,* P. tuberculatus *Zone; (B)* Gothanipollis *sp. cf.* G. gothani *Krutzsch, 1959 — Wilmot Dam DH 4558 at 23.6 m,* P. tuberculatus *Zone; (C)* Gothanipollis *sp. cf.* G. bassensis *Stover & Partridge, 1973 — Wilmot Dam DH 4558 at 23.6 m,* P. tuberculatus *Zone; (D)* Tricolpites simatus *Stover & Partridge, 1973 — Wilmot Dam DH 4558 at 21.3 m,* P. tuberculatus *Zone; (E)* Tricolpites trioblatus *Mildenhall & Pocknall, 1989; equatorial view — Wilmot Dam DH 4558 at 23.6 m,* P. tuberculatus *Zone; (F)* Stephanocolpites oblatus *Martin, 1973 — Wilmot Dam DH 4558 at 21.3 m,* P. tuberculatus *Zone; (G)* Striasyncolpites laxus *Mildenhall & Pocknall, 1989; phase contrast — Lemonthyme DH 5825 at 29.3 m,* P. tuberculatus *Zone; (H)* Striasyncolpites laxus *Mildenhall & Pocknall, 1989; phase contrast — Lemonthyme DH 5825 at 29.3 m,* P. tuberculatus *Zone; (I–J) Droseraceae; ×788 — Lemonthyme DH 5825 at 31.1 m,* P. tuberculatus *Zone; (K–L) Droseraceae; ×788 — Lemonthyme DH 5825 at 39.9 m,* P. tuberculatus *Zone; (M)* Liliacidites *sp.; phase contrast — Wilmot Dam DH 4558 at 21.3 m,* P. tuberculatus *Zone; (N)* Tricolpites reticulatus *Cookson ex Couper* emend. *Jarzen & Dettmann, 1989; phase contrast — Wilmot Dam DH 4558 at 23.6 m,* P. tuberculatus *Zone; (O)* Retistephanocolpites *sp. aff.* Callitriche *(Callitricheaceae) — Wilmot Dam DH 4558 at 23.6 m,* P. tuberculatus *Zone; (P)* Stephanocolpites sphericus *(Couper) Mildenhall & Pocknall, 1989; phase contrast — Lemonthyme DH 5825 at 31.1 m,* P. tuberculatus *Zone; (Q)* Ischyosporites *(al.* Klukisporites*)* lachlanensis *Martin, 1973; ×788 — Wilmot Dam DH 4558 at 21.3 m,* P. tuberculatus *Zone; (R)* Latrobosporites marginis *Mildenhall & Pocknall, 1989; × 788 — Lemonthyme DH 5825 at 24.7 m,* P. tuberculatus *Zone.*