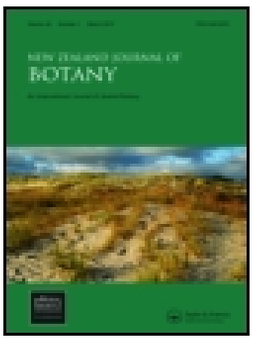
The New Zealand fossil record of ferns for the past 85 million years

Cieraad, E.; Lee, D.



New Zealand Journal of Botany

ISSN: 0028-825X (Print) 1175-8643 (Online) Journal homepage: http://www.tandfonline.com/loi/tnzb20

The New Zealand fossil record of ferns for the past 85 million years

Ellen Cieraad & Daphne E. Lee

To cite this article: Ellen Cieraad & Daphne E. Lee (2006) The New Zealand fossil record of ferns for the past 85 million years, New Zealand Journal of Botany, 44:2, 143-170, DOI: 10.1080/0028825X.2006.9513015

To link to this article: http://dx.doi.org/10.1080/0028825X.2006.9513015

New Zealand Journal of Botany, 2006, Vol. 44: 143–170
0028–825X/06/4402–0143

The New Zealand fossil record of ferns for the past 85 million years

ELLEN CIERAAD*
DAPHNE E. LEE
Department of Geology
University of Otago
PO Box 56
Dunedin, New Zealand
*Also: Faculty of Science, University of Amsterdam, Postbus 94062, 1090 GB Amsterdam, The Netherlands. ellencieraad@gmail.com

Abstract The near-continuous record of the New Zealand terrestrial flora since the landmass broke away from Gondwana provides an excellent opportunity to assess the history of the pteridophyte flora in the region. A database of all published records of fossil ferns from the late Cretaceous onwards is presented, along with references to original reports. This compilation provides evidence for the time of arrival for fern lineages, continuity of their presence, and times of radiation, thereby greatly assisting the reconstruction of the history and biogeography of ferns in the region. Additionally, it provides a valuable source of lineage age estimates, which are required to calibrate the molecular clock for much needed molecular studies on pteridophytes.

Keywords fern; pteridophyte; fossil record; index; lineage; age estimates; biogeography; late Cretaceous; Cenozoic; New Zealand

INTRODUCTION

Of several studies of the history and biogeography of New Zealand's flora, only a few have considered the fossil record of ferns, which comprise a major component of the present and past New Zealand biota (e.g., Lovis 1959; Mildenhall 1980; Pole 1994; Brownsey 2001; Winkworth et al. 2002). Biogeographic and phylogenetic analyses of living pteridophytes, as well as the record of macrofossils and spores, indicate that many fern families evolved and diversified after the break-up of Gondwana (e.g., Collinson 2001; Parris 2001; Skog 2001; Lovis 2003; Pryer et al. 2004; Schneider et al. 2004). Species in these families, as well as several angiosperm families with a suggested similar evolutionary history, are now distributed on widely separated continents, particularly in the Southern Hemisphere. Both vicariance, a process through which continuously distributed taxa are fragmented by geological or climatic changes of the earth surface (Kato 1993), and long-distance dispersal have been suggested as possible mechanisms to explain this (see and compare Lovis 1959; Pole 1994; Macphail 1997; Winkworth et al. 1999, 2002; McGlone et al. 2000; Wolf et al. 2001). The fossil record of ferns in the New Zealand region indicates a diverse, rich, and near-continuous pteridophyte flora for the past 85 million years (and probably since the Jurassic). That the fern flora has undergone major changes through time is also apparent, but no comprehensive investigation of these changes has been carried out.

There have been previous reviews on first occurrences and/or ranges of present plant taxa (including a small number of ferns) in New Zealand (e.g., Mildenhall 1980; Macphail 1997). However, references in those reviews are incomplete and much new information has come to light since those studies were carried out. Collinson (2001) published a comprehensive review of Cenozoic ferns and their distribution worldwide (with an emphasis on macrofossils). However, in this review she included only three references to the diverse New Zealand fern flora.

This paper includes a summary of all published records of fern micro- and macrofossils in the New Zealand region for the past 85 million years (M yr). The identifications and age determinations are summarised as recorded by the original authors. The data will provide a foundation for studies in different fields that aim to increase the understanding of the history, phylogeny, and biogeography of extant ferns in the New Zealand region.

B05050; Online publication date 2 May 2006
Received 22 November 2005; accepted 2 March 2006

Table 1 Summary of the New Zealand fossil record of pteridophytes from the Late Cretaceous onwards. Cr, Cretaceous; Pal, Paleocene; Eo, Eocene; Oli, Oligocene; Mio, Miocene; Pli, Pliocene; Ple, Pleistocene; H, Holocene; E, early; M, middle; L, late. The digit in each time period column corresponds to the number of references recording

Family Modern Genus	Modern species	Recorded genus	Recorded species	Authority
FERN ALLIES				
Equisetaceae				
Equisetum	*E.* sp.			
Isoetaceae				
Isoetes	*I.* sp.			
Isoetes	cf. *I.* sp.			
?		*Leptolepidites*	*L. verrucatus*	Couper
Lycopodiaceae				
Lycopodium	*L.* sp.			
Lycopodium	? *L.* sp.			
Lycopodium	*L. australianum*			Herter
Lycopodium	*L. australianum*	*Foveotriletes*	*F. palaequetrus*	Partridge
Lycopodium	cf./? *L. australianum*			
Lycopodium	cf. *L. australianum*	*Foveotriletes*	cf. *F. palaequetrus*	
Lycopodium	*L. cernuum*			L.
Lycopodium	*L. cernuum*	*Lycopodium*	*L. cerniidites*	Ross
Lycopodium	*L. cernuum*	*Lycopodium*	*L. cernuoides*	Couper
Lycopodium	*L. densum*			Labill.
Lycopodium	cf. *L. densum*			
Lycopodium	*L. deuterodensum*			Herter
Lycopodium	*L. diffusum*	*Lycopodium*	as *L. ramulosum*	Kirk
Lycopodium	*L. fastigiatum*			R.Br.
Lycopodium	*L. fastigiatum*	*Lycopodium*	cf./type *L. fastigiatum*	
Lycopodium	*L. fastigiatum*	*Lycopodium*	*L. fastigioides*	Couper
Lycopodium	*L. fastigiatum-volubile*	*Lycopodium*	*L.* sp. *fastigiatum/volubile* gp.	
Lycopodium	*L. laterale*			R.Br.
Lycopodium	cf. *L. laterale*			
Lycopodium	*L. laterale*-type	*Latrobosporites*	*L. marginis*	
Lycopodium	*L. scariosum*			G.Forst.
Lycopodium	aff./cf. *L. scariosum*			
Lycopodium	*L. varium*			R.Br.
Lycopodium	*L. varium*	*Lycopodium*	as *L. sp. billardieri/varium* gp.	
Lycopodium	*L. varium*	*Lycopodium*	as *L. billardierei*	Spring
Lycopodium	cf. *L. varium*	*Lycopodium*	as *L.* cf. *billardieri*	
Lycopodium	*L. volubile*			G.Forst.
Lycopodium	aff./cf. *L. volubile*			
Phylloglossum				
unspec	unspec			
?		*Camarozonosporites*	*C. amplus*	(Stanley)
?		*Camarozonosporites*	*C. ohaiensis*	
?		*Foveotriletes*	*F. lacunosus*	Partridge
?		*Lycopodiumsporites*	*L.* sp.	
?		*Lycopodiumsporites*	*L. austroclavatidites*	(Cookson)
?		*Lycopodiumsporites*	*L.* cf. *austroclavatidites*	
?		*Lycopodiumsporites*	*L. circolumenus*	Cookson & Dettmann
?		*Lycopodiumsporites*	*L. eminulus*	Dettmann
?		*Lycopodiumsporites*	*L.* cf. *eminulus*	
?		*Lycopodiumsporites*	*L. facetus*	Dettmann
?		*Lycopodiumsporites*	? *L. fastigioides*	(Couper)
?		*Lycopodiumsporites*	*L. nodosus*	Dettmann
?		*Lycopodiumsporites*	*L. reticulumsporites*	(Rouse) Dettmann

the respective fern in that time period. Bold and underlined numbers include macrofossil records. No digits in any column implies that no fossils of the respective extant family or genus have been recorded. *, taxa that are extinct, not extant in the New Zealand region, or considered exotic.

Cr	Pal		Eo			Oli		Mio			Pli		Ple		H	Reference
L	E	L	E	M	L	E	L	E	M	L	E	L	E	L		(see Appendix 1)
1																77
										2	1	2	2		1	29,30,52,58,68,71
														1		73
3																63,66,98
3		1	1	1	1					2	1	1	3	2	1	33,39,52,58,60,78,90,91,109,110,111
												1	1			**44**
										1	2	6	1	1	3	32,34,49,51,58,60,64,68,71,72
					2	5	5	4	1	1		1				30,59,65,81,83,85,87,89,91,98
												2				15,49
					1											61
												1				15
	1	1														98
			1	2	1											11,98
												1				15
								1	1	1						59
												4	2	2	1	26,51,53,55,68,111
					1		1	3	1	1			2	3	1	9,16,59,81,89,90,91
								1		3	4	5	2	5	3	21,31,32,33,34,49,54,58,60,68,81,106
1		1	1		1			1								52,61,79
3																9,14,99
4	2	1	1	2	2	1	2	3	2	2	3	7	4	4	2	9,14,15,16,27,43,44,45,46,53,59,64,89,92,103,108
								3	2	2	1	3	1	2	3	8,9,28,53,59,64,68
											1	1				58
								1								30
					1		1	3	1	2	3	6	1	4	4	9,16,21,32,33,36,46,49,57,58,59,68,81,89,91,104
		1	1		1	1	1	2	1							18,24,61,79,83
										1	1	1		1	1	6,33,49,54
						2	1	1	2	4	4	11	4	5	3	4,9,15,16,28,42,43,44,45,46,52,53,58,60,64,92,104,106
												2	1	2	1	28,49,68
															1	20
					1					2	2	7	1	4	6	20,32,33,36,44,49,52,53,57,58,60,68,90,91,104,106
1							1	1								41,79,83
1	1	1			1											3,48
1																65
1																99
					1	1	3	4	2	3	2	2				5,58,59,81,83,85,89
11	4	4	3	4	5	2	1									1,5,27,47,50,61,63,65,66,67,91,93,97,98,99,100,112
4																50,63,66,98
			1	1												1
1																63
1																63
1																50
2																63,98
1																50
3																63,65,98
4																50,63,65,98

Table 1 (*continued*)

Family Modern Genus	Modern species	Recorded genus	Recorded species	Authority
?		*Lycopodiumsporites*	*L. saturnalis*	Norris
?		*Lycopodiumsporites*	*L. tenuis*	(Balme)
?		*Lycopodiacidites*	cf. *L.* sp.	
?		*Lycopodiacidites*	*L. asperatus*	Dettmann
?		*Lycopodiacidites*	*L. bullerensis*	Couper
?		*Lycopodiacidites*	*L. cristatus*	Couper
?		*Peromonolites*	*P. problematicus*	(Couper)
?		*Peromonolites*	? *P. problematicus*	
?		*Verrucosisporites*	*V. kopukuensis*	(Couper) Stover
Lycopsida				
?		*Camarozonosporites*	*C.* sp.	
?		*Camarozonosporites*	*C. australiensis*	Burger
?		*Camarozonosporites*	*C.* cf. *australiensis*	
?		*Ceratosporites*	*C.* sp.	
?		*Ceratosporites*	? *C.* sp.	
?		*Ceratosporites*	*C. equalis*	Cookson & Dettmann
?		*Ceratosporites*	*C.* cf. *C. equalis*	Cookson & Dettmann
?		*Densoisporites*	*D. microrugulatus*	Brenner
?		*Densoisporites*	*D. velatus*	Weyland & Krieger
?		*Dictyotosporites*	*D. complex*	Cookson & Dettmann
?		*Dictyotosporites*	? *D. complex*	Cookson & Dettmann
?		*Herkosporites*	*H. proxistriatus*	Burger
?		*Herkosporites*	*H.* sp.	
?		*Latrobosporites*	*L. marginis*	n.sp.
?		*Neoraistrickia*	*N. neozealandica*	(Couper) Potonie
?		*Neoraistrickia*	*N. truncata*	(Cookson)
?		*Perotrilites*	*P. senonicus*	Raine
?		*Trilites*	*T. morleyi*	Couper
Lycopsida/Bryophyta				
?		*Rouseisporites*	*R.* sp.	
Psilotaceae				
Psilotum	*P.* sp.			
Tmesipteris	*T.* sp.			
Tmesipteris	*T. tannensis*			Bernh.
Tmesipteris		*Polypodiisporites*	*P. irregularis*	Pocknall & Mildenhall
Tmesipteris		*Polypodiisporites*	*P.* cf. *irregularis*	
unspec	unspec			
Selaginellaceae*				
Selaginella		*Foveosporites*	*F. canalis*	Balme
Selaginella		*Grapnelispora*	*G. evansii*	Stover & Partridge
?		*Perotrilites*	*P. granulatus*	Couper
FERNS				
Aspleniaceae				
Asplenium	*A.* sp.			
Asplenium	? *A.* sp.			
Asplenium	*A. oblongifolium*	*Asplenium*	as *A. lucidum*	G.Forst.
Asplenium	*A. polyodon*	*Asplenium*	as *A. falcatum*	Lam.
Pleurosorus	*P.* sp.			
Azollaceae				
Azolla	*A.* sp.			
Blechnaceae				
Blechnum	*B.* sp			
Blechnum	cf./? *B.* sp.			
Blechnum	type *B. capense*			

Cr	Pal		Eo			Oli		Mio			Pli		Ple		H	Reference
L	E	L	E	M	L	E	L	E	M	L	E	L	E	L		(see Appendix 1)
3					1											63,65,98
1																63
		1	1													61
1																63
2																65,98
1																63
											3	7		1	1	9,13,15,16,28,51,53,58,71
												2				2,44
			1	5	7	4	4	4	1	1						30,59,67,79,80,81,83,87,88,89,91,97,98,99
5	3	3	5	4	3			1	1	1						1,3,27,59,63,65,97,98,99,100
1																98
	1	1	1													100
2												1				47,49,99
		1	1													61
4		1			1					1	1	1				3,23,27,63,66
1					1		2	2	1	1						59,80,89,98
1																98
1																63
1																63
1																50
2																63,65
								1								81
								1	1							59
1																98
3																50,63,98
1																65
9	1	1														3,9,13,14,82,98,99,108,109
														1	2	28,64
													1			52
								1					1			30,52
											1	1	1	2	3	6,9,16,20
				1	2	1	3	2	2	2	1	1				58,83,85,89,91,99
					1	1	1									66
												3	2	3	1	28,44,49,53,68
1																63
2																93,102
1																98
									1			1		1	1	28,52,53
										1	1					58
											1				1	16,20
															1	20
													1			52
													1	3	1	30,33,52,90
1				1	1			3	**2**	4	7	**11**	2	3	5	8,9,10,12,14,15,16,24,31,33,36,44,52,53,54,60,68,90,103,111
3	1	1	1	2	2	1	1	1	1	1					1	6,9,14,47,52,59,103
															3	6,32,34

Table 1 (*continued*)

Family Modern Genus	Modern species	Recorded genus	Recorded species	Authority
Blechnum	aff. *B. colensoi*	*Blechnum*	as *B.* aff. *patersonii*	(R.Br.) Mett.
Blechnum	*B. discolor*			(G.Forst.) Keyserl.
Blechnum	*B.* aff. *discolor*			
Blechnum	*B. novae-zelandiae*	*Blechnum*	as *B.* sp. 1	Chambers & Farrant
Blechnum		*Blechnum*	*B. priscum* *	Ettingsh.
Blechnum	cf. *B. procerum*	*Blechnum*	as *B.* cf. *procerum*	(G.Forst.) Sw.
Blechnum	cf. *B. procerum*	*Blechnum*	as *B. proceroides*	(Oliv.)
Blechnum	cf. *B. procerum*	*Lomariopsis*	as *L. dunstanensis*	Ettingsh.
Blechnum	cf. *B. procerum*	*Lomaria*	as *L. proceroides*	Oliv.
Blechnum	*B. vulcanicum*			(Blume) Kuhn
Blechnum	cf. *B. vulcanicum*	*Blechnum*	*B. maruiense* *	unpubl.
Doodia	*D.* sp.			
?		*Peromonolites*	*P. bowenii*	Couper
?		*Peromonolites*	*P. densus*	Harris
Cyatheaceae				
Cyathea	*C.* sp.			
Cyathea	*C. colensoi*			Domin
Cyathea	cf./type *C. colensoi*			
Cyathea	*C. dealbata*			(G.Forst.) Sw.
Cyathea	aff./cf./type *C. dealbata*			
Cyathea	aff. *C. dealbata*	*Alsophila*	*A. tricolor*	(Colenso) R.M.Tryon
Cyathea	*C. medullaris*			(G.Forst.) Sw.
Cyathea	*C. smithii*			Hk.fil.
Cyathea	aff./cf./type *C. smithii*			
*Hemitelia**				
*Hemitelia**		*Foveotriletes*	*F. crater*	Partridge
*Hemitelia**		*Foveotriletes*	*F. verrucosus*	Pocknall & Mildenhall
*Hemitelia**		*Kuylisporites*	*K. waterbolkii*	Potonie
unspec				
?		*Cyathidites*	*C.* sp.	
?		*Cyathidites*	*C. australis*	Couper
?		*Cyathidites*	*C. concavus*	(Bolkh.) Dettmann
?		*Cyathidites*	aff./cf. *C. concavus*	
?		*Cyathidites*	*C. minor*	Couper
?		*Cyathidites*	*C. punctatus*	(Delcourt & Sprumont)
?		*Cyathidites*	*C.* cf. *smithii*	
?		*Cyathidites*	*C. splendens*	
?		*Cyathidites*	*C. subtilis*	Partridge
?		*Cyathidites/Leiotriletes* sp.		
?		*Foveotriletes*	*F. labrus*	n.sp.
?		*Triancoraesporites*	*T.* sp.	
Cyatheaceae/Dicksoniaceae				
?		*Cibotiidites*	*C.* sp.	
Davalliaceae				
Davallia	*D.* sp.			
Davallia	*D. tasmani*			Field
Dennstaedtiaceae				
Histiopteris	*H.* sp.			
Histiopteris	cf. *H.* sp.			
Histiopteris	*H. incisa*			(Thunb.) J.Sm.

Cr	Pal		Eo			Oli		Mio			Pli		Ple		H	Reference
L	E	L	E	M	L	E	L	E	M	L	E	L	E	L		(see Appendix 1)
									1							24
															1	6
									1	1	1	1	1	1	**1**	24
															1	6
2																19,76
								1	**1**							94
									1	2	1	**2**				16,24
								1	1	**1**						19
										1			1			74,75
															1	20
									1	**1**						24
													1	2	1	9,16
10	2	2	3	1	2	1										9,13,14,27,50,63,65,82,97,98,99,100,108
5	3	2	2	2	3	2										1,5,27,30,65,96,98,99,100
1				2	2	1			1	6	**4**	12	5	8	6	4,28,37,38,39,42,43,44,45,46,49,51,52,53,54,58,60,64,68,70, 71,73,78,90,92,106
										1	1	2	1	2	1	6,16,40,60,111
												1		1		15,33
						1				**4**	6	12	5	7	6	9,10,12,15,16,20,21,26,31,33,40,45,49,53,57,60,64,68,70,103, 104,111
2	1	1	1	2	3	2								1	3	6,9,14,18,32,33,34
										1	1	1	1	1	**1**	24
										1	3	12	**4**	6	5	6,9,13,15,16,20,21,26,33,45,46,49,53,54,57,60,68,111
						1				3	5	12	5	**4**	5	6,12,16,20,21,40,45,46,49,53,54,57,60,64,68,70,90,92,103, 104,111
2	1	1	1	1	3	2	1	2		2	2	2	2	2	6	6,7,8,9,9,10,14,18,31,32,33,34,78,92
			1	1	1	1	1									52
							4	**4**	1	2	1					52,60,79,80,81,83,89
							2	2	1	1						85,89
		1			6	6	7	3								30,52,65,69,80,83,85,87,89,91,98,99
			1		1	1	2	**2**								24,84,86
8	3	3	**4**	6	11	**4**	6	6	2	1						1,3,24,27,30,48,59,61,65,66,67,79,80,81,83,85,88,89,91,97,98, 99,100,107,108
6	1	2	2	1		1				1	1	1				23,25,47,50,61,63,65,98,100
1																63
2																47,93
8	2	2	3	**4**	**4**	2	1			1	1	1				3,5,23,25,27,47,50,61,63,88,93,97,98
1																63
												1				7
	1	1	1													100
						1	1									83,89
1	1	1														93
								1	1			1				54,59
	1	1	2	1												1,100
2	2	1		1	1	1	1									98,107
													1			52
									1	1	1	1	1	1	**1**	24
						1								1	1	33,34,52
								1								79
									1	8	7	12	**4**	5	7	4,9,10,15,16,20,21,28,32,34,44,46,49,53,54,57,58,60,68,90, 104,106

Table 1 (*continued*)

Family Modern Genus	Modern species	Recorded genus	Recorded species	Authority
Histiopteris	*H. incisa*?	*Polypodiisporites*	*P. histiopterioides*	(Krutzsch) Nagy
Histiopteris	cf. *H. incisa*	*Polypodiisporites*	*P.* cf. *histiopterioides*	(Krutzsch) Nagy
Hypolepis	*H.* sp.			
Hypolepis	*H. ambigua* or *dicksonioides*	*Hypolepis*	as *H. tenuifolia*	(G.Forst.) Bernh.
Hypolepis	*H. ambigua* or *dicksonioides*	*Hypolepis*	as aff./cf. *H. tenuifolia*	
Hypolepis		*Hypolepis*	*H. maruiensis**	unpubl.
Hypolepis		"*Hypolepis*"	*H. spinyspora**	
Leptolepia	*L.* sp.			
Lindsaea	*L.* sp.			
Lindsaea	*L. linearis*			Sw.
Lindsaea	*L. trichomanoides*			Dryand.
Lindsaea	*L. trichomanoides*	*Lindsaea*	as *L. cuneata*	(G.Forst.) C.Chr.
Lindsaea	aff. *L. trichomanoides*			
Paesia	*P.* sp.			
Paesia	*P. scaberula*			(A.Rich.) Kuhn
Paesia	aff./? *P. scaberula*			(A.Rich.) Kuhn
Pteridium	*P.* sp.			
Pteridium	*P. esculentum*			(G.Forst.) Cockayne
Pteridium	*P. esculentum*	*Pteridium*	as *P. aquilinum*	(L.) Kuhn
Pteridium	*P. esculentum*	*Pteridium*	as *P. aquilinum* var. *esculentum*	(G.Forst.) Kuhn
Pteridium	cf. *P. esculentum*	*Pteridium*	as cf. *P. aquilinum*	
Dicksoniaceae				
Dicksonia	*D.* sp.			
Dicksonia	*D. fibrosa*			Col.
Dicksonia	*D. fibrosa* ?			Col.
Dicksonia	*D. lanata*			Col.
Dicksonia	aff./? *D. lanata*			
Dicksonia	*D. squarrosa*			(G.Forst.) Sw.
Dicksonia	aff./? *D. squarrosa*			
Dicksonia		*Dicksonia*	*D. pterioides*	Ettingsh.
Dicksonia		*Matonisporites*	*M. ornamentalis*	(Cookson) Partridge
*Culcita**		*Rugulatisporites*	*R.* sp.	
*Culcita**		*Rugulatisporites*	*R. cowrensis*	(Martin)
*Culcita**		*Rugulatisporites*	*R. mallatus*	Stover
*Culcita**		*Rugulatisporites*	cf./? *R. mallatus*	Stover
*Culcita**		*Rugulatisporites*	*R. micraulaxus*	Partridge
*Culcita**		*Rugulatisporites*	*R. trophus*	Partridge
*Culcita**		*Rugulatisporites*	*R.* cf. *trophus*	Partridge
?		*Cibotiidites*	*C. tuberculiformis*	(Cookson)
?		*Concavissimisporites*	*C.* cf. *penolaensis*	Dettmann
?		*Trilites*	*T. kopukuensis*	Couper
?		*Trilites*	*T. tuberculiformis*	Cookson
?		*Trilites*	cf. *T. tuberculiformis*	
Dicksoniaceae/Schizaeaceae				
?		*Ischyosporites*	*I.* sp.	
?		*Ischyosporites*	*I. gremius*	Stover
?		*Ischyosporites*	cf. *I. gremius*	
Dryopteridaceae				
Arachnoides				
Athyrium	*A.* sp.			
Ctenitis	*C.* sp.			
Cyrtomium				
Cystopteris				
Deparia	*D. petersenii*	*Athyrium*	as *A. japonicum*	

Cr	Pal		Eo			Oli		Mio			Pli		Ple		H	Reference
L	E	L	E	M	L	E	L	E	M	L	E	L	E	L		(see Appendix 1)
						1		1	1	1	1	1	1	1	1	30,59
										1	1					58
								1			2	5	2	2	5	20,21,26,28,32,52,53,54,58,60,68,92
												2	1	2	2	28,44,53
									1	1	1	1	2	3	**2**	9,16,24
									1	**1**						24
								1								30
													1			52
										1				1	1	28,52
										1	1	5	1	2	2	28,44,45,53,60,64,68
												1			1	20,68
										1	1	2	1	2	1	9,16
					1	1										18
						1							1	2		33,52,111
										3	5	13	**4**	7	5	9,15,16,20,21,28,36,40,44,45,46,49,53,54,58,60,92,104,106
					2	1	**4**	5	2	3	2	3	3	2	1	13,18,44,58,59,68,79,80,81,83,89,91
						1				2	**1**	1		1	2	10,16,20,33,52,57,78
											1	1	2	1	3	31,32,34,54,74
								1	2	6	3	9	**4**	5	5	4,9,10,15,16,28,36,40,44,45,49,53,60,64,68,71,90
					1	1		1	1	1	1	2	1	1	**2**	16,18,20,24
								1	1	1						59
1												1		1		52,58,92
										2	2	5	2	5	6	6,9,15,16,20,28,32,33,34,40,60,68
												1				7
												2			3	6,26,34,44,58
									1	1	1	1	1	1	**2**	24,104
									1	7	6	14	8	11	13	4,6,9,16,20,21,26,28,31,32,33,34,36,40,42,43,44,45,49,53,54, 57,58,60,64,68,78,90,92,104,106,111
1	1	2	2	3	5	**4**	1	1	1	1	1	2	1	1	1	13,15,18,35,37,38,39,70,110
1	1	1	1	1	1	1	1	1	1	1	**1**					19
1	2	1										2				30,68,72,96,98
4	1				1							2				3,58,67,91,93,99,106
								1	2	2	2					30,59,60
	2	3	3	3	2	**4**	6	3	1	1	1	1				1,30,59,65,80,81,83,87,88,89,91,98,100
								1	1			1				24,58
							1	**4**								79,81,85,89
			1	1	1	1	2	**4**	1	2	2	3	1			30,54,59,60,85,89,106
								1								81
2	1	1	2	**4**	5	3										1,5,65,88,97,99,100
1																98
				1	2											13,14
5	2	2	3	**4**	**4**	2	**4**	5	2	2	1	1				24,27,50,58,59,61,63,66,67,79,80,81,83,88,89,91,93,108
2	1	1			1			1		1	1					3,9,7,48,58,67
			1													66
				1	1		2	2	1	1						59,66,81,83,89,91
							1			1	1					58,80
												1				52
													1			52
										1	1					60

Table 1 (*continued*)

Family Modern Genus	Modern species	Recorded genus	Recorded species	Authority
Diplazium				
Dryopteris	*D.* sp.			
Dryopteris		*Dryopteris*	*D. novae-zealandiae*	Oliv.
Lastreopsis	*L. glabella*	as *Ctenitis*	as *C. glabella*	(A.Cunn.) Copel.
Lastreopsis	*L. hispida*	as *Rumohra*	as *R. hispida*	(Sw.) Cop.
Polystichum	*P.* sp.			
Rumohra	*R.* sp.			
Rumohra	*R. adiantiformis*			(G.Forst.) Ching
Gleicheniaceae				
Dicranopteris	*D.* sp.			
Dicranopteris		*Dictyophyllidites*	*D. arcuatus*	Pocknall & Mildenhall
Gleichenia	*G.* sp.			
Gleichenia	? *G.* sp.			
Gleichenia	*G. dicarpa*	as *Gleichenia*	as *G. circinata*	Sw.
Gleichenia	aff. *G. dicarpa*	as *Gleichenia*	as aff./? *G. circinata*	Sw.
Gleichenia		*Gleichenia*	*G. obscura*	Ettingsh.
Gleichenia		*Cladophlebis*	*C. obscura*	(Ettingsh.) McQueen
Gleichenia		*Sticherus*	*S. obscurus*	(Ettingsh.) Oliver
Gleichenia		*Gleichenia*	*G. southlandica*	n.sp.
Sticherus	*S.* sp.			
Sticherus	*S. cunninghamii*			(Hew. ex Hook.) Ching
Sticherus	*S. cunninghamii*	as *Gleichenia*	as *G. cunninghamii*	Hew. ex Hook.
unspec	unspec			
?		*Clavifera*	*C.* sp.	
?		*Clavifera*	*C. rudis*	Bolkh.
?		*Clavifera*	*C. triplex*	(Bolkh.)
?		*Gleicheniidites*	*G.* sp.	
?		*Gleicheniidites*	type/? *G.* sp.	
?		*Gleicheniidites*	*G. circinidites*	Cookson
?		*Gleicheniidites*	cf. *G. fernonensis*	(Delcourt & Sprumont)
?		*Gleicheniidites*	*G. senonicus*	Ross
?		*Ornamentifera*	*O.* sp.	
Grammitidaceae				
Ctenopteris	*C. heterophylla*			
Ctenopteris	*C. heterophylla*	*Grammitis*	as *G. heterophylla*	Labill.
Grammitis	*G.* sp.			
Grammitis	cf./? *G.* sp.			
Grammitis		*Gemmatriletes*	*G. multiglobus*	n.sp.
Grammitis		*Gemmatriletes*	*G.* sp.	Pierce
Hymenophyllaceae				
Hymenophyllum	*H.* sp.			
Hymenophyllum	type *H.* sp.			
Hymenophyllum	cf. *H. bivalve*			(G.Forst.) Sw.
Hymenophyllum	*H. demissum*			(G.Forst.) Sw.
Hymenophyllum	*H. demissum/flexuosum*	*Hymenophyllum*	*H.* sp. (*demissum-flexuosum* gp.)	
Hymenophyllum	*H. dilatatum/pulcherrimum*	*Hymenophyllum*	*H.* sp. (*dilatatum-pulcherrimum* gp.)	
Hymenophyllum	cf. *H. ferrugineum*			Colla
Hymenophyllum	*H. multifidum*			(G.Forst.) Sw.
Hymenophyllum	cf. *H. multifidum*			(G.Forst.) Sw.
Hymenophyllum	*H. sanguinolentum*			(G.Forst.) Sw.
Hymenophyllum	aff./cf. *H. sanguinolentum*			(G.Forst.) Sw.
Hymenophyllum	*H. scabrum*			A.Rich.

Cr	Pal		Eo			Oli		Mio			Pli		Ple		H	Reference
L	E	L	E	M	L	E	L	E	M	L	E	L	E	L		(see Appendix 1)
										3	**1**					9,10,16
											1	1	**1**			16,74
												1				15
															1	20
										1	1	1	1			52,60,68
										1						52
										1	1	1	1	1	2	9,20
1																52
								2	1	1		1				54,59,89
1		1	1	2	2		1			1	1	**4**	1	2	**4**	6,22,32,33,34,37,38,39,44,52,55,58,71,90,92,110,111
												1				**44**
							1	2	2	6	**4**	12	2	5	3	7,15,16,28,36,44,49,51,53,54,57,58,59,60,64,68,89
2	1	1	1	2	2	1	1	1	1	1	1	1	1	1	2	9,14,64
1																19
1																41
1																76
							1	**1**								24
1											1	5	1	2	1	9,12,15,16,52,60
										1	1				1	58
												1			1	6,20,68
								1								84
3	2	1														27,52,93
2	2	2	1		1											65,98,99,100
7	5	5	5	2												3,27,61,62,63,86,93,97,98,99,100,108
3	2							2								27,79,81,93,107
1			1	1	1											66,82
8	**4**	5	6	5	8	3	1									3,5,27,50,61,63,65,67,86,88,91,93,97,98,99,100,108
1																91
3	2	2	1		1											65,93,98,99,100
1																52
															1	6
															1	104
										2	3	5	3	5	2	28,33,49,52,53,58,60,68,90,92
								1	2	2	1	2				4,24,58,106
								1	1							59
								1								81
3	1	1	1	2	3	2	1	2	1	**4**	6	**11**	6	7	7	6,8,9,14,15,16,24,32,33,36,43,44,46,52,53,58,60,68,70,78,92, 103,104,111
															1	6
												1				15
															2	6,20
											1	1	1	1	1	9
											1	1	1	1	1	9
											1	1	1	1	1	9
															1	20
										1	1					60
										1	1	2	1	2	3	20,28,53,60,68
									1	**1**		1				24,58
												2	1	3	2	9,16,28,40,49

Table 1 (*continued*)

Family Modern Genus	Modern species	Recorded genus	Recorded species	Authority
Hymenophyllum	cf. *H. scabrum* cf. *sanguinolentum*			
Hymenophyllum		*Hymenophyllum*	*H. miozealandicum*	unpubl.
Trichomanes	*T.* sp.			
? *Trichomanes*	? *T.* sp.			
Trichomanes	*T. elongatum-strictum*	*Trichomanes*	*T.* sp. (*elongatum-strictum* gp.)	
Trichomanes	*T. reniforme*			G.Forst.
Trichomanes	aff/? *T. reniforme*			Forst.
Trichomanes	? *T. reniforme*	*Cardiomanes*	as ? *C. reniforme*	(G.Forst.) Presl.
unspec	unspec			
?		*Biretisporites*	*B.* sp.	
?		*Biretisporites*	cf. *B.* sp.	
?		*Hymenophyllumsporites*	*H.* sp.	
?		*Trilites*	*T. fragilis*	Couper
Loxsomataceae				
Loxsoma				
Marattiaceae				
Marattia	*M.* sp.			
?		*Pecopteris*	*P. ovata*	
?		*Tuberculatisporites*	*T.* sp.	
Marsileaceae				
Pilularia	*P.* sp.			
Pilularia	*P. novae-zealandiae*			
Pilularia		*Dictyotosporites*	*D.* sp.	
?		*Crybelosporites*	cf. *C. berberoides*	Burger
?		*Crybelosporites*	*C. stylosus*	Dettman
Nephrolepidaceae				
Nephrolepis	*N.* sp.			
Nephrolepis	*N. cordifolia*			Presl.
Nephrolepis		*Polypodiisporites*	*P. minimus*	(Couper) Khan & Martin
Nephrolepis		*Polypodiisporites*	cf. *P. minimus*	
Oleandraceae				
Arthropteris	*A.* sp.			
Ophioglossaceae				
Botrychium	*B.* sp.			
Ophioglossum	*O.* sp.			
Ophioglossum	*O. coriaceum*			A.Cunn.
Ophioglossum	cf. *O. coriaceum*			A.Cunn.
Osmundaceae				
Leptopteris	*L.* sp.			
Leptopteris	*L. hymenophylloides*			(A.Rich.) Presley
Leptopteris	?/cf. *L. hymenophylloides*			
Leptopteris	cf. *L. hymenophylloides*	*Todea*	as cf. *T. hymenophylloides*	
Leptopteris	*L. superba*			
*Osmunda**		*Baculatisporites*	*B. disconformis*	Stover
*Osmunda**		*Baculatisporites*	cf. *B. disconformis*	Stover
Todea	*T.* sp.			
unspec	unspec			
?		*Baculatisporites*	*B.* sp.	
?		*Baculatisporites*	*B. comaumensis*	(Cookson)
?		*Baculatisporites*	cf. *B. comaumensis*	(Cookson)
?		*Balmeisporites*	*B. glenelgensis*	Cookson & Dettmann
?		*Balmeisporites*	*B. holodictyus*	Cookson & Dettmann
?		*Cladophlebis*	*C. prisca*	(Ettingsh.) McQueen

Cr	Pal		Eo			Oli		Mio			Pli		Ple		H	Reference
L	E	L	E	M	L	E	L	E	M	L	E	L	E	L		(see Appendix 1)
												1				15
										1	**1**					24
1										1	1	1		1		16,52,60
									1	**1**						24
											1	1	1	1	1	9
															1	20
									1							24
											1	1	1	1	1	9
					1			1	2	5	3	6	2	2	1	4,28,49,54,58,59,60,68,84,106
2			1		1	1										5,63,97,99
				1												61
1																63
4	3	2	1	1	1	1										3,9,13,14,98
1																52
1																43
				1	1											88
1														1	1	28,52
										1	1	1				58,60
1																65
1																63
2																63,98
										1		1		1		52,92
										3	2	3	1	1	1	9,10,16,103
	1	1	2	5	5	**4**	**4**	**4**	2	3	1	1				13,54,58,59,66,67,79,80,81,83,88,89,91,99
				1	1											48,61
													1			52
										1	1	3	2	5	3	28,31,32,33,34,52,54,58,68,92
											1	1	1	2	2	28,54,64
								1	1	1						59
														1	1	6,16
									1	1	1	1	1	1	**1**	24
						1										70
															1	104
															1	6
1	1	1	1	3	**4**	2	2	**4**	3	3	1	1				5,24,27,58,59,65,81,83,88,89,98,100
1		1	1	1												27,61
					1	**1**					1	1	1	1		5,52,68
								1	1			1	1			24,58
2	2	2	2	3	5	3	3	2	2	2						4,5,48,52,61,66,80,81,83,91,107,108
10	1	2	1					1								25,27,50,61,63,65,66,79,82,93,98,99
2								1	1	1						59,67,109
1																63
1																63
2																41,77

Table 1 (*continued*)

Family Modern Genus	Modern species	Recorded genus	Recorded species	Authority
?		*Cladophlebis*	*C. australis*	(Morris) Halle
?		*Cladophlebis*	*C. reversa*	Seward & Holttum
?		*Cladophlebis*	*C. wellmannii*	McQueen
?		*Osmundacidites*	*O.* sp.	
?		*Osmundacidites*	? *O.* sp.	
?		*Osmundacidites*	*O. comaumensis*	
?		*Osmundacidites*	*O. wellmanii*	Couper
?		*Osmundacidites*	cf. *O. wellmanii*	
?		*Todisporites*	*T.* sp.	
?		*Todisporites*	*T. major*	Couper
?		*Todisporites*	*T. minor*	Couper
Polypodiaceae				
Anarthropteris	? *A. dictyopteris**			(Mett.) Copel.
*Belvisia**		*Monolites*	*M. alveolatus*	Couper
*Belvisia**		*Monolites*	? *M. alveolatus*	Couper
Microsorum	*M.* sp.	*Phymatodes*	as *P.* sp.	
Microsorum	*M.* sp.	*Phymatosorus*	as *P.* sp.	
Microsorum	? *M.* sp.	*Phymatodes*	as ? *M.* sp.	
Microsorum	*M. pustulatum*	*Microsorium*	as *M. diversifolium*	(Willd.) Copel.
Microsorum	*M. pustulatum*	*Phymatodes*	as *P. diversifolium*	(Willd.) Pic. Serm.
Microsorum	*M. pustulatum*	*Phymatosorus*	as *P. diversifolius*	(Willd.) Pic. Serm.
Microsorum	aff. *M. pustulatum*	*Microsorum*	as aff. *M. diversifolium*	
Microsorum	aff. *M. pustulatum*	*Phymatodes*	as aff. *P. diversifolium*	
Microsorum	aff. *M. pustulatum*	*Phymatosorus*	as aff. *P. diversifolius*	
Microsorum	*M. scandens*	*Phymatodes*	as *P. scandens*	
Microsorum	*M. scandens*	*Phymatosorus*	as *P. scandens*	
Microsorum		*Polypodiisporites*	*P. radiatus*	Pocknall & Mildenhall
Microsorum		*Polypodiisporites*	*P. variscabratus*	Mildenhall & Pocknall
*Platycerium**		*Platycerium*	*P. morganii*	Oliv.
Polypodium				
Pyrrosia	*P.* sp.			
Pyrrosia	*P. eleagnifolia*	*Pyrrosia*	as *P. serpens*	
unspec				
?		*Monolites*	*M. major*	
?		*Monolites*	*M. minor*	Cookson
?		*Polypodiidites*	*P.* sp.	
?		*Polypodiidites*	*P. inangahuensis*	Couper
?		*Polypodiidites*	*P. minimus*	Couper
?		*Polypodiidites*	cf. *P. minimus*	Couper
?		*Polypodiidites*	*P. perverrucatus*	Couper
Microsorum	*M.*-type	*Polypodiisporites*	*P.* sp.	
?		*Polypodiisporites*	*P. inangahuensis*	(Couper) Potonie
?		*Polypodiisporites*	cf. *P. inangahuensis*	(Couper)
?		*Polypodiisporites*	*P. perverrucatus*	(Couper) Khan & Martin
Polypodiaceae/Blechnaceae				
unspec				
?		*Laevigatosporites*	*L.* sp.	
?		*Laevigatosporites*	*L. major*	(Cookson) Krutzsch
?		*Laevigatosporites*	*L. ovatus*	Wilson & Webster
Pteridaceae				
Adiantum	*A.* sp.			
Adiantum	type *A.* sp.			
Anogramma	*A.* sp.			
Anogramma	*A. leptophylla*			(L.) Link
Cheilanthes				

Cr	Pal		Eo			Oli		Mio			Pli		Ple		H	Reference
L	E	L	E	M	L	E	L	E	M	L	E	L	E	L		(see Appendix 1)
2			1	1	1	1	1	1	1	**1**						41,56,77
1																56
1																41
6	3	3	3	**4**	5	3	2	2	1	1						3,5,39,52,59,61,67,68,89,97,98,99,109
1																99
1		1														3
10			1	1												1,13,25,47,50,63,65,66,98,99,108
					1	1										99
1			1	1	1	1										1,5,50
2																50,63
2																50,63
												1				15
						2	6	5	3	**4**	2					13,30,52,59,60,71,79,81,83,85,89
										1	1					58
					1					1	1	1	1	2		33,52,58,111
												2	1	1	3	26,34,**44**,58,68,78,92
												1				**44**
						1	1	2	1	3	3	7	1	2	1	7,8,9,10,12,15,16,40,103
									1	3	3	9	2	3	5	4,20,21,28,42,**44**,46,49,53,57,58,60,64,90,104,106
										2	1	2	2	2	**4**	6,32,34,54,68,71,90
					1	1	1	1	1	1	1	1	1	1	1	13
				1	3	1		1								18,37,38,81
							3	**4**	2	2	1	1	1	1	**1**	24,59,79,80,89
										1	1			1	1	28,60
												2	1	1		54,68
						2	**4**	**4**	3	3	3	7	2	1		24,54,58,59,68,72,83,85,87,89,92,106
						1	1	1	1	1		1				59,68,87
												2	**1**			16,74,76
													1	1		33,52
											1	**4**	1	1		43,**44**,53,54,68
							1	3		1	1	2				7,8,58,68,84
		1	1	1												61
					1											48
4				2	2	2	1				1	1				5,27,43,**44**,97,98,109
						1	1	2	2	3	3	6	1			9,12,13,15,16,**44**,105
	2	2	1	3	5	**4**	1									1,3,5,13,36,38,65,98
2											1					3,43,109
						2	3	1	1							9,13,98
1	2	**4**	2	1	**4**	1	1	2		3	3	5	2	2	1	28,30,**48**,49,53,54,58,60,61,81,85,91,93,99,100
				3	**4**	3	2	**4**	3	7	**4**	**4**				2,**4**,10,21,49,58,59,60,70,79,81,83,88,89,90,91,99
					2	1						1				48,99,106
						3	5	5	2	3	1					58,59,79,80,81,83,85,87,89
					1											84
3	2	1	1	3	3											63,66,66,88,91,93,107
7	**4**	3	1	3	3	3	1									3,27,63,65,88,98,99,100,108
10	**4**	**4**	**4**	**4**	**4**	3	1									1,3,5,27,47,50,61,63,65,66,98,99,100,108
2	1	1	1	1	2	1	1	2	2	6	6	8	1	3	3	9,10,12,14,14,15,16,20,28,43,45,52,59,60,68,103
															1	32
													1			52
												1				2

Table 1 (*continued*)

Family Modern Genus	Modern species	Recorded genus	Recorded species	Authority
Pellaea	*P.* sp.			
Pteris	*P.* sp.			
Pteris	?*P.* sp.			
Pteris	*P. comans*			G.Forst.
Pteris	cf. *P. comans*			
Pteris	*P. tremula*			R.Br.
Pteris		*Pteris*	*P. pterioides*	(Ettingsh.) Oliv.
Pteris		*Camarozonosporites*	*C. bullatus*	Harris
Pteris		*Camarozonosporites*	cf. *C. bullatus*	
Pteris		*Polypodiaceoisporites*	*P.* sp.	
Pteris		*Polypodiaceoisporites*	*P. papuanus*	(Khan) Pocknall
Pteris		*Polypodiaceoisporites*	cf. *P. retirugatus*	
Pteris		*Polypodiaceoisporites*	*P. tumulatus*	Partridge
Pteris		*Polypodiaceoisporites*	cf. *P. tumulatus*	
?		*Contignisporites*	*C.* sp.	
Schizaeaceae				
*Anemia**		*Cicatricosisporites*	*C.* sp.	
*Anemia**		*Cicatricosisporites*	*C. australiensis*	(Cookson)
*Anemia**		*Cicatricosisporites*	cf. *C. australiensis*	(Cookson)
*Anemia**		*Cicatricosisporites*	cf. *C. cuneiformis*	Pocock
*Anemia**		*Cicatricosisporites*	*C. hughesii*	Dettmann
*Anemia**		*Cicatricosisporites*	*C. ludbrookiae*	Dettmann
*Anemia**		*Cicatricosisporites*	*C. venustus*	Deak
Lygodium	*L.* sp.			
Lygodium	cf. *L.* sp.			
Lygodium	*L. articulatum*			A.Rich.
Lygodium	aff. *L. articulatum*			A.Rich.
Lygodium		*Crassoretitriletes*	*C.* sp.	
Lygodium		*Crassoretitriletes*	*C. vanraadshoovenii*	
Schizaea	*S.* sp.			
Schizaea	cf. *S.* sp.			
Schizaea	cf. *S. fistulosa*			Labill.
unspec	unspec			
?		*Microfoveolatosporites*	*M.* sp.	
?		*Microfoveolatosporites*	*M. canaliculatus*	Dettmann
?		*Microfoveolatosporites*	*M. fromensis*	(Cookson) Harris
?		*Microfoveolatosporites*	*M.* cf. *fromensis*	(Cookson)
Thelypteridaceae				
Christella		*Christella*		
Cyclosorus	*C.* sp.			
Macrothelypteris		*Macrothelypteris*		
Pneumatopteris	*P. pennigera*	*Cyclosorus*	as *C. tertiario-zeelandicus*	(Ettingsh.) Oliver
Pneumatopteris	*P. pennigera*	*Goniopteris*	as *G. pennigera*	J.Sm.
Pneumatopteris	*P. pennigera*	*Goniopteris*	as *G. pennigera*	J.Sm.
Pneumatopteris	*P. pennigera*	*Thelypteris*	as *T. pennigera*	(G.Forst.) Allan
Pneumatopteris	*P. pennigera*	*Aspidium*	as *A. tertiario-zeelandicum*	Ettingsh.
Pneumatopteris	cf. *P. pennigera*			(G.Forst.) Holttum
Thelypteris	*T.* sp.			
Thelypteris	? *T.* sp.			
Thelypteris	*T. confluens*	*Thelypteris*	as *T. palustris*	Schott.
?		*Aspidium*	*A. cretaceozelandicum*	Ettingsh.
?		*Aspidium*	*A. otagoicum*	Ettingsh.
?		*Cyclosorus*	*C. cretico-zeelandicus*	(Ettingsh.) Oliv.
Vittariaceae				
*Antrophyum**	? *A.* sp.			

Cr	Pal		Eo			Oli		Mio			Pli		Ple		H	Reference
L	E	L	E	M	L	E	L	E	M	L	E	L	E	L		(see Appendix 1)
													1			52
3	1	2	2	2	2	1	1	1	1	1	1	6	2	3	1	7,9,14,15,16,33,52,58,92,106,110
												1				49
						1				1	2	5	2	2	2	21,28,49,54,60,64,68,70,106
									1	1						4
												2				54,68
1																76
1	2	2	1													98,100
							1	1								89
1	1	2	2	**4**	2	2	1	1								1,30,79,91,93,98,99
					2	1	2									83,87,91
1	1															3
			2	**4**	3	1	1	5	**4**	3	1	3	2	1	1	4,24,54,59,66,67,68,79,81,89,91,97
				1	2	1										5,66
1																99
2	2	2	1													52,63,93,100
2																50,63
		1	1	1												61
		1	1													61
1																63
1																63
1																63
	1	**1**		2					1	1						52,95,101
		1	1													110
										2	3	5	3	5	2	6,28,53,54,58,60,68,90,92,106
					1	1										18
					1			1								81,91
				1												30
								2		1	2	2	2	3	2	8,16,20,28,52,58,68
		1	1				1	1	1	1						4,61,79,80
								1	1	1	1	1	1	1	1	9
1																52
1					3	1		1	1	1						5,52,59,97,98
2																50,63
2																63,98
							1	1								89
					1	**1**										5
1																76
													1			75
												1				16
															1	20
1	1	1	1	1	1	1	1	1	1	1	**1**					19
								1	**1**							94
													1			52
												1				54
													1	1		16
2																19,41
1	1	1	1	1	1	1	1	1	1	1	**1**					19
1																76
									1	**1**						24

Table 1 (*continued*)

Family Modern Genus	Modern species	Recorded genus	Recorded species	Authority
RECORDS OF UNKNOWN AFFINITY				
Monolete spores unspec				
Trilete spores unspec				
?		*Appendicisporites*	*A. distocarinatus*	Dettmann & Playford
?		*Cingutrilites*	*C.* sp.	
?		*Cingutriletes*	*C. clavus*	(Balme)
?		*Cingutriletes*	*C.* cf. *C. clavus*	(Balme)
?		*Cingutriletes*	*C. regium*	
?		*Cladophlebis*	*C.* cf. *albertsi*	(Dunker) Seward
?		*Clavatisporites*	*C.* sp.	
?		*Coniopteris*	*C.* sp.	
?		*Coniopteris*	*C. ?lobata*	(Oldham) McQueen
?		*Contignisporites*	*C.* cf. *C. cooksoniae*	(Balme)
?		*Contignisporites*	*C.* cf. *C. glebulentus*	Dettmann
?		*Contignisporites*	*C.* cf. *C. multimuratus*	Dettmann
?		*Cyclosporites*	*C. hughesii*	(Cookson & Dettmann)
?		*Dictyophyllidites*	*D.* sp.	
?		*Dictyophyllidites*	*D. concavus*	Harris
?		*Dictyophyllidites*	*D.* cf. *D. concavus*	Harris
?		*Dictyotosporites*	*D.* sp.	
?		*Dictyotosporites*	*D.* cf. *complex*	Cookson & Dettmann
?		*Dictyotosporites*	*D. speciosus*	Cookson & Dettmann
?		*Echinosporis*	*E.* sp.	
?		*Foveogleicheniidites*	*F.* sp.	
?		*Foveotriletes*	*F.* sp.	
?		*Foveotriletes*	*F. parviretus*	(Balme) Dettmann
?		*Hazaria*	*H.* sp.	
?		*Kuylisporites*	*K. lunaris*	Cookson & Dettmann
?		*Latrobosporites*	*L. ohaiensis*	(Couper) Stover
?		*Leiotriletes*	*L.* sp.	
?		*Leptolepidites*	*L. major*	Couper
?		"*Microrugulate*"		
?		*Neoraistrickia*	*N.* sp.	
?		*Papillosporis*	*P.* sp.	
?		*Peregrinisporis*	*P.* sp.	
?		*Peromonolites*	*P.* sp.	
?		*Peromonolites*	*P. vellosus*	Partridge
?		*Perotrilites*	*P.* sp.	
?		*Perotrilites*	? *P.* sp.	
?		*Perotrilites*	*P. laceratus*	Norris
?		*Perotrilites*	*P. linearis*	(Cookson & Dettmann)
?		*Perotrilites*	*P. majus*	(Cookson & Dettmann) Evans
?		*Perotrilites*	*P. papillatus*	Harris
?		*Phyllopteroides*	*P.* sp.	
?		*Phyllopteroides*	cf. *P. dentata*	Medwell
?		*Phyllopteroides*	cf. *P. lanceolata*	(Walkom) Medwell
?		*Phyllopteroides*	cf. *P. laevis*	Cantrill & Webb
?		*Phyllopteroides*	cf. *P. serrata*	Cantrill & Webb
?		*Plicifera*	*P.* sp.	
?		*Punctatosporites*	*P.* sp.	
?		*Punctatosporites*	cf. *P.* sp.	
?		*Radialisporis*	*R.* cf. *radiatus*	(Krutzsch) Krutzsch
?		*Reticulatisporites*	*R.* sp.	
?		*Reticulatisporites*	*R. mangapipiensis*	Mildenhall

Cr	Pal		Eo			Oli		Mio			Pli		Ple		H	Reference
L	E	L	E	M	L	E	L	E	M	L	E	L	E	L		(see Appendix 1)
1		1	2	2	2	2	2	3	2	4	4	13	6	9	11	4,6,22,24,26,28,31,33,34,42,43,44,45,46,48,49,50,53,54,57,58, 60,61,64,66,68,70,73,78,79,80,81,83,92,104,106,111
2		1	1		2					3	3	5			2	22,46,48,49,50,53,54,58,60,61,66,78,106
1																63
2																27,108
3		1	1													61,63,65,99
								1	1	1						59
1																108
1																77
1																99
1																56
1																77
1																63
1																63
1																63
1																63
3	1	1	1					1								27,50,63,81,100
	3	2	1	2	1	1										3,98,99,100
			1	2												67,99
1																98
1		1	1													61,98
1																63
3	2	2	2	2	2	2	1	1	1	1						1,5,59,63,97,98,99,100
			1													97
2					1			1								63,81,91,99
1																98
					1											97
1																50
1	1	1														98
3	3	2	1	2	2	2	1									27,97,98,99,100
1																63
	1															27
	1	1	1													100
								1	1	1						59
	1	1														98
2				1	1	1										5,61,99,108
								1	1	2	1					59,60
2																93,98
	1	1	1													100
1																63
1																63
2																63,98
	2	2	1													98,100
1																56
1																77
1																77
1																77
1																77
	1	1														98
2					1	1				1	1					5,27,58,98
				1												61
			1	1												1
2					1			1								50,66,81,91
												3			1	45,49,51,64

Table 1 (*continued*)

Family Modern Genus	Modern species	Recorded genus	Recorded species	Authority
?		*Reticulatisporites*	? *R. mangapipiensis*	Mildenhall
?		*Reticulatisporites*	*R. pudens*	Balme
?		*Reticulatisporites*	? *R. pudens*	Balme
?		*Reticuloidosporites*	*R. arcus*	(Balme)
?		*Rubinella*	*R.* sp.	
?		*Rubinella*	*R. major*	(Couper) Norris
?		*Schizosporis*	*S.* cf. *parvus*	Cookson & Dettmann
?		*Sphenopteris*	*S.* sp.	
?		*Sphenopteris*	*S. mackayi*	McQueen
?		*Sphenopteris*	*S. pterioides*	Ettingsh.
?		*Toricingulatisporites*	*T.* sp.	
?		*Trilites*	*T.* sp.	
?		*Trilites*	*T.* cf. *annulata*	
?		*Trilites*	*T. bifurcatus*	Couper
?		*Trilites*	*T.* cf. *bifurcatus*	Couper
?		*Trilites*	*T. hayii*	n.sp.
?		*Trilites*	*T. lachlanae*	Couper
?		*Trilites*	*T. microfoveolatus*	
?		*Trilites*	*T. ohaiensis*	Couper
?		*Trilites*	*T. verrucatus*	Couper
?		*Trilites*	*T.* cf. *verrucatus*	Couper
?		*Trilites*	*T.* types	
?		*Verrucatosporites*	*V.* sp.	
?		*Verrucatosporites*	? *V.* sp.	
?		*Verrucosisporites*	*V.* sp.	
?		*Verrucosisporites*	*V. cristatus*	Partridge
?		*Verrucosisporites*	cf./? *V. cristatus*	Partridge

CONVENTIONS FOLLOWED

A database of all fossil records of ferns (macrofossils and spores) in New Zealand was compiled from published literature and some in press and unpublished sources. With the history of the extant fern flora in mind, the late Cretaceous, c. 90 million years before present (M yr BP), was chosen as a starting point of this database. By c. 100 M yr BP, many Mesozoic lineages had become extinct, and from the Late Cretaceous it becomes easier to assign spores to extant fern taxa (e.g., Hill & Jordan 1998; Nagalingum et al. 2002). Moreover, New Zealand broke away from Gondwana c. 85 M yr BP; thus, the database covers the period after which New Zealand became a separate biogeographical region (Sutherland 1999 and references therein; Lee et al. 2001).

As part of the Species 2000 project, great efforts have been made to produce an electronic list of all known extinct and extant species in the world (http://www.sp2000.org). Three workers have produced the section on pre-Pleistocene fern macro- and microfossils of New Zealand (Pole (in Breitweiser et al. in press) and Raine & Mildenhall (in Breitweiser et al. in press), respectively). These authors kindly allowed their records, which are awaiting publication, to be used in the compilation of this database.

The database includes more than 3300 occurrences of fern macro- and microfossils as recorded in 112 references. The oldest reference is Ettingshausen (1891), but most references are post 1960. Using Microsoft Excel, each fossil occurrence was documented for the time period recorded in the references.

We provide a summary of all fern fossil records in New Zealand from the late Cretaceous onwards (Table 1). In this table each row refers to one taxon and the number of records per time period is noted. The references for these records are numbered in the "Reference" column and included as Appendix 1. When macrofossils are included in one or more of the records, the relevant digit is printed in bold and underlined.

Cr	Pal		Eo			Oli		Mio			Pli		Ple		H	Reference
L	E	L	E	M	L	E	L	E	M	L	E	L	E	L		(see Appendix 1)
												1				49
1																63
1																50
1																63
3																65,98
2																65,98,99
1																50
1																17
2																41,77
1																41
			1													97
8	1	2								1	1	3	1			3,15,27,52,58,68,108,109,112
1																3
											1	3	3	1	1	2,13,44,57
												1				57
								1								9
											1	1	1			9,16
1																108
6	1	2	1	1	1	1										3,9,13,14,27,109
8	2	1			1	1										3,9,13,14,18,27,50,82,93
2																27,108
1																52
1																109
					1											97
					1					1	1					58,91
								1	1	2	1					59,60
							1	1		1	1					58,89

Taxa are arranged under the following groups: fern allies, true ferns, and records of unknown affinity. Within these groups, taxa are listed alphabetically by family, genus, and species. Form-taxa that have a probable or known affinity with a certain modern taxon are included under that taxon. The form-taxa are then listed in the "Recorded Genus/Species" column(s), with the affinity in the "Modern Family/Genus/Species" column(s). The taxa are shown as recorded by the original author, including "aff.", "cf.", or "?" where appropriate. These represent records of a spore/macrofossil with affinity to or comparable to a known (form) taxa, or a spore/macrofossil possibly identifiable as a certain taxon, respectively. In this condensed version of the data, these records are combined (as shown in the appropriate columns).

The nomenclature used in the original reference is updated where currently accepted names (following Brownsey & Smith-Dodsworth 2000) could be unequivocally determined. In that case, the original name is cited in the "Recorded Genus/Species" column(s). This is not always possible; for example, when the old name has been split into two or more new names, in which case the original name is still used in the "Modern Genus/Species" column(s).

In the original references, the time range for each fossil record was given in terms of New Zealand stages or international time series. For incorporation in the database, the New Zealand stages were all transferred to the international timescale using the latest version of the New Zealand geological timescale (Cooper 2004). If records were given in terms of both New Zealand stages and international time series and this combination was incongruent with Cooper (2004), the New Zealand stage noted was then reassigned to the international time period according to the new timescale. The data are summarised as recorded by the original author, and care should therefore be taken regarding inconsistencies and out-of-date stratigraphic information and identifications.

The summary presented here (Table 1) is the abbreviated version of the electronic data (in Microsoft

Excel format), which is available on http://www.otago.ac.nz/geology/databases and from the authors on request. More detail can be obtained from this electronic version where each fossil record mentioned in all references is included as one row. This shows the appropriate time interval for each fossil taxon as well as the geographical ranges in which the fossils were found. The bibliographical references to the affinities of the form-taxa are also provided. This electronic version is the recommended way of using the data, since searching, sorting, adding, amending, and deleting taxa may be readily carried out.

DISCUSSION

This study provides the first complete and comprehensive review of the late Cretaceous–Cenozoic fern fossil record of New Zealand. The database should form the foundation of future studies on the history, biogeography, and phylogeny of New Zealand ferns. It provides minimum estimates for times of arrival and/or origin of lineages in the region, which should greatly increase our understanding of the biogeography of ferns.

For example, Brownsey (2001) suggested that ferns are plants of ancient lineage, but that "most pteridophytes have arrived in New Zealand relatively recently, by long-distance dispersal". This hypothesis can now be re-assessed with the use of the above up-to-date fossil information (Cieraad 2003).

The database shows that 11 of the 23 extant families with a fossil record have been in the New Zealand region since the late Cretaceous, while eight families have probably arrived since Miocene times (Table 2). Most modern species have appeared in the known fossil record since the early to late Miocene as shown by the presence of their spores in the fossil record, although morphologically very similar spores may have been present for much longer periods (Table 1; Polypodiaceae, *Microsorum pustulatum*). That the Miocene is a significant transition period is evident in the database (Table 1), where spores which are possibly related to ("aff.", "cf.") now become indistinguishable from their modern equivalent. This could be an artefact caused by researcher conservatism (i.e., not wanting to attribute a fossil spore >20 million years old to a living species), or by actual morphological differences in the spores relating to species evolution.

The database also provides a valuable source for age estimates of lineages that are needed to calibrate molecular dating studies. For example, a recent study on molecular data of temperate Australasian *Polystichum* ferns (Perrie et al. 2003) has found that the genus probably arrived in New Zealand through trans-oceanic dispersal from Australia within the last 20 million years. These authors noted that, in all likelihood, the arrival occurred much more recently than the 20 M yr estimate. The New Zealand fossil record (Table 1, Dryopteridaceae, *Polystichum* sp.) is in line with the findings of Perrie et al. (2003), with the first appearance of the family in the late Miocene (c. 11–6 M yr BP) (rather than in the Quaternary as stated by Mildenhall (1980)).

It should be kept in mind that the oldest fossil record of a taxon gives only a minimum estimate of its age and may not always be a good approximation of the length of time the taxon has actually existed (e.g., Moran & Smith 2001). As Pole (2001) pointed out, the accuracy of first appearances depends on the

Table 2 Appearance of extant New Zealand fern families in the fossil record since the separation of New Zealand from Gondwana. *, also present prior to 85 M yr BP.

Time period	Family
Late Cretaceous (from c. 85 Mya)	Blechnaceae*?, Cyatheaceae*, Dicksoniaceae*, Gleicheniaceae*, Hymenophyllaceae, Lycopodiaceae*, Marattiaceae*, Osmundaceae*, Polypodiaceae, Pteridaceae, Schizaeaceae, Thelypteridaceae
Paleocene	Nephrolepidaceae
Eocene	Dennstaedtiaceae, Psilotaceae
Oligocene	-
Miocene	Aspleniaceae, Davalliaceae, Dryopteridaceae, Grammitidaceae, Isoetaceae, Marsileaceae, Ophioglossaceae
Pliocene	-
Pleistocene	Azollaceae, Oleandraceae
Holocene	-

"length of time over which an organism is found as a fossil and the number of fossiliferous horizons [that have been studied] within that period". Gaps in the fossil record can be caused by differences in preservation of sedimentary environments. First appearances should therefore be seen in the light of the number of gaps in the records, and increasing data should usually reduce the confidence limits on these appearances (Pole 2001). Similarly, apparent discontinuities are not always an indicator for the interruption of *in situ* lineages and new long-distance introductions (Winkworth et al. 1999).

ACKNOWLEDGMENTS

We would like to thank Jennifer Bannister, Patrick Brownsey, Bill Lee, John Lovis, Dallas Mildenhall, Leon Perrie, and two anonymous referees who helped improve this paper. We also thank Tim Bishop for his help with the database and Dallas Mildenhall, Mike Pole, and Ian Raine for providing the Species 2000 data.

REFERENCES

Breitweiser I, Garnock-Jones P, Wilton A, Mildenhall DC, Raine JI, Pole M, Brownsey P in press. Phylum Tracheophyta – Ferns and fern allies, conifers and flowering plants. In: Gorden DP ed. The New Zealand inventory of biodiversity volume 3: kingdoms bacteria, protozoa, chromista, plantae and fungi. Christchurch, Canterbury University Press.

Brownsey PJ 2001. New Zealand's pteridophyte flora – plants of ancient lineage but recent arrival? Brittonia 53: 284–303.

Brownsey PJ, Smith-Dodsworth JC 2000. New Zealand ferns and allied plants. 2nd ed. Auckland, New Zealand, David Bateman.

Cieraad E 2003. New Zealand fossil ferns: history and ecological significance. Unpublished MSc thesis, University of Amsterdam, Amsterdam, The Netherlands. Held at Science Library, University of Otago, Dunedin, New Zealand.

Collinson ME 2001. Cainozoic ferns and their distribution. Brittonia 53: 173–235.

Cooper RA 2004. The New Zealand Geological Timescale. Institute of Geological and Nuclear Sciences Monograph 22.

Ettingshausen CB von 1891. Contributions to the knowledge of the fossil flora of New Zealand. Transactions and Proceedings of the New Zealand Institute 23: 237–310.

Hill RS, Jordan GJ 1998. The fossil record of ferns and fern allies in Australia. Flora of Australia 48: 29–35.

Kato M 1993. Biogeography of ferns: dispersal and vicariance. Journal of Biogeography 20: 265–274.

Lee DE, Lee WG, Mortimer N 2001. Where and why have all the flowers gone? Depletion and turnover in the New Zealand Cenozoic angiosperm flora in relation to palaeogeography and climate. Australian Journal of Botany 49: 341–356.

Lovis JD 1959. The geographical affinities of the New Zealand pteridophyte flora. The British Fern Gazette 9: 16–22.

Lovis JD 2003. When and where did 'polypodiaceous' ferns arise? Journal of Biogeography 30: 963–966.

Macphail MK 1997. The New Zealand flora – Entirely long-distance dispersal? Comment. Journal of Biogeography 24: 113–117.

McGlone MS, Duncan RP, Heenan PB 2000. Endemism, species selection and the origin and distribution of the vascular plant flora of New Zealand. Journal of Biogeography 28: 199–216.

Mildenhall DC 1980. New Zealand Late Cretaceous and Cenozoic plant biogeography: a contribution. Palaeogeography, Palaeoclimatology, Palaeoecology 31: 197–233.

Moran RC, Smith AR 2001. Phytogeographic relationships between neotropical and African-Madagascan pteridophytes. Brittonia 53: 304–351.

Nagalingum NS, Drinnan AN, Lupia R, McLoughlin S 2002. Fern spore diversity and abundance in Australia during the Cretaceous. Review of Palaeobotany and Palynology 119: 69–92.

Parris BS 2001. Circum-Antarctic continental distribution patterns in pteridophyte species. Brittonia 53: 270–283.

Perrie LR, Brownsey PJ, Lockhart PJ, Brown EA, Large MF 2003. Biogeography of temperate Australasian *Polystichum* ferns as inferred from chloroplast sequence and AFLP. Journal of Biogeography 30: 1729–1736.

Pole M 1994. The New Zealand flora – entirely long-distance dispersal. Journal of Biogeography 21: 625–635.

Pole MS 2001. Can long-distance dispersal be inferred from the New Zealand plant fossil record? Australian Journal of Botany 49: 357–366.

Pryer KM, Schuettpelz E, Wolf PG, Schneider H, Smith AR, Cranfill R 2004. Phylogeny and evolution of ferns (monilophytes) with a focus on the early leptosporangiate divergences. American Journal of Botany 91: 1582–1598.

Schneider H, Schuettpelz E, Pryer KM, Cranfill R, Magallon S, Lupia R 2004. Ferns diversified in the shadow of angiosperms. Nature 428: 553–557.

Skog JE 2001. Biogeography of Mesozoic leptosporangiate ferns related to extant ferns. Brittonia 53: 236–269.

Sutherland R 1999. Basement geology and tectonic development of the greater New Zealand region: an interpretation from regional magnetic data. Tectonophysics 308: 341–362.

Winkworth RC, Robertson AW, Ehrendorfer F, Lockhart PJ 1999. The importance of dispersal and recent speciation in the flora of New Zealand. Journal of Biogeography 26: 1323–1325.

Winkworth RC, Wagstaff SJ, Glenny D, Lockhart PJ 2002. Plant dispersal NEWS from New Zealand. Trends in Ecology & Evolution 17: 514–520.

Wolf PG, Schneider H, Ranker TA 2001. Geographic distributions of homosporous ferns: does dispersal obscure evidence of vicariance? Journal of Biogeography 28: 263–270.

Appendix 1. References to Table 1.

1 Aitchison JC, Campbell HJ, Campbell JD, Raine IJ 1983. Appendix: Geological setting of the Livingstone fossil insect. In: Harris AC. An Eocene larval insect fossil (Diptera: Bibionidae) from North Otago, New Zealand. Journal of the Royal Society of New Zealand 13: 93–105.

2 Bowen FE, Harris WF, Parsons WH 1968. The age of the Wairakau andesitic breccia at the Whangaroa harbour, Northland. New Zealand Journal of Geology and Geophysics 11: 262–264.

3 Browne KW, MacKinnon DI 1989. Palynological correlations at Kaitangata Coalfield. Energy Research and Development Report 8819. Wellington, Ministry of Energy.

4 Campbell JD 1985. Casuarinaceae, Fagaceae, and other plant megafossils from Kaikorai Leaf Beds (Miocene), Kaikorai Valley, Dunedin, New Zealand – Unpublished palynological data by D.C. Mildenhall. New Zealand Journal of Botany 23: 311–320.

5 Cieraad E 2003. New Zealand fossil ferns: history and ecological significance. Unpublished MSc thesis, University of Amsterdam, Amsterdam, The Netherlands. Held at Science Library, University of Otago, Dunedin, New Zealand.

6 Clarkson BR, McGlone MS, Lowe DJ, Clarkson BD 1995. Macrofossils and pollen representing forests of the pre-Taupo volcanic eruption (c.1850 yr BP) era at Pureora and Benneydale, central North Island, New Zealand. Journal of the Royal Society of New Zealand 25: 263–281.

7 Couper RA 1951. Microflora of a submarine lignite from Toetoes Bay, near Bluff, New Zealand. New Zealand Journal of Science and Technology 33 B: 179–186.

8 Couper RA 1952. The spore and pollen flora of the *Cocos*-bearing beds, Mangonui, North Auckland. Transactions of the Royal Society of New Zealand 79: 340–348.

9 Couper RA 1953a. Upper Mesozoic and Cainozoic spores and pollen grains from New Zealand. New Zealand Geological Survey Paleontological Bulletin 22.

10 Couper RA 1953b. Plant microfossil dating of some New Zealand upper Tertiary volcanic rocks. New Zealand Journal of Science and Technology 34 B: 373–377.

11 Couper RA 1954a. Plant microfossils from New Zealand No. 1. Transactions of the Royal Society of New Zealand 81: 479–483.

12 Couper RA 1954b. Lower Pleistocene plant microfossils from the Glenhope beds and Moutere gravels, Nelson, New Zealand. New Zealand Journal of Science and Technology 36 B: 136–139.

13 Couper RA 1960. New Zealand Mesozoic and Cainozoic plant microfossils. New Zealand Geological Survey Paleontological Bulletin 32.

14 Couper RA 1964. Plant microfossils from the Ohai and Nightcaps Groups. In: Bowen FE. Geology of Ohai Coalfield. New Zealand Geological Survey Bulletin 51: 145–156.

15 Couper RA, Harris WF 1960. Pliocene and Pleistocene plant microfossils from drillholes near Frankton, New Zealand. New Zealand Journal of Geology and Geophysics 3: 15–22.

16 Couper RA, McQueen DR 1954. Pliocene and Pleistocene plant fossils of New Zealand and their climatic interpretation. New Zealand Journal of Science and Technology 35 B: 398–420.

17 Edwards WN 1926. Cretaceous plants from Kaipara, New Zealand. Transactions and Proceedings of the New Zealand Institute 56: 121–128.

18 Edwards AR 1991. The Oamaru Diatomite. New Zealand Geological Survey Paleontological Bulletin 64: 240–241.

19 Ettingshausen CB von 1891. Contributions to the knowledge of the fossil flora of New Zealand. Transactions and Proceedings of the New Zealand Institute 23: 237–310.

20 Harris WF 1961. Peat samples. In: Hamilton WM ed. Little Barrier Island (Hauturu). DSIR Bulletin 137: 78–86.

21 Harris WF 1964. Pollen and spores of the Makara Tertiary beds. In: Grant-Taylor TL, Hornibrook, NdeB. The Makara Faulted Outlier and the age of Cook Strait. New Zealand Journal of Geology and Geophysics 7: 311–313.
22 Harris WF, Filmer DW 1946. A peat profile in the agricultural area, Hauraki Plains, New Zealand. New Zealand Journal of Science and Technology 28 B: 1–19.
23 Haskell TR, Wilson GJ 1975. Palynology of sites 280–284, DSDP Leg 29, off southeastern Australia and western New Zealand. In: Kennett JP, Houtz RE ed. Initial reports of the Deep Sea Drilling Project -XXIX. Washington, US Government Printing Office. Pp. 723–741.
24 Holden AM 1983. Studies in New Zealand Oligocene and Miocene plant macrofossils. Unpublished PhD thesis, Victoria University of Wellington, Wellington, New Zealand.
25 Hornibrook NdeB, Edwards AR, Mildenhall DC, Webb PN, Wilson GJ 1976. Major displacements in Northland, New Zealand; Micropaleontology and stratigraphy of Waimamaku 1 and 2 wells. New Zealand Journal of Geology and Geophysics 19: 233–263.
26 Horrocks M, Jones MD, Beever RE, Sutton DG 2002. Analysis of plant microfossils in prehistoric coprolites from Harataonga Bay, Great Barrier Island, New Zealand. Journal of the Royal Society of New Zealand 32: 617–628.
27 Kennedy EM 1993. Palaeoenvironment of an Haumurian plant fossil locality within the Pakawau group, Northwest Nelson, New Zealand. Unpublished MSc thesis, University of Canterbury, Christchurch, New Zealand.
28 Lewis KB, Mildenhall DC 1985. The late Quaternary seismic, sedimentary and palynological stratigraphy beneath Evans Bay, Wellington Harbour. New Zealand Journal of Geology and Geophysics 28: 129–152.
29 Lintott WH, Burrows CJ 1973. A pollen diagram and macrofossils from Kettlehole Bog, Cass, South Island, New Zealand. New Zealand Journal of Botany 11: 269–282.
30 Macphail MK 1997. The New Zealand flora – Entirely long-distance dispersal? Comment. Journal of Biogeography 24: 113–117.
31 McGlone MS 2002. A Holocene and latest Pleistocene pollen record from Lake Poukawa, Hawke's Bay, New Zealand. Global and Planetary Change 33: 283–299.
32 McGlone MS, Wilmshurst JM 1999. A Holocene record of climate, vegetation change and peat bog development, east Otago, South Island, New Zealand. Journal of Quaternary Science 14: 239–254.
33 McGlone MS, Howorth R, Pullar WA 1984. Late Pleistocene stratigraphy, vegetation and climate of the Bay of Plenty and Gisborne regions, New Zealand. New Zealand Journal of Geology and Geophysics 27: 327–350.
34 McGlone MS, Mark AF, Bell D 1995. Late Pleistocene and Holocene vegetation history, Central Otago, South Island, New Zealand. Journal of the Royal Society of New Zealand 25: 1–22.
35 McIntyre DJ 1962. Pollen from deeply buried coal measures, Taranaki, New Zealand – No. 2. New Zealand Journal of Geology and Geophysics 5: 314–319.
36 McIntyre DJ 1963. Appendix. Pollen analysis of a peat in Koputaroa dune sand. In: Cowie JD. Dune-building phases in the Manawatu District, New Zealand. New Zealand Journal of Geology and Geophysics 6: 268–280.
37 McIntyre DJ, Harris WF 1961. Pollen from deeply buried coal measures, Taranaki, New Zealand – No. 1. New Zealand Journal of Geology and Geophysics 4: 400–406.
38 McIntyre DJ, Norris G 1966a. Lower Tertiary pollen and microplankton from deeply buried coal measures, Taranaki, New Zealand. New Zealand Journal of Geology and Geophysics 9: 243–246.
39 McIntyre DJ, Norris G 1966b. Subsurface lower Tertiary microfloras from Westland, New Zealand. New Zealand Journal of Geology and Geophysics 9: 247–250.
40 McQueen DR 1953. A fossil flora from the Upper Pliocene of Rangitikei Valley. New Zealand Journal of Science and Technology 35 B: 134–140.
41 McQueen DR 1956. Leaves of Middle and Upper Cretaceous pteridophytes and cycads from New Zealand. Transactions of the Royal Society of New Zealand 83: 673–685.
42 Mildenhall DC 1971. Appendix: Pollen and spores from Palmers Beach, Auckland. In: Moore PR, McKelvey RJ. Pliocene and Quaternary sediments from Weymouth, Auckland. Tane 17: 181–195.
43 Mildenhall DC 1974. Appendix II. Pollen and spores from the Wainora Formation (Whitianga Group), Coromandel Peninsula, North Island, New Zealand. In: Hayward BW. Whitianga Group sediments of the Table Mountain area, Coromandel Peninsula. Journal of the Royal Society of New Zealand 4: 161–176.
44 Mildenhall DC 1975a. Palynology of the *Acacia*-bearing beds in the Komako district, Pohangina Valley, North Island, New Zealand. New Zealand Journal of Geology and Geophysics 18: 209–228.
45 Mildenhall DC 1975b. New fossil spore from the Pakihikura pumice (Okehuan; Quaternary), Rangitikei Valley, New Zealand. New Zealand Journal of Geology and Geophysics 18: 667–673.
46 Mildenhall DC 1975c. Lower Pleistocene palynomorphs from the Ohuka carbonaceous sandstone, South-West Auckland, New Zealand. New Zealand Journal of Geology and Geophysics 18: 675–681.
47 Mildenhall DC 1976a. Appendix. Palaeobotanical samples from the Kyeburn Formation at Deep Creek (S135), South Island, New Zealand. In: Bishop DG, Laird MG. Stratigraphy and depositional environment of the Kyeburn Formation (Cretaceous), a wedge of coarse terrestrial sediments in Central Otago. Journal of the Royal Society of New Zealand 6: 55–71.

48 Mildenhall DC 1976b. Appendix. Palynomorphs from 9520 and 9940 feet, Parara 1; Palynomorphs from 10270, 10440 and 10480 feet, Parara 1. In: Hornibrook NdeB. Report on the biostratigraphy of Parara No. 1 offshore well. New Zealand Geological Survey Report PAL 12.
49 Mildenhall DC 1977a. Appendix 2. Hautawan and presumed Hautawan palynomorphs from northern Hawke's Bay. In: Beu AG, Grant-Taylor TL, Hornibrook NdeB. Nukumaruan records of the Subantarctic scallop *Chlamys delicatula* and crab *Jacquinotia edwardsii* in Central Hawke's Bay. New Zealand Journal of Geology and Geophysics 20: 217–248.
50 Mildenhall DC 1977b. Cretaceous palynomorphs from the Waihere Bay Group and Kahuitara Tuff, Chatham Islands, New Zealand. New Zealand Journal of Geology and Geophysics 20: 655–672.
51 Mildenhall DC 1978. Palynology of the Waipipian and Hautawan Stages (Pliocene and Pleistocene), Wanganui, New Zealand (Note). New Zealand Journal of Geology and Geophysics 21: 775–777.
52 Mildenhall DC 1980. New Zealand Late Cretaceous and Cenozoic plant biogeography: a contribution. Palaeogeography, Palaeoclimatology, Palaeoecology 31: 197–233.
53 Mildenhall DC 1985. Appendix. Quaternary palynology: North Kaipara Barrier. In: Richardson RJH. Quaternary geology of the North Kaipara Barrier, Northland, New Zealand. New Zealand Journal of Geology and Geophysics 28: 111–127.
54 Mildenhall DC 1999. Pollen analysis of the Plio-Pleistocene Kowai Formation (Kurow Group), MacKenzie Basin, Central Otago. Institute of Geological and Nuclear Sciences Science Report 99/17.
55 Mildenhall DC 2001. Pollen analysis of Pliocene-Pleistocene Kowai Formation (Kurow Group), Mackenzie Basin, South Canterbury, New Zealand. New Zealand Journal of Geology and Geophysics 44: 97–104.
56 Mildenhall DC. Unpublished list of macrofossil plants described from New Zealand, in systematic order. Held at Institute of Geological & Nuclear Sciences, Lower Hutt, New Zealand.
57 Mildenhall DC, Harris WF 1970. A cool climate pollen assemblage from the type Waipipian (Middle Pliocene) of New Zealand. New Zealand Journal of Geology and Geophysics 13: 586–591.
58 Mildenhall DC, Pocknall DT 1986. Palynology of the Miocene Pleistocene Tauranga Group, Ohinewai, South Auckland, New Zealand. New Zealand Geological Survey Report PAL 120.
59 Mildenhall DC, Pocknall DT 1989. Miocene – Pleistocene spores and pollen from Central Otago, South Island, New Zealand. New Zealand Geological Survey Paleontological Bulletin 59.
60 Mildenhall DC, Suggate RP 1981. Palynology and age of the Tadmor Group (late Miocene-Pliocene) and Porika Formation (early Pleistocene), South Island, New Zealand. New Zealand Journal of Geology and Geophysics 24: 515–528.
61 Mildenhall DC, Wilson GJ 1976. Report on palynomorphs from between 3246 m and 3682 m, Kupe 1. New Zealand Geological Survey Report PAL 10.
62 Mildenhall DC, Wilson GJ 1978. Redeposited Lower and Upper Cretaceous palynomorphs from the Mangere Formation, Mangere Island, Chatham Islands, New Zealand (Note). New Zealand Journal of Geology and Geophysics 21: 661–662.
63 Mildenhall DC, Wilson GJ 1993. Cretaceous palynomorphs identified from Tupuangi Formation and Kahuitara Tuff, Pitt Island. In: Campbell HJ, Andrews PB, Beu AG, Maxwell PA, Edwards AR, Laird MG, Hornibrook N de B, Mildenhall DC, Watters WA, Buckeridge JS, Lee DE, Strong CP, Wilson GJ, Hayward BW. Cretaceous-Cenozoic geology and biostratigraphy of the Chatham Islands, New Zealand. Institute of Geological & Nuclear Sciences Monograph 2: 44–45.
64 Mildenhall DC, Williams DN, Seward D 1977. Ohariu tephra and associated pollen bearing sediments near Wellington, New Zealand. New Zealand Journal of Geology and Geophysics 20: 157–164.
65 Mildenhall DC, Raine JI, Scott GH, Wilson GJ 1985. Biostratigraphy of Mawhero 1 exploratory well, Westland. New Zealand Geological Survey Report PAL 90.
66 Mildenhall DC, Wilson GJ, Scott GH 1986a. Biostratigraphy of Te Ranga 1 offshore well, South Auckland. New Zealand Geological Survey Report PAL 116.
67 Mildenhall DC, Wilson GJ, Scott GH 1986b. Supplementary biostratigraphy of Te Ranga 1 offshore well, South Auckland. New Zealand Geological Survey Report PAL 119.
68 Mildenhall DC, Stokes S, Nelson CS 1992. Palynology, age and paleoenvironments of carbonaceous facies in the Kaihu Group (late Pliocene-Pleistocene), northern North Island. New Zealand Geological Survey Record 46.
69 Mohr BAR, Lazarus DB 1994. Paleobiogeographic distribution of *Kuylisporites* and its possible relationship to the extant fern genus *Cnemidaria* (Cyatheaceae). Annals of the Missouri Botanical Garden 81: 758–767.
70 Nelson CS 1978. Stratigraphy and paleontology of the Oligocene Te Kuiti Group, Waitomo County, South Auckland, New Zealand. New Zealand Journal of Geology and Geophysics 21: 553–594.
71 Nelson CS, Kamp PJJ, Mildenhall DC 1989. Late Pliocene distal silicic ignimbrites, Port Waikato, New Zealand: implications for volcanism, tectonics, and sea-level changes in South Auckland. New Zealand Journal of Geology and Geophysics 32: 357–370.
72 Nelson CS, Mildenhall DC, Todd AJ, Pocknall DT 1988. Subsurface stratigraphy, paleoenvironments, palynology, and depositional history of the late Neogene Tauranga Group at Ohinewai, Lower Waikato Lowland, South Auckland, New Zealand. New Zealand Journal of Geology and Geophysics 31: 21–40.

73 Newnham R, Lusk 1990. Comparison of plant micro- and macrofossils, Karioitahi, Awhitu Peninsula. Tane 32: 171–178.
74 Oliver WRB 1929. The flora of the Waipaoa Series (Later Pliocene) of New Zealand. Transactions and Proceedings of the New Zealand Institute 59: 287–303.
75 Oliver WRB 1936. The Tertiary flora of the Kaikorai Valley, Otago, New Zealand. Transactions and Proceedings of the Royal Society of New Zealand 66: 284–304.
76 Oliver WRB 1950. The fossil flora of New Zealand. Tuatara 3: 1–11.
77 Parrish JT, Daniel IL, Kennedy EM, Spicer RA 1998. Paleoclimatic significance of mid-Cretaceous floras from the middle Clarence Valley, New Zealand. Palaios 13: 149–159.
78 Pocknall DT 1980. Modern pollen rain and Aranuian vegetation from Lady Lake, north Westland, New Zealand. New Zealand Journal of Botany 18: 275–284.
79 Pocknall DT 1981. Pollen and spores from the Rifle Butts Formation (Altonian, lower Miocene), Otago, New Zealand. New Zealand Geological Survey Report PAL 40.
80 Pocknall DT 1982a. Palynology of late Oligocene Pomahaka estuarine bed sediments, Waikoikoi, Southland, New Zealand. New Zealand Journal of Botany 20: 263–287.
81 Pocknall DT 1982b. Palynology of the Bluecliffs Siltstone (early Miocene), Otaio River, South Canterbury, New Zealand. New Zealand Geological Survey Report PAL 55.
82 Pocknall DT 1984. Summary of palynological investigations in the Ohai coalfield. New Zealand Geological Survey Report PAL 78.
83 Pocknall DT 1985. Palynology of Waikato Coal Measures (late Eocene – late Oligocene) from the Raglan area, North Island, New Zealand. New Zealand Journal of Geology and Geophysics 28: 329–349.
84 Pocknall DT 1989. Late Eocene to early Miocene vegetation and climate history of New Zealand. Journal of the Royal Society of New Zealand 19: 1–18.
85 Pocknall DT 1990a. Palynology. In: Isaac MJ, Lindqvist JK. Geology and lignite resources of the East Southland Group, New Zealand. New Zealand Geological Survey Bulletin 101: 141–152.
86 Pocknall DT 1990b. Palynological evidence for the early to middle Eocene vegetation and climate history of New Zealand. Review of Palaeobotany and Palynology 65: 57–69.
87 Pocknall DT 1991. Palynostratigraphy of the Te Kuiti Group (late Eocene–Oligocene), Waikato basin, New Zealand. New Zealand Journal of Geology and Geophysics 34: 407–417.
88 Pocknall DT 1992. Palynology of Brunner Coal Measures and Kaiata Formation, Buller Coalfield, South Island, New Zealand. Institute of Geological and Nuclear Sciences Science Report 92/1. Pp. 21.
89 Pocknall DT, Mildenhall DC 1984. Late Oligocene – early Miocene spores and pollen from Southland, New Zealand. New Zealand Geological Survey Paleontological Bulletin 51: 1–66.
90 Pocknall DT, Tremain R 1988. New Zealand palynology and paleobotany – a field guide to palynological and paleobotanical localities. New Zealand Geological Survey Record 33. 7th International Palynological Conference, Brisbane, Australia.
91 Pocknall DT, Turnbull IM 1989. Paleoenvironmental and stratigraphic significance of palynomorphs from Upper Eocene (Kaiatan) Beaumont coal measures and Orauea mudstone, Waiau Basin, western Southland, New Zealand. New Zealand Journal of Geology and Geophysics 32: 371–378.
92 Pocknall DT, Waterhouse BS 1984. Age, paleoenvironment and correlation of carbonaceous horizons, Aotea Harbour, South Auckland, New Zealand. New Zealand Geological Survey Record 3: 8–16.
93 Pocknall DT, Strong CP, Wilson GJ 1989. Biostratigraphy of Kupe South-4, offshore petroleum exploration well, South Taranaki Bight. New Zealand Geological Survey Report PAL 144: 1–32.
94 Pole M 1992. Early Miocene flora of the Manuherikia Group, New Zealand – 1. Ferns. Journal of the Royal Society of New Zealand 22: 279–286.
95 Pole M 1997. Paleocene plant macrofossils from Kakahu, South Canterbury, New Zealand. Journal of the Royal Society of New Zealand 27: 371–400.
96 Raine JI 1981. Palynological correlation of the Dunollie/Rewanui member boundary in drillholes 621 and 622, Greymouth Coalfield. New Zealand Geological Survey Report PAL 47.
97 Raine JI 1982. Reconnaissance palynological study of Eocene coal measures, Northland Coal Region. New Zealand Geological Survey Report PAL 54.
98 Raine JI 1984. Outline of a palynological zonation of Cretaceous to Paleogene terrestrial sediments in West Coast region South Island, New Zealand. New Zealand Geological Survey Report 109.
99 Raine JI 1989. Summary of palynological investigations in the Ohai Coalfield and Wairaki Hills, Southland, 1985–1988. New Zealand Geological Survey Report PAL 142.
100 Raine JI, Wilson GJ 1988. Palynology of the Mt Somers (South Island, New Zealand) early Cenozoic sequence (Note). New Zealand Journal of Geology and Geophysics 31: 385–390.
101 Rozefelds AC, Christophel DC, Alley NF 1992. Tertiary occurrence of the fern *Lygodium* (Schizaeaceae) in Australia and New Zealand. Memoirs of the Queensland Museum 32: 203–222.
102 Stover LE, Partridge AD 1984. A new late Cretaceous megaspore with grapnel-like appendage tips from Australia and New Zealand. Palynology 8: 139–144.

103 Suggate RP 1957. The geology of the Reefton Subdivision (Reefton sheet S38). New Zealand Geological Survey Bulletin 56.
104 Suggate RP 1968. The Paringa Formation Westland, New Zealand. New Zealand Journal of Geology and Geophysics 11: 345–355.
105 Suggate RP, Couper RA 1952. The stratigraphic relations and plant microfossils of New Zealand coal measures. New Zealand Journal of Science and Technology 34 B: 106–117.
106 Turnbull IM, Lindqvist JK, Mildenhall DC, Hornibrook Nd, Beu AG 1985. Stratigraphy and paleontology of Pliocene – Pleistocene sediments on Five Fingers Peninsula, Dusky Sound, New Zealand. New Zealand Journal of Geology and Geophysics 28: 217–231.
107 Vajda V, Raine IJ, Hollis CJ 2001. Indication of global deforestation at the Cretaceous-Tertiary boundary by New Zealand fern spike. Science 294: 1700–1702.
108 Ward SD, Moore TA, Newman J 1995. Floral assemblage of the "D" coal seam (Cretaceous): implications for banding characteristics in New Zealand coal seams. New Zealand Journal of Geology and Geophysics 38: 283–297.
109 Warnes MD 1990. The palynology of the Morley Coal Measures, Ohai Coalfield. Energy and Resources Division, Ministry of Commerce, New Zealand, Resource Information Report 1.
110 Wilson GJ 1968. Palynology of some Lower Tertiary coal measures in the Waihao District, South Canterbury, New Zealand. New Zealand Journal of Botany 6: 56–62.
111 Wilson GJ 1973. Palynology of the middle Pleistocene Te Piki Bed, Cape Runaway, New Zealand. New Zealand Journal of Geology and Geophysics 16: 345–354.
112 Wilson GJ 1975. Palynology of Deep Sea cores from DSDP Site 275, southeast Campbell Plateau. In: Kennett JP, Houtz RE ed. Reports of the Deep Sea Drilling Project- XXIX. Washington, U.S. Government Printing Office. Pp. 1031–1035.