Lucy Cranwell Lecture, 6th November 2013

Botanising in the Miocene

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How can we identify the vegetation growing at a particular site in the Early Miocene? First of all we need some idea of the geological setting. At Foulden Maar, near Middlemarch, Otago, a small lake formed 23 million years ago when a volcanic explosion punched through the schist bedrock and formed a deep crater that filled up with water. Soils around the crater developed from both schist and basaltic rock and these rich basaltic soils help to explain the diversity of the rainforest that grew around the lake. Over time the lake filled with finely varved diatomite which preserved both microfossils (diatom frustules, freshwater sponge spicules, chrysophycean cysts and other algal resting spores, spores and pollen) and macrofossils (leaves, flowers, fruits and seeds as well as insects and fish).

Initial plant identifications can be made from a pollen and spore list. There is, however, a problem with pollen lists, as some fragile pollen such as Lauraceae is not preserved. In addition, pollen from wind-pollinated plants may have been transported from some distance, thus giving a regional signal rather than that from the actual site (e.g. conifer and *Nothofagus* pollen). Further, many pollen types are not yet described and identified, and many of those that are described have no definite affinity. In contrast, leaves, flowers, fruits and seeds that can be identified can all be used to provide definite evidence of the type of forest growing at or very close to the fossil site in the Early Miocene.

Looking at the pollen list alone (Table 1), the forest type appears to be a mixed *Nothofagus* / conifer forest, but the leaves indicate that the forest surrounding the Foulden Maar lake was dominated by Lauraceae, as almost half of the 700 or so leaves studied to date can be assigned to this family.

Leaves can often be identified using leaf characters and cuticular features, although sometimes they belong to extinct genera or even families (Table 2).

Table 1. Fossil flora of Foulden Maar.

Taxon	Pollen	Leaves
Nothofagus	8 types	No leaves
Conifers	12 types	Two leaf types
Lauraceae	No pollen	Ten leaf types

Fossil leaves are often dark with few features visible (Figs. 1, 9); some of these leaves can be cleared and preserved so that they can be photographed and the features recorded (Figs. 2-4). The Manual of Leaf Architecture was developed in USA so that people can characterise any fossil or living leaf in the same way. Some leaves are too thin to clear, and yield few characters; others are present as fragments so that only cuticular features can be recorded.

Cuticles can be prepared using a variety of methods, depending on the sediment and way the leaf has been preserved. Small pieces of fossil leaf, after being cleared, are separated into upper and lower cuticles, cleaned using fine paintbrushes, stained and mounted on a slide using thymol glycerine jelly (Figs. 5, 6, 10). In some cases the pieces of cuticle can be mounted on stubs and examined using a Scanning Electron Microscope (SEM). Cuticles can then be examined for features and photographs enable measurements to be made. Identification of the cuticles is attempted by comparison with reference slides of modern plants and I have made my own set of reference slides using leaves mainly from New Zealand, Australia, and New Caledonia. It is also useful if botanists have described cuticles from the groups of interest. Unfortunately, as yet there are not many useful papers available.

Flowers, fruits and seeds may show useful features that can make an identification possible (Table 3). If flowers have *in situ* pollen, these grains may be identifiable and an affinity found with modern plants. We named the first flower found at Foulden Maar *Fouldenia staminosa* (Fig. 7), but although it had sepals, petals and large anthers, it did not have enough features to permit a family identification, and because the pollen, although well-preserved and close to a known pollen grain, was not distinctive, no affinity could be made (Fig. 8).

Using these methods we have built up a picture of a diverse evergreen rainforest surrounding the Foulden Maar lake and growing in warm temperate to subtropical conditions 23 million years ago. We continue to identify the vegetation in the Miocene rain forest of Foulden Maar.

We are happy to make pdfs of any of our papers available to members of the Auckland Botanical Society.

Table 2. Plants identified from leaves and cuticle from Foulden Maar.

Plant Group	Family	Taxon	Publication
Ferns		*Davallia* * with spores (Figs. 11, 12)	**9**
Conifers	Podocarpaceae	*Podocarpus* (Figs. 9, 10), *Prumnopitys*	
Dicotyledons	Araliaceae	*Meryta*, *Pseudopanax*, *Schleffera*	
	Atherospermataceae	*Laurelia* * (Figs. 1-6)	**10**
	Celastraceae		
	Cunoniaceae		
	Elaeocarpaceae	*Elaeocarpus*	
	Euphorbiaceae	*Mallotus / Macaranga* *	**21**
	Lauraceae	*Beilschmiedia*, *Cryptocarya*, *Litsea* *	**2**
	Menispermaceae		
	Malvaceae (Sterculiaceae)		
	Meliaceae		
	Monimiaceae	*Hedycarya* *	In preparation
	Myrtaceae		
	Primulaceae	*Myrsine*	
	Proteaceae	cf. *Alloxylon* cf. Tribe Macadamieae*	**6**
	Rutaceae		
	Winteraceae		
Monocotyledons		*Astelia* *	**25**
		Cordyline *	**12**
	Orchidaceae	*Dendrobium*,* *Earina* *	**8**
		Luzuriaga *	**11**
		Ripogonum *	**12**
		Typha *	**12**

Table 3. Plants identified by flowers from Foulden Maar.

Plant Group	Family	Taxon	Publication
Dicotyledons	Cunoniaceae	?*Ackama*	
	Elaeocarpaceae		
	Euphorbiaceae	*Malloranga* *	**21**
	Lauraceae	*Litsea* *	**2**
	Loranthaceae		
	Meliaceae	*Dysoxylum*	
	Monimiaceae	*Hedycarya* *	In preparation
	Onagraceae	*Fuchsia* *	**23**
	?Picrodendraceae		
	?Rutaceae	*Fouldenia* * (Figs. 7, 8) (+ one other flower)	**1**

*denotes publications (numbered according to publications listed in Table 4)

Fig. 1. Fossil leaf of *Laurelia otagoensis* as found in the diatomite. Leaf 4 cm long.

Fig. 2. Cleared leaf of *L. otagoensis*, 4 cm long.

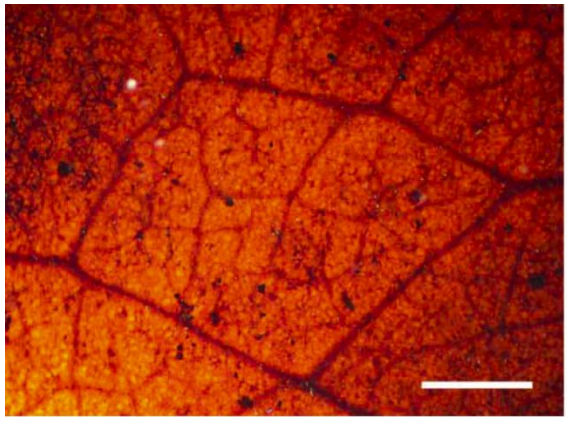

Fig. 3. Venation detail in cleared leaf of *L. otagoensis*. Scale bar 1 mm.

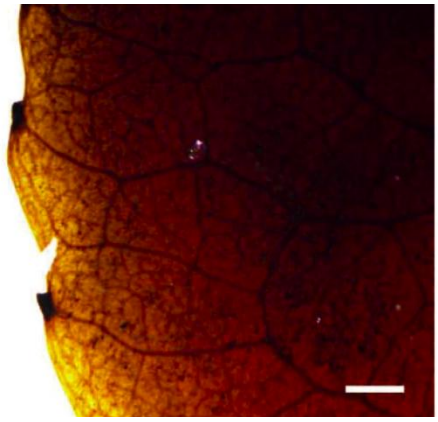

Fig. 4. Marginal teeth in cleared leaf of *L. otagoensis*. Scale bar 1 mm.

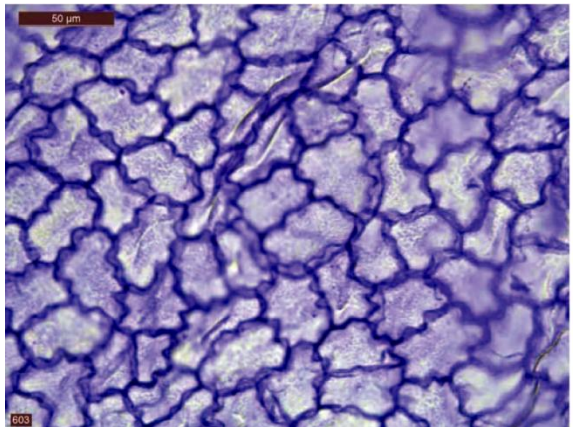

Fig. 5. Stained adaxial cuticle surface (upper face of leaf) of *L. otagoensis*. Scale bar 50 µm.

Fig. 6. Stained abaxial cuticle surface (lower face of leaf) of *L. otagoensis*. Scale bar 50 µm.

Fig. 7. ***Fouldenia staminosa*****, a new fossil genus and species. Flower 23 mm diam.**

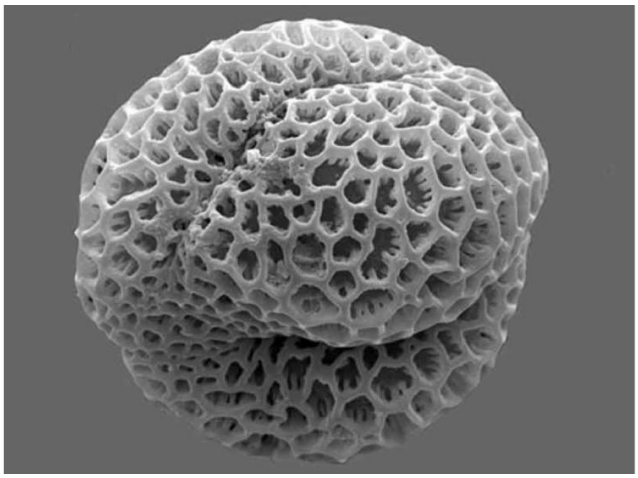

Fig. 8. ***F. staminosa*****, SEM of pollen grain, 40 µm diam. (cf.** ***Rubipollis oblatus*****).**

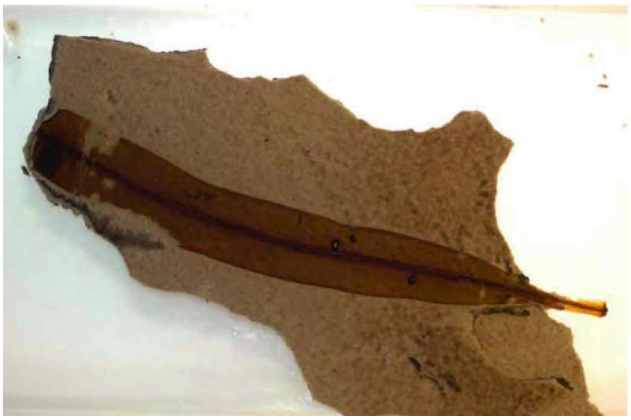

Fig. 9. ***Podocarpus travisiae*** **(named by Mike Pole). Part of leaf, 80 mm long.**

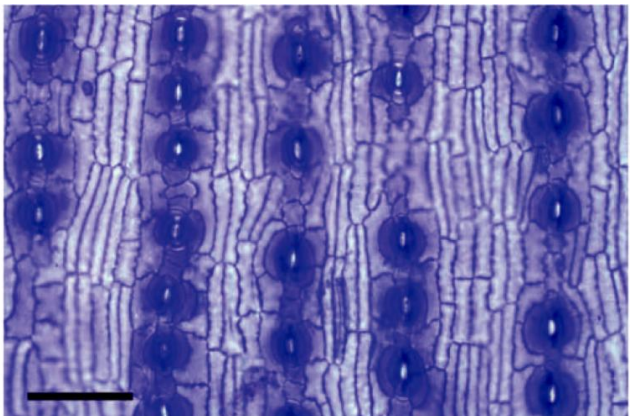

Fig. 10. ***P. travisiae*****, stained leaf cuticle. Stomata in longitudinal rows on abaxial face. Scale bar 100 µm.**

Fig. 11. ***Davalia walkeri*****, a new fossil fern species. Fertile frond, 10 cm long from base of photo.**

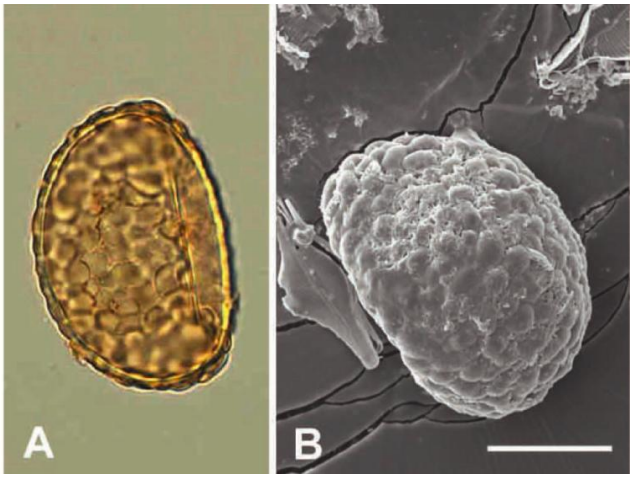

Fig. 12. A: ***Davallia walkeri*** **spore, 36 x 53 µm (LM). This matches** ***Polypodiisporites radiata*****, a NZ fossil spore that can now be linked with** ***Davallia*****. B:** ***D. walkeri*** **spore (SEM). Scale bar 20 µm.**

Table 4. Publications 2005-2013 (Foulden Maar and Newvale Swamp).

1 Bannister, J.M., Lee, D.E., Raine, J.I. 2005: A fossil flower, *Fouldenia staminosa*, with associated pollen from the Early Miocene Foulden Hills Diatomite, Otago, New Zealand. *New Zealand Journal of Botany* 43: 515-525.

2 Bannister, J.M., Lee, D.E., Conran, J.G. 2012: Lauraceae from rainforest surrounding an early Miocene maar lake, Otago, southern New Zealand. *Review of Palaeobotany and Palynology* 178: 13–34.

3 Carpenter, R.J., Jordan, G.J., Lee, D.E., Hill, R.S. 2010: Leaf fossils of *Banksia* (Proteaceae) from New Zealand: an Australian abroad. *American Journal of Botany* 97: 288-297.

4 Carpenter, R.J., Bannister, J.M., Jordan, G.J., Lee, D.E. 2010: Leaf fossils of Proteaceae tribe Persoonieae from the Late Oligocene-Early Miocene of New Zealand. *Australian Systematic Botany* 23: 1-15.

5 Carpenter, R.J., Jordan, G.J., Mildenhall, D.C., Lee, D.E. 2011: Leaf fossils of the ancient Tasmanian relict *Microcachrys* (Podocarpaceae) from New Zealand. *American Journal of Botany* 98: 1164-1172.

6 Carpenter, R.J., Bannister, J.M., Jordan, G.J., Lee, D.E. 2012: Proteaceae leaf fossils from the Oligo-Miocene of New Zealand: new species and evidence of biome and trait conservatism. *Australian Systematic Botany* 25: 375-389.

7 Carpenter, R.J., Bannister, J.M., Lee, D.E., Jordan, G.J. *Nothofagus* subgenus *Brassospora* (Nothofagaceae) leaf fossils from New Zealand: a link to Australia and New Guinea? *Botanical Journal of the Linnean Society* 2014. In press.

8 Conran, J.C., Bannister, J.M., Lee, D.E., 2009. Earliest orchid macrofossils: Early Miocene *Dendrobium* and *Earina* (Orchidaceae: Epidendroideae) from New Zealand. *American Journal of Botany* 96: 466-474.

9 Conran, J.G., Kaulfuss, U., Bannister, J.M., Mildenhall, D.C. Lee, D.E. 2010: *Davallia* (Pteridophyta: Davalliaceae) macrofossils from Early Miocene Otago (New Zealand) with *in situ* spores. *Review of Palaeobotany and Palynology* 162: 84-94.

10 Conran, J.G., Bannister, J.M., Lee, D.E. 2013. Fruits and leaves with cuticle of *Laurelia otagoensis* sp. nov. (Atherospermataceae) from the early Miocene of Otago (New Zealand). *Alcheringa* 37: 1-14.

11 Conran, J.G., Bannister, J.M., Mildenhall, D.C., Lee, D.E., Chacon, J., Renner, S.S. 2014: Leaf fossils of *Luzuriaga* and a monocot flower with *in situ* pollen of *Liliacidites contortus* Mildenh. & Bannister sp.nov. (Alstroemeriaceae) from the Early Miocene. *American Journal of Botany* 101: 141-155.

12 Conran et al. Monocot macrofossils in Australasia. *Botanical Journal of the Linnean Society*. In press.

13 Ferguson, D.K., Lee, D.E., Bannister, J.M., Zetter, R., Jordan, G.J., Vavra, N., Mildenhall, D.C. 2010: The taphonomy of a remarkable leaf bed assemblage from the Late Oligocene-Early Miocene Gore Lignite Measures, southern New Zealand. *International Journal of Coal Geology* 83: 173-181.

14 Harris, A.C., Bannister, J.M. Lee, D.E. 2007: Fossil scale insects (Hemiptera, Coccoidea, Diaspididae) in life position on an angiosperm leaf from an Early Miocene lake deposit, Otago, New Zealand. *Journal of the Royal Society of New Zealand* 37: 1-13.

15 Hartwich, S.J., Conran, J.G., Bannister, J.M., Lindqvist, J.K., Lee, D.E. 2010: Calamoid fossil palm leaves and fruits (Arecaceae: Calamoideae) from Late Eocene Southland, New Zealand. *Australian Systematic Botany* 23: 131-140.

16 Jordan, G.J., Bannister, J.M., Mildenhall, D.M., Zetter, R., Lee, D.E. 2010: Fossil Ericaceae from New Zealand - deconstructing the use of fossil evidence in historical biogeography. *American Journal of Botany* 97: 59–70.

17 Jordan, G.J., Carpenter, R.J., Bannister, J.M., Lee, D.E., Mildenhall, D.C., Hill, R.S. 2011: High conifer diversity in Oligo-Miocene New Zealand. *Australian Systematic Botany* 24: 121-136.

18 Kaulfuss U. 2012: Geology and Palaeontology of Foulden Maar, Otago, New Zealand. Unpublished PhD thesis, University of Otago.

19 Kaulfuss, U., Harris, A.C., Lee, D.E. 2010: A new fossil termite (Isoptera, Stolotermitidae, Stolotermes) from the Early Miocene of Otago, New Zealand. *Acta Geologica Sinica* 84 (4): 705-709.

20 Lee, D.E., Bannister, J.M. Lindqvist, J.K. 2007: Late Oligocene-Early Miocene leaf macrofossils confirm a long history of *Agathis* in New Zealand. *New Zealand Journal of Botany* 45: 565-578.

21 Lee, D.E., Bannister, J.M., Raine, J.I., Conran, J.C. 2010: Euphorbiaceae: Acalyphoideae fossils from Early Miocene New Zealand: *Mallotus–Macaranga* leaves, fruits, and inflorescence with *in situ Nyssapollenites endobalteus* pollen. *Review of Palaeobotany and Palynology* 163: 127-138.

22 Lee, D.E., Conran, J.G., Lindqvist, J.K., Bannister, J.M., Mildenhall, D.C. 2012: New Zealand Eocene, Oligocene and Miocene macrofossil and pollen records and modern plant distributions in the Southern Hemisphere. *The Botanical Review* 78: 235-260.

23 Lee, D.E., Conran, J.G., Bannister, J.M., Kaulfuss, U., Mildenhall, D.C. 2013: A fossil *Fuchsia* L. (Onagraceae) flower and a bud with *in situ* pollen from the early Miocene of New Zealand. *American Journal of Botany* 100(10): 2052 - 2065.

24 Lindqvist, J.K., Lee, D.E., 2009: High-frequency paleoclimate signals from Foulden Maar, Waipiata Volcanic Field: An Early Miocene varved lacustrine diatomite deposit, southern New Zealand. *Sedimentary Geology* 222: 98-110.

25 Maciunas, E., Conran, J.G., Bannister, J.M., Paull, R., Lee, D.E. 2011: Miocene *Astelia* (Asparagales: Asteliaceae) macrofossils from southern New Zealand. *Australian Systematic Botany* 24: 19-31.

26 Mildenhall, D.C., Kennedy, E.M., Lee, D.E., Kaulfuss, U., Bannister, J.M., Fox, B., Conran, J.G. Palynology of the Early Miocene Foulden Maar, Otago, New Zealand: diversity following destruction. *Review of Palaeobotany and Palynology.* 2014. In press.

27 Reichgelt, T., Kennedy, E.M., Mildenhall, D.C., Conran, J.G., Grenwood, D.R., Lee, D.E. 2013: Quantitative palaeoclimate estimates for Early Miocene southern New Zealand: evidence from Foulden Maar. *Palaeogeography, Palaeoclimatology, Palaeoecology* 378: 36-44.

Mike D. Wilcox

Honorary Life Member, 5 March 2014

Ewen Cameron & Maureen Young

Ewen Cameron (proposer)

Mike Wilcox BSc (Auckland), MA (Oxon.), PhD (North Carolina State) is a Registered Forestry Consultant who had a career from 1959 to 1990 with the New Zealand Forest Service, later the Ministry of Forestry, based 1966-1990 at the Forest Research Institute, Rotorua (from Anon. 2004). There he was involved in species evaluation and tree breeding, and later as a research director. He himself specialised in *Eucalyptus*, and also on genetic improvement of radiata pine and Douglas fir. In 1990 Mike started work in Auckland (moved house in 1991) for Groome Pöyry Ltd (later Jaakko Pöyry Consulting) as a Senior Forest Consultant undertaking assignments on forest development in many overseas countries until 'retirement' in 2005.

Rotorua's loss was Auckland's gain. In 1996 Mike became a committee member of ABS for 5 years (Mar 1996 - Feb 2001), Vice-president for 2 years (Mar 2001- Feb 2003), and then President for 10 years (Mar 2003 - Feb 2013). During that time he contributed solely (or co-authored) an amazing 139 articles to our *Journal*, led (or co-led) 52 field trips (Fig. 1) and gave 19 talks (Fig. 2).

Articles (139) varied from reports of field surveys, to specific genera or species (wild or cultivated), seaweeds (Mike's interested in all plants), weed species, and included topics like: palms of Auckland, elms of Auckland, grasses of Auckland, *Spergularia, Bolboschoenus*, eucalypts, China, Italy, sea lavender, *Clivia, Furcraea*, and perhaps my favourite 'The Avondale and Otara markets'.

Field trips (52) Mike led (or co-led) trips to a great range of places including: local islands (Kawau, Mayor, Puketutu, Rangitoto); local areas (Anawhata, Auckland Zoo, Ayrlies Garden, Bartlett's forest, Leigh Marine Reserve, Murphy's Bush, Waipu Gorge); camps (Eastwoodhill, Hawkes Bay, Mt Ruapehu, Pouto, Pureora, Rotorua, Ruahines, Turangi); and three overseas trips (New Caledonia (Fig. 1); Sydney; and Tasmania).

Talks (19) included the Flora of central Australia, Auckland's marine plants, Wild flowers of Italy, and Conifers of the world – why limit yourself to New Zealand?

During his Presidency he encouraged more field trips to be written up in the journal "if it isn't written-up it didn't happen!" and instigated the inclusion of a 'participants list' in the write-ups. Mike published two books during this time: 'Natural History of Rangitoto Island' 192p. (2007) – although multi-authored Mike masterminded the project and contributed the most text and photographs. The second book he was the sole author: Auckland's remarkable urban forest' 348p. (2012). Mike not only wrote the book, took the