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COMMENTARY

Biogeographic insights from a short-lived Palaeocene island in the Ninetyeast Ridge

Talk about the needle in a haystack! It's been found at site 214 of the Deep Sea Drilling Project, and it turns out to be golden. Site 214 is located towards the southern end of the Ninetyeast Ridge (NER), named because it parallels the 90°E meridian. This narrow submerged ridge in the Indian Ocean was generated by hotspot volcanism (the Kerguelen plume) and runs from 32°S to 9°N for a total length of 5000 km. The same plume also formed the southern Kerguelen plateau (120–110 Ma), the central plateau (105–100 Ma) and the Broken Ridge (100–95 Ma). Basalt rocks from the NER date to *c.* 82 Ma in the north and to *c.* 38 Ma in the south, and site 214, which is located at 11°S, dates to 58–59 Ma (references in Carpenter *et al.*, 2010). Presently, it is covered by 1.6 km of water. Cores from site 214 contain pollen and spores of distinctly Australian and New Zealand affinities, with weaker similarity to fossil assemblages from southern South America and Antarctica (Kemp & Harris, 1975, 1977).

At its formation, site 214 was located somewhere around 50°S and would have been 1000+ km distant from Australia and Antarctica (Carpenter *et al.*, 2010). The combined evidence from the basalt dates and the well-preserved assemblage of spores and pollen, dinoflagellate cysts, acritarchs, foraminifera, nannofossils and molluscs provides time limits for the emergence and subsidence of a small island during the interval 56.5–59.0 Ma (references in Carpenter *et al.*, 2010). The remarkable discovery of this small and short-lived late Palaeocene island is of great biogeographic interest. Its flora included four or five conifer species, *c.* 15 flowering plants, and 20 species of ferns and club mosses, all identified from pollen and spores.

Carpenter *et al.* (2010) have now re-analysed Harris's site 214 samples from the 1970s and in doing so have discovered plant cuticles belonging to the Lauraceae. This is an exciting discovery in several ways. The cuticles resemble those of extant species in the *Cryptocarya* group (Nishida & van der Werff, 2007; Carpenter *et al.*, 2010; S. Nishida, The Nagoya University Museum, Nagoya, Japan, pers. comm., March 2010), a clade that comprises *Beilschmiedia*, *Cryptocarya*, *Endiandra* and a few other Asian and Australasian genera. The Cryptocaryeae have been dated to 91 ± 20 Ma in a molecular-phylogenetic study of Lauraceae (Chanderbali *et al.*, 2001), and it is not difficult to imagine one of their species growing on an offshore island 58 million years ago. Today, as noted by Carpenter *et al.* (2010), species of *Cryptocarya* occur on Lord Howe Island and Hawaii, *Ocotea* occurs in the Mascarenes, and *Litsea* and *Persea* on Krakatau. One of the Lord Howe Island species, *Cryptocarya triplinervis* R. Br., also occurs in Australia, some 580 km away.

The broader importance, however, of the discovery of Lauraceae on an island that is part of the NER lies in the light this throws on the role of both the ridge and the Kerguelen Plateau as possible stepping stones for the spread of organisms across the Indian Ocean region, for example from Australia and Antarctica northwards. The Kerguelen Plateau was at least in part emergent and vegetated during the Lower Cretaceous (*c.* 110 Ma) and the early Upper Cretaceous (*c.* 85 Ma) (Mohr & Gee, 1992a,b; Mohr, 1998; Mohr *et al.*, 2002), when the NER began to form. During the course of the Upper Cretaceous, the Kerguelen Plateau subsided below sea level from south to north, and subsidence appears to have been complete across most of the region by 80 Ma (Ali & Aitchison, 2009).

The question of how long vegetated islands persisted in the southern Indian Ocean between the Kerguelen region and the northward-drifting Indian landmass is relevant for solving certain long-standing biogeographic riddles. One of them concerns the Monimiaceae, a close relative of the Lauraceae. The most striking geographic disjunction in this family involves the Sri Lankan genus *Hortonia* (and its relatives) and a clade consisting of *Peumus* from Chile, *Monimia* from the Mascarenes, and *Palmeria* from eastern Australia/New Guinea (Renner *et al.*, 2010). One explanation for this disjunction might be the northward rafting of *Hortonia* on the Indian Plate (India/Sri Lanka) after it split from Madagascar and the Seychelles *c.* 90 Ma. The *Hortonia* stem lineage dates to 71 (57–84) Ma, as inferred from a molecular clock, but the distance between Antarctica and India at 83 Ma was at least 2100 km (Ali & Aitchison, 2009). Any Monimiaceae would thus have had to cross a vast distance of ocean. Unless, of course, there were stepping-stone islands. The short-lived and tiny 58-Myr-old island on the NER and its vegetation in this context are of considerable interest.

Other plants growing on the island were arecoid palms, *Gunnera* and plants related to Chloranthaceae (Carpenter *et al.*, 2010). Whether all these plants arrived by long-distance dispersal over 1000 km of ocean or whether there were closer vegetated regions that are now submerged cannot be decided. Drilling cores are too sparse to preclude the presence of terrestrial land in the northern part of the Kerguelen Plateau/Broken Ridge region in the Palaeogene. Carpenter *et al.* (2010) think it possible that emergent regions of the southern Kerguelen Plateau existed until 70 Ma, or perhaps more recently. If these regions were suitable for the existence of terrestrial biota, they could have facilitated dispersal between Antarctica and Site 214, and also perhaps towards a more northern landmass (such as India).

The physical connectivity of the southern continents in the Upper Cretaceous has recently attracted considerable attention as workers try to reconcile evidence for relatively young dispersal events from molecular clocks with the vast ocean expanses between the southern landmasses (examples in Ali & Aitchison, 2009; Michalak *et al.*, 2010; Renner *et al.*, 2010). While only small portions of the Kerguelen Plateau may have been above sea level after 80 Ma, the presence of more or less tropical forests with Lauraceae and palms at 58 Ma on a palaeo-island situated at 50°S on the NER demonstrates

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the possibility of stepping stones in the middle of the Indian Ocean, making it easier to accept inferred Oligocene or Miocene dispersal between the Australian region and Madagascar or Africa.

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