

Definition of a Cenozoic alkaline magmatic province in the southwest Pacific without rift or plume origin

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A Cenozoic (<50 Ma) bimodal, but largely basaltic, mostly alkaline igneous province covers a broad area of continental and oceanic lithosphere in the southwest Pacific (Fig. 1) has been conjecturally linked to rifting, mantle plumes, or hundreds of hot spots, but all of these associations have flaws. For example, plate reconstructions demonstrate that the last episode of major regional rifting in west Antarctica, eastern Australia and New Zealand occurred during the Mesozoic break-up of Gondwana. GPS and stress-field measurements show no extension in Australia, New Zealand and much of west Antarctica, suggesting that the widespread magmatism cannot be explained by rifting alone. Estimates of volumes of magmas erupted in west Antarctica and Australia, as well as magma production rates are low compared to areas associated with plumes. Uplift and doming typically associated with mantle plumes are also largely absent. Also, to explain the areal distribution of the volcanism, an unusually large plume would have to underlie the entire southwest Pacific, or there would have to be hundreds of hot spots, which are not observed. Clearly, new models for volcanism are required.

Comparison of the location of volcanoes and seismic shear wave perturbation models (Fig. 1), show that this alkaline volcanic province occurs in thin (<80 km) lithosphere (e.g. Fig. 2). Offshore areas of old (> 100 Ma), thick lithosphere like the Weddell Sea (Fig. 2) do not contain Cenozoic alkali basalts. The province correlates with distinct low seismic velocity anomalies (Fig. 1) restricted to a zone in the mantle between ~60 and 200 km depth (e.g. Fig. 2).

Geochemical studies show that for most of the region, the magmatism is a result of small degrees of melting ($F = 1-3\%$) of a source enriched in incompatible elements relative to primitive upper mantle. The enrichment may have involved the introduction of volatile-rich fluids or melts into pre-existing upper mantle. This suggests that melting of metasomatized upper mantle can occur without excessive temperatures (Fig. 3) and that the low seismic velocities are primarily related to slightly elevated temperatures, water and, in places, melt.

The key to generating long-lived, low volume alkaline magmatism is the combination of thin (<80 km) lithosphere underlain by metasomatized, mostly Pacific mantle at only slightly elevated temperatures. The age of the metasomatism is not known but may be related to a combination of Paleozoic-Mesozoic subduction along the Pacific margin of Gondwana and possible plume-related activity in the Jurassic. During Cretaceous break-up of Gondwana, rifting in east Australia and west Antarctica did not result in voluminous magmatism despite thinning and regional extension of continental lithosphere containing metasomatized mantle. This suggests that a regional heating and/or mantle upwelling event is required to allow alkaline magmatism.

Plate motion and seismic tomography studies propose that high density and velocity subducted slabs lying in the lower mantle detached from the mantle transition zone in the Eocene (e.g. Fukao et al., 2001). Geodynamic model of the effects of an “avalanche” of detached slabs suggest that it is possible to generate vertical and lateral flow and high temperatures in the upper mantle. Although we do not call for a dramatic increase in temperature or mantle flow near the detached slabs, such a mechanism may induce slight heating, catalyzing melting of metasomatized mantle and eruption during extension.

References

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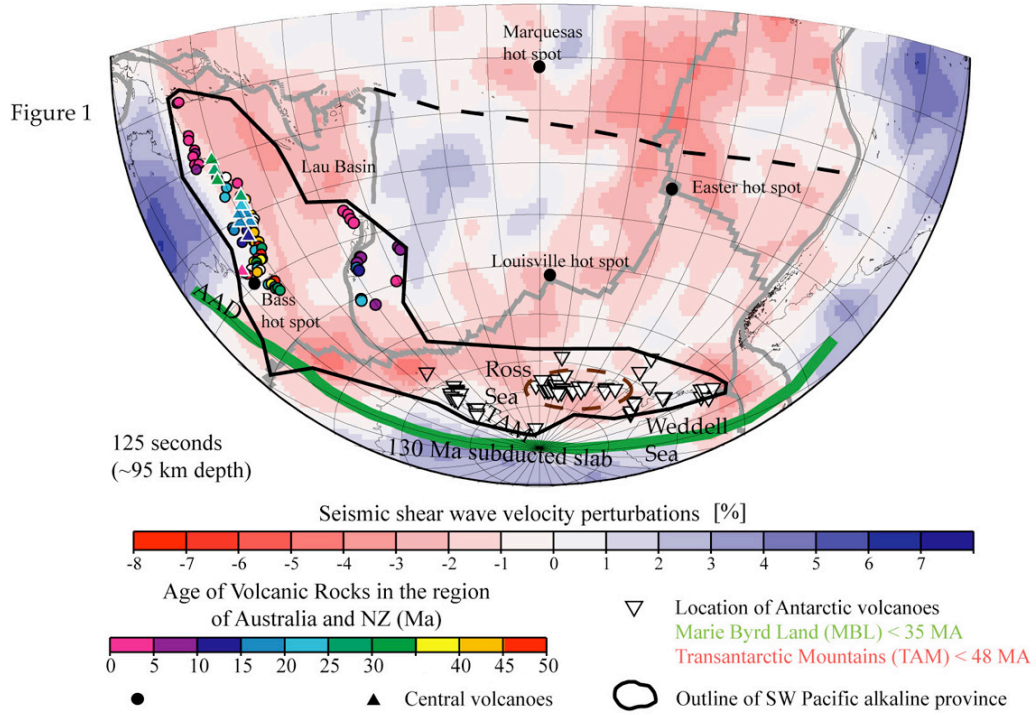


Figure 1. Rayleigh wave 125s group velocity map (~95 km depth) of the SW Pacific (Larson and Ekström, 2001). Only robust, hot spots with long traces (Clouard and Bonneville, 2001) are shown.

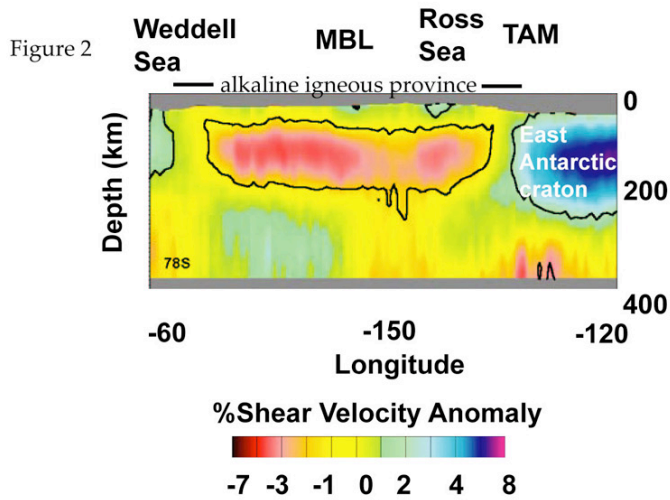


Figure 2. Shear wave velocity perturbation model derived from inversion of Rayleigh and Love wave data and relative to AK135, Antarctica (from Ritzwoller et al., 2001).

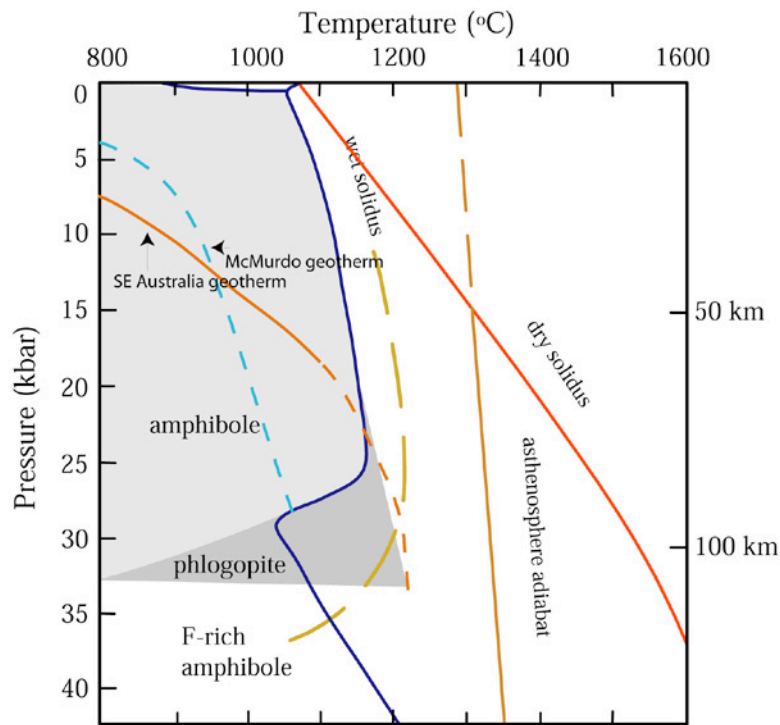


Figure 3. McMurdo/SE Australia geotherm (from Berg et al., 1989; O'Reilly and Griffin, 1985) with 2 possible extrapolations (solid and dashed lines), compared to stability fields of amphibole and phlogopite. Also shown are water-saturated and water-undersaturated solidi and an adiabatic path for asthenospheric mantle.