

Macquarie Island: evidence for multi-stage ocean crust formation from enriched magmas and implications for upper mantle heterogeneity.

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Macquarie Island, a small 30x5 km island in the Southern Ocean halfway between New Zealand and Antarctica (figure 1), is a fragment of young (Miocene) oceanic crust and upper mantle that has been uplifted and exposed above sea-level in an entirely intra-oceanic setting, without being obducted onto a continental margin. As such, it is unique in the world and it is generally considered as an important type-locality of oceanic crust and mantle and as a key link between oceanic basement and ophiolites. Several workers have pointed out the similarity between the crustal section on the island - which consists of sediments, volcanics, a sheeted dyke complex, and gabbros including layered gabbros – and the 'classical' ophiolite pseudo-stratigraphic sequence. Recent work on the island has, however, shown that the formation history of the island is more complex than originally envisaged. In this paper we will outline these complexities, give an overview of our recent and current research on this unique island, and we will present a model for its formation.

The first complexity is that there is evidence from field relations that the volcanics, dykes and gabbros on the island were formed during different magmatic episodes and it seems unlikely that the main pseudo-stratigraphic units are co-magmatic (Dijkstra & Cawood, 2004). Secondly, the volcanic rocks on the island are unusual: there are few N-MORB basalts and the majority of the volcanics are strongly incompatible element enriched, E-MORB to OIB-like basalts ($La/Sm < 8$; Kamenetsky et al., 2000). Moreover, our new geochemical data show that the dykes, evolved gabbros and cumulate ultramafic and gabbroic rocks on the island are derived from parental melts that range from slightly depleted MORB to enriched MORB, but that they were significantly less enriched ($La/Sm < 5$) than the volcanic rocks on the island, ruling out a co-magmatic origin. Nd isotope data confirm that there is little compositional overlap between the parental melts of the gabbroic rocks ($\epsilon Nd(9Ma) = +7.8-9.3$) and those of the volcanics ($\epsilon Nd(9Ma) = +7.2-8.3$).

In addition, we present geochemical data to show that the residual mantle harzburgites on the island are much more depleted (residue of >20% near-fractional melting) than expected from the tectonic setting and reconstructed slow spreading rate of the Macquarie paleo-ridge system. Their ultra-depleted character is also inconsistent with the thin magmatic crust (~3 km or less), and with the highly enriched character of the volcanic section on the island. This probably means that these mantle rocks are not the source residue of the exposed magmatic rocks and that their depleted character is the result of an earlier melting episode (Dijkstra et al., submitted).

We will attempt to tie these disparate observations into one model for the formation of the oceanic basement section on Macquarie Island. Most of the parental magmas that formed the crustal section were probably derived from enriched and isotopically distinct lithological heterogeneities within the mantle (e.g., pyroxenites), with a limited contribution from partial melting of depleted mantle. Over a short time interval (~1 My), the input of enriched melts increased dramatically due to changes in the magma plumbing system, in the spreading geometry, or in the nature of the mantle material entering the base of the melting domain underneath the ridge system.

The question remains how a-typical Macquarie Island really is? We note that complexities such as found at Macquarie Island are increasingly being recognized in present oceans, and we will make comparisons with modern ridge systems such as the Fifteen-Twenty Fracture Zone, the Siqueiros Fracture Zone and Hess Deep.

REFERENCES

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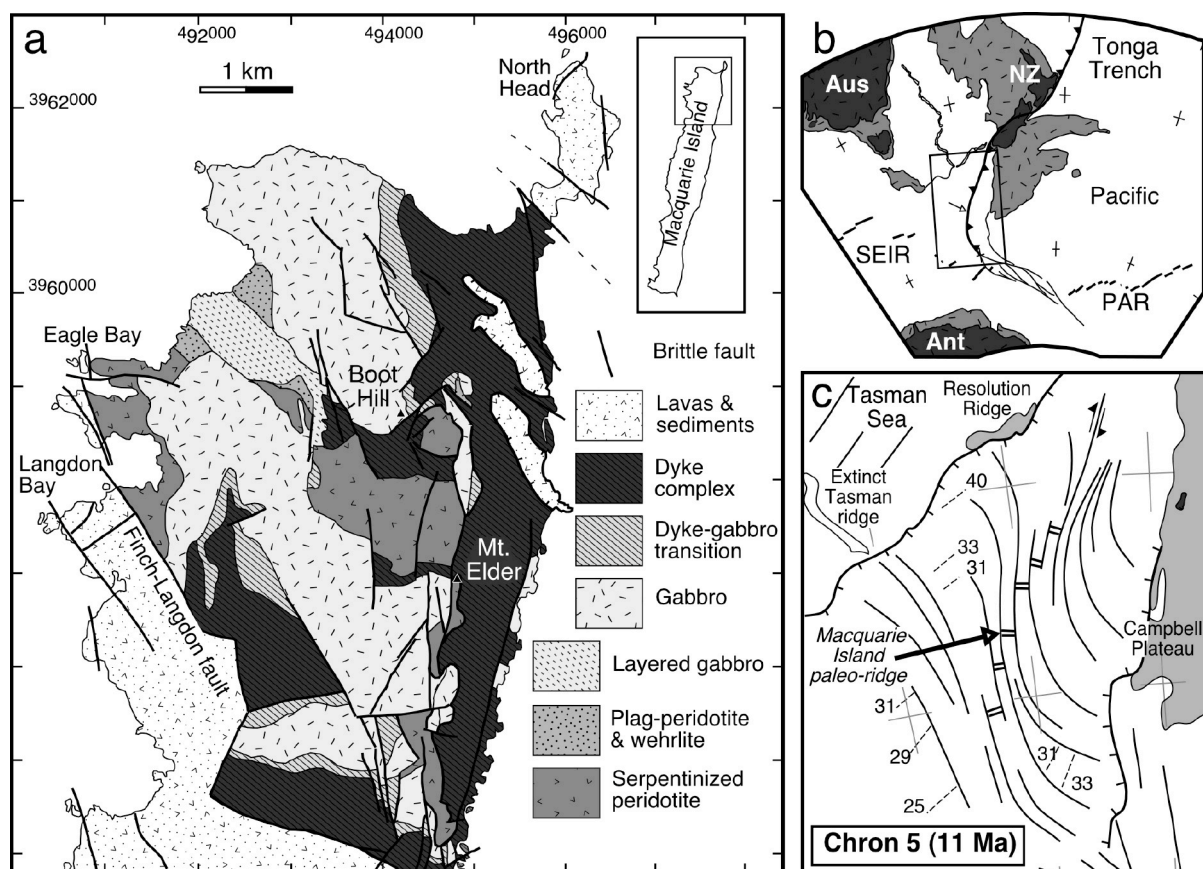


Figure 1. (a) Map of northern part of Macquarie Island, where harzburgites, gabbroic rocks, (sheeted) dykes and volcanics are exposed together; (b) Location of Mac-

quarie Island on the present-day Antarctic-Pacific plate boundary; (c) Plate reconstruction for the region at 11 Ma, just before the formation of the rocks on Macquarie Island, when the plate boundary was still divergent.