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Spatial and Temporal Evolution of Magmatism in an Arc-Arc Collision: The Halmahera and Sangihe Arcs, Eastern Indonesia

Colin Macpherson (colin.macpherson@durham.ac.uk)[1], **Emily Forde**[2], **Robert Hall** (r.hall@gl.rhbnc.ac.uk)[2] & **Matthew Thirlwall** (matthewt@gl.rhbnc.ac.uk)[3]

[1] Department of Geological Sciences, University of Durham, South Road, DH1 3LE, UK
[2] SE Asia Research Group, Royal Holloway University of London, Egham, TW20 0EX, UK
[3] Department of Geology, Royal Holloway University of London, Egham, TW20 0EX, UK

Many processes can influence the geochemistry of magmas generated in subduction zones. Factors such as the composition of the mantle wedge, the composition of components derived from the subducted slab, the mechanism of mass transfer from slab to wedge and the composition of the overriding lithosphere will all exert controls on the nature of magmas produced. The large number of variables controlling magma geochemistry of any individual arc complicates comparisons between magmatic products of different arcs. A unique opportunity to minimise some of uncertainty involved in such comparisons is available in eastern Indonesia where an orthogonal collision between the Sangihe and Halmahera arcs has resulted from consumption of a single plate (the Molucca Sea plate) at both subduction zones. New data for Neogene magmatic centres in the Halmahera arc are compared with published analyses for the Quaternary Halmahera arc (Morris et al., 1983) and Neogene to Quaternary magmatism in Sangihe (Elburg and Foden, 1998) to constrain the temporal evolution within each arc and the differences between the two arcs.

The major and trace element and isotopic geochemistry of Neogene magmatism on the islands of Obi and Bacan and in central Halmahera was studied. After distinguishing the effects of crustal contamination there are clear differences between the volcanic centres. The Zr/Nb ratios increase from MORB-like values in Obi to successively higher values in central Halmahera and Bacan. Increasing Zr/Nb is accompanied by increases in La/Nb and Ba/Nb suggesting the presence of a component enriched in fluid-mobile elements. These data are consistent with slab-dehydration carrying the most mobile elements into the mantle wedge. The wedge itself must have experienced variable degrees of previous melt extraction to generate the range in Zr/Nb since this ratio is unaffected by fluid addition. Isotopic ratios of Pb indicate that the mantle wedge is similar to Indian Ocean MORB. While a sedimentary component may have contributed a small fraction to the recycled flux, dehydration of altered oceanic crust was probably the most important mass transfer process during the Neogene.

Quaternary lavas in Halmahera possess higher $^{206}Pb/^{204}Pb$, $^{207}Pb/^{204}Pb$, $^{208}Pb/^{204}Pb$ and lower $^{143}Nd/^{144}Nd$ than Neogene magmatism in the same arc. This difference is most readily explained by an increase in the contribution from subducted sediment in the source of arc magmatism. In addition, the Quaternary lavas display a wide range in Zr/Nb ratios including some values lower than MORB. Since typical melting processes cannot lower Zr/Nb this requires the addition of a low Zr/Nb component such as melt derived from sediment. The wide range in Zr/Nb and some overlap in the isotopic ratios of the Neogene and Quaternary lavas suggest that both slab dehydration and sediment melting have operated in the Neogene and the Quaternary but that the latter process has become more important through time.

Comparison of the Halmahera data with analyses of Sangihe magmatism suggests that the Neogene to Quaternary development of the two arcs has been similar since Sangihe lavas also record an increased contribution from sedimentary material through time (Elburg and Foden, 1998). This may reflect changing stratigraphy on the subducted slabs. Alternatively underthrusting of accreted sediment may have occurred as the arcs began to collide. In a plot of $^{206}Pb/^{204}Pb$ versus $^{143}Nd/^{144}Nd$ there is an offset between the fields for the two arcs with the Halmahera lavas possessing consistently higher $^{206}Pb/^{204}Pb$. This suggests a difference between the two arcs either in the composition of end-members and/or in the mass transfer processes. Since changes in mass transfer processes, from fluid-dominated to fluid + melt, have been recognised within each dataset and do not produce this type of offset some form of compositional contrast is preferred. This contrast could reflect isotopic differences between the two mantle wedges or may result from variable depletion of the wedges.

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