Oxygen- and Sr-isotope systematics of the Banda Arc volcanics (Indonesia): Evidence for subduction of continental material

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Introduction

The Banda Arc has been widely cited in the literature as an example of an island-arc where magma genesis is influenced by large amounts of subducted continental sediments which are derived from the Australian craton (Whitford and Jezek, 1979; Vroon *et al.*, 1993). This was first suggested by an combined Sr- and oxygen isotope study of Magaritz *et al.* (1978). They showed that correlations existed between oxygen and Sr isotopes, and that these could be interpreted as evidence for source mixing of up to 20–50% continental sediments. However, subsequent work (Morris, 1984) suggested that assimilation of continental material in the arc crust could also be an important process in the Banda Arc. The limited number of samples analysed for oxygen isotopes by Magaritz *et al.* (1978) precludes a definite answer on whether the assimilation of arc crust or subducted sediments is the cause of the elevated oxygen isotope ratios. Furthermore, secondary water uptake of whole rock samples has proven to be one of the causes of high $d^{18}O$ values. This study therefore sets out to use the new laser fluorination technique for oxygen isotopes of mineral separates in combination with whole rock Pb-Sr-Nd isotopes. This enables us to analyse all the phenocryst phases in one sample avoiding the problems of whole rock work and therefore establish if assimilation was important.

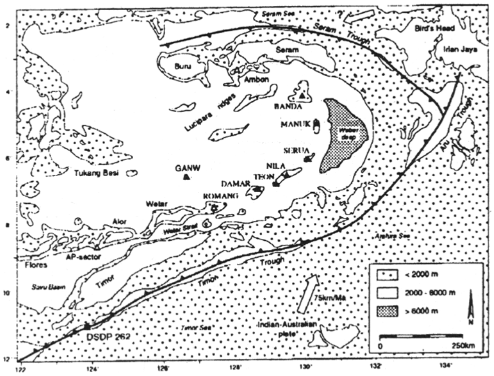

FIG. 1. Map of the Banda Sea region showing the volcanic islands studied (solid black triangles) and active volcanoes (unlabelled open triangles). Romang, Wetar and Alor form an inactive segment between the Banda and Sunda Arcs.

Method

The Laser Fluorination technique used in this study is described by Mattey and Macpherson (1993). Mineral grains from a 125–250 μm sieve fraction were separated using a conventional Frantz magnetic separator and heavy liquids. Final selection involved handpicking of 1.0–1.5 mg for each analysis (10–20 grains). Minerals were heated with a Nd-YAG laser in the presence of ClF_3. Oxygen is converted to CO_2 over hot graphite. Replicate analysis fall within 0.2‰. The LF oxygen isotope data are calibrated to V-SMOW and NBS-30 biotite.

Results

The Banda Archipelago, in the northern part of the Banda Arc (Fig. 1), displays normal mantle $\delta^{18}O$ values: olivine, 4.9–5.2; clinopyroxene, 5.5–5.8; and plagioclase, 6.0–6.3. Manuk (Fig. 1), displays similar oxygen isotope values: olivine, 5.2 and clinopyroxene, 5.6–5.8. Serua (Fig. 1) shows the highest $\delta^{18}O$ values: clinopyroxene, 5.9–7.1, and there is a clear positive relation between oxygen and Sr isotopes (Fig. 2). Nila, Teon, Damar and Romang, in the southern part of the Banda Arc (Fig. 1), have clino- and orthopyroxene $\delta^{18}O$ of 5.4–6.0, despite extremely high $^{87}Sr/^{86}Sr$ (0.7060–0.7095). Compared with the whole rock data of Magaritz *et al.* (1978), our values for clinopyroxene display significantly less scatter and are in general up to 2‰ lower (see Fig. 2). This is

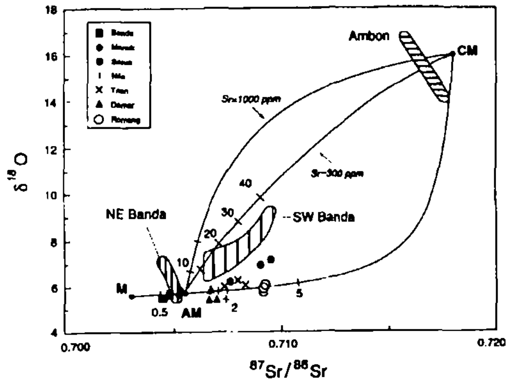

FIG. 2. $^{87}Sr/^{86}Sr$ versus $\delta^{18}O$ plot for Banda Arc rocks. Clinopyroxene $\delta^{18}O$ and whole rock $^{87}Sr/^{86}Sr$ for each sample are shown. Banda Arc fields and Ambon (cordierite-bearing lavas) are from Magaritzet *al.* (1978). Banda Arc data plot close to a source-mixing curve between MORB and continental material (CM). Assimilation curves are shown for arc melts (AM) with 300 and 1000 ppm Sr and CM. End-member compositions are: M: $^{87}Sr/^{86}Sr$ = 0.703, $\delta^{18}O$ = 5.7 and Sr = 9 ppm; CM: $^{87}Sr/^{86}Sr$ = 0.718, $\delta^{18}O$ = 16 and Sr = 180 ppm; AM: $^{87}Sr/^{86}Sr$ = 0.7055, $\delta^{18}O$ = 5.7 and Sr = 300 or 1000 ppm. Oxygen concentrations are equal for each end-member. Tick marks indicate percentages of CM.

outside the maximum range which can be caused by fractional crystallization, which is in the order of 0.5–1‰.

Discussion

Only one volcanic centre (Serua) displays a strong positive correlation between oxygen- and Sr isotopes (Fig. 2). The trend for Serua is steeper than the one predicted for source contamination, but is not similar to the curve expected for assimilation of the arc crust. This could be explained by having different amounts of source contamination and arc-crust assimilation for each sample. Alternatively it is possible that high $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ melts mix with low $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ melts to produce the linear trend. The low $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ melt is a result of source contamination, whereas the high $^{87}Sr/^{86}Sr$-$\delta^{18}O$ melt could be both a result of source contamination or arc crust assimilation.

All other volcanic centres fall close to the source contamination curve. The northern Banda Arc volcanoes (Banda Archipelago and Manuk) can be explained by 0.5-1% addition of sediment to their source, whereas the southern Banda Arc volcanics (Nila, Teon, Damar and Romang) require some 2-5%. This is in agreement with the models based on Pb-Nd isotopes (Vroon *et al.*, 1993).

Conclusion

The Banda Arc (excluding Serua) is so far the only arc where high $^{87}Sr/^{86}Sr$ is accompanied by low $\delta^{18}O$ values. This in contrast to other arcs where subducted sediment is thought to be important source component: the Lesser Antilles (Davidson and Harmon, 1989) and the Eolian arc (Ellam and Harmon, 1990) have both high $^{87}Sr/^{86}Sr$ and $\delta^{18}O$, suggesting arc crust assimilation. Therefore the Banda Arc represents the best example of an active island-arc were sediment subduction plays a major role in magma genesis.

References

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