Secular evolution of proto-Izu-Bonin-Mariana arc volcanism: Constraints from statistical analysis of melt inclusion compositions

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International Ocean Discovery Program (IODP) Expedition 351 'Izu–Bonin–Mariana (IBM) Arc Origins' drilled Site U1438, situated in the north-western margin of the Philippine Sea, into volcaniclastic sediments of the proto-IBM arc. Brandl *et al.* (2017, *Earth and Planetary Science Letters*) have analysed the major, trace and volatile elements of 304 melt inclusions hosted in fresh silicate minerals to unveil the magmatic evolution of the proto-IBM arc between 30 and 40 Ma, when the arc volcanism matured following subduction initiation at 52 Ma. Brandl *et al.* (2017) concluded that: (1) volcanism of the proto-IBM arc shifted from calc-alkaline affinity to tholeiitic affinity over time; and (2) such compositional shift is linked to both the volcanic productivity and the maturation of an evolving island arc. To better integrate the composition of melt inclusions with the magmatic evolution of the proto-IBM arc, this study extends the dataset of Brandl *et al.* (2017) by: (1) additional analysis of volatiles (H_2O, S, F and Cl) and P_2O_5 for 47 carefully selected melt inclusions by Secondary Ion Mass Spectrometry (SIMS); and (2) statistical analysis on the composition of 237 representative melt inclusions covering the full time range (30–40 Ma) of the dataset. Based on statistical analysis of the melt inclusion compositions and by considering trace element compositions and volatile concentrations, we can confidently distinguish five main clusters of melt inclusion compositions which can be further separated into a total of nine sub-clusters. Among the nine sub-clusters, we identified three major magma types: (1) medium-K enriched magmas which form a tholeiitic trend (30–38 Ma); (2) less-depleted medium-K melts which form a calc-alkaline trend (35–39 Ma); and (3) low-K depleted magmas which form a calc-alkaline trend (35–40 Ma). We demonstrate that: (1) volcanism of calc-alkaline depleted magmas lasted until 35 Ma; (2) the volcanism of calc-alkaline depleted magmas and that of more enriched normal arc magmas (tholeiitic and calc-alkaline affinities) overlap between 35 and 38–39 Ma and; (iii) the volcanism of normal arc magmas became predominant thereafter at the proto-IBM arc. Such identification of three major magma types is distinct from that of Brandl *et al.* (2017), in which less-depleted medium-K calc-alkaline magmas amd depleted low-K calc-alkaline gammas were not distinguished. We infer that depleted source mantle had been replaced by enriched mantle due to mantle convection beneath the proto-IBM arc from >40 Ma to 35 Ma. Statistical analysis is a useful tool to partition a mixture of multivariable dataset, such as datasets of melt inclusion compositions, into several distinct groups and potentially reconstruct their geological evolution.

Keywords: Amami Sankaku Basin, International Ocean Discovery Ptrogram, Izu-Bonin-Mariana arc, Melt inclusion, Statistical analysis, Volatiles

