Temporal evolution of proto-Izu-Bonin-Mariana arc volcanism over 10 Ma: Constraints from statistical analysis of melt inclusion compositions

*Morihisa Hamada[1], Hikaru Iwamori[1,2,3], Philipp A. Brandl[4], Takayuki Ushikubo[1], Kenji Shimizu[1], Motoo Ito[1], He Li[5], Ivan P. Savov[6]

1. Japan Agency for Marine-Earth Science and Technology, 2. Department of Earth and Planetary Sciences, Tokyo Institute of Technology, 3. Earthquake Research Institute, University of Tokyo, 4. GEOMAR Helmholtz Centre for Ocean Research Kiel, 5. Institute of Oceanology, Chinese Academy of Sciences, 6. School of Earth and Environment, University of Leeds

International Ocean Discovery Program (IODP) Expedition 351 "Izu–Bonin–Mariana (IBM) Arc Origins" drilled Site U1438, situated in the north-western region of the Philippine Sea. Here volcaniclastic sediments and the igneous basement of the proto-IBM volcanic arc were recovered. To gain a better understanding of the magmatic processes and evolution of the proto-IBM arc, we studied melt inclusions hosted in fresh igneous minerals and sampled from 30- to 40-Ma-old deposits, reflecting the maturation of arc volcanism following subduction initiation at 52 Ma. We performed a novel statistical analysis on the major element composition of 237 representative melt inclusions selected from a previously published dataset, covering the full age range between 30 and 40 Ma. In addition, we analysed volatiles (H_2O, S, F and Cl) and P_2O_5 by Secondary Ion Mass Spectrometry (SIMS) for a subset of 47 melt inclusions selected from the dataset. Based on statistical analysis of the major element composition of melt inclusions and by considering their trace and volatile element compositions, we distinguished five main clusters of melt inclusions, which can be further separated into a total of eight subclusters. Among the eight subclusters, we identified three major magma types: (1) enriched medium-K magmas, which form a tholeiitic trend (30–38 Ma); (2) enriched medium-K magmas, which form a calc-alkaline trend (30–39 Ma); and (3) depleted low-K magmas, which form a calc-alkaline trend (35–40 Ma). We demonstrate that (1) the eruption of depleted low-K calc-alkaline magmas occurred prior to 40 Ma and ceased sharply at 35 Ma; (2) the eruption of depleted low-K calc-alkaline magmas, enriched medium-K calc-alkaline magmas and enriched medium-K tholeiitic magmas overlapped between 35 and 38–39 Ma; and (3) the eruption of enriched medium-K tholeiitic and enriched medium-K calc-alkaline magmas became predominant thereafter at the proto-IBM arc. Identification of three major magma types are distinct from the previous work, in which enriched medium-K calc-alkaline magmas and depleted low-K calc-alkaline magmas were not identified. This indicates the usefulness of our statistical analysis as a powerful tool to partition a mixture of multivariable geochemical datasets, such as the composition of melt inclusions in this case. Our data suggest that a depleted mantle source had been replaced by an enriched mantle source due to convection beneath the proto-IBM arc from >40 to 35 Ma. Finally, thermodynamic modelling indicates that the overall geochemical variation of melt inclusions assigned to each cluster can be broadly reproduced either by crystallisation differentiation assuming P = 50 MPa (about 2-km deep) and 2 wt % H_2O (almost saturated H_2O content at 50 MPa) or P = 300 MPa (about 15-km deep) and ~6 wt % H_2O (almost saturated H_2O content at 300 MPa). Assuming oxygen fugacity (f_{O2}) of log f_{O2} equal to +1 relative to nickel-nickel oxide (NNO) buffer best reproduces the overall geochemical variation of melt inclusions, but assuming a more oxidising conditions (log f_{O2} = +1 to +2 NNO) likely reproduces the geochemical variation of enriched medium-K and calc-alkaline melt inclusions (30–39 Ma).

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

