Evolution of the proto-Izu-Bonin-Mariana arc volcanism: Constraints from statistical analysis on geochemical data of melt inclusions

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IODP Expedition 351 "Izu-Bonin-Mariana (IBM) Arc Origins" drilled volcaniclastic sediments deposited immidiately after subduction initiation and the inception of island arc volcanism at ~52 Ma around Site U1438 in the northwest margin of the Philippine Sea Plate. In order to unveil the magmatic history of the proto-IBM arc, we have analyzed major and volatile elements (S and Cl) of 339 melt inclusions from Unit III (30-40 Ma), Site U1438, which record magmatic evolution of island arc from 40 Ma to 30 Ma. Clinopyroxene- and plagioclase-hosted melt inclusions are diverse in composition, ranging from low- to high-K series basalt through rhyolite. These melt inclusions were recovered from volcaniclastic sedimentary cores and thus can be a mixture of material derived from several volcanic centeres. In order to better link the melt inclusions with the magmatic evolution of the proto-IBM arc, we performed statistical analysis (K-means cluster analysis) on geochemical data of melt inclusions.

After performing cluster analysis, melt inclusion data were separated into 6 clusters termed Clusters 1 to 6. Four clusters (Clusters 1, 3, 4 and 5) are composed of basaltic to andesitic melt inclusions. Geochemical trends of these four clusters can be explained by fractional crystallization from respective primitive melts at f_{O2}=NNO+1. Variations in the degree of partial melting and dissolved H_2O concentration in melt are necessary to fully reproduce geochemical variations of melt inclusions. Cluster 1 melt inclusions (medium-K tholeiitic series) and Cluster 5 melt inclusions (calc-alkaline high-Mg andesites) are independent. Cluster 5 melt inclusions could be derived from partial melts of depleted mantle, which disappeared at ~37 Ma. Cluster 1 melt inclusions could be derived from partial melts of replenished fertile mantle, which occur throughout Unit III but became dominant after disappearance of Cluster 5 melt inclusions at ~37 Ma. Clusters 3 and 4 melt inclusions steadily occur throughout Unit III. Cluster 3 melt inclusions are characterized by higher S concentrations, which would be derived from partial melts of metasomatized mantle by S-rich slab fluids. Cluster 4 melt inclusions are characterized by higher concentrations of Cl and K_2O, which would be derived from partial melts of metasomatized mantle by Cl- and K-rich slab fluids. Besides four clusters reflecting heterogeneity of the mantle wedge arc magma source, other two clusters are identified. Cluster 2 is characterized by extremely high Cl concentration (up to 1 wt.%) and can be explained as Cluster 1 melts being assimilated by brine. Cluster 6 is composed of silicic melt inclusions ranging from dacite to rhyolite.

Identification of subgroups of melt inclusions as summarized above cannot be made by conventional graphical approach using two-dimensional diagrams, demonstrating usefulness of introducing statistical approach into geochemistry.

Keywords: Izu-Bonin-Mariana volcanic arc, Amami Sankaku Basin, Kyushu-Palau ridge, Melt inclusion, Statistical analysis