Isotopic Characteristics of Volcanic Rocks from the Shimabara Peninsula: A Study of Mantle-Crust Interaction

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A large set of samples was collected in and around Shimabara Peninsula, with Unzen volcano at its center, and analyzed for age data, major, trace element, and strontium (Sr), neodymium (Nd), and lead (Pb) isotopic compositions. According to the age data, the group is divided into Younger (0-0.15Ma) and Older (0.15-0.5Ma) Unzen and Pre-Unzen (older than 0.5Ma) stages. The Younger and Older stages are dominated by andesite and dacite while the Pre-Unzen stage is represent by basalt and pyroxene andesite. Major and trace element compositions of the Pre-Unzen andesitic and basaltic magmas were interpreted to be derived by mantle source and that the basalt-andesite evolution was governed primarily by fractional crystallization. Meanwhile, Unzen andesite-dacite evolutional trend was interpreted to reflect mixing of mantle-derived melt with crustal materials.

The studied samples together with samples from northern Kyushu, the Sea of Japan and the Ryukyu Arc were plotted relative to major mantle isotopic components. The Shimabara samples and those from northern Kyushu are embedded within a triangular represent by N-MORB (Normal Mid-Ocean Ridge Basalt), EM1 (Enriched Mantle Type 1) and EM2 (Enriched Mantle Type 2). However, unlike other northern Kyushu basalt centers, the Shimabara samples strictly spread along a trend connecting N-MORB and EM2 fields, suggesting, on the one hand, mixing between the two components is essential, and its source(s) is different from those of other northern Kyushu basalt centers.

Strontium isotopic data of the Shimabara samples span a rather narrow range, from about 0.704 to 0.705, accompanied by a limited variation of neodymium (0.51268-0.51275) and lead isotopes, for example, 206Pb/204Pb ratios vary only from 18.1 to about 18.4 (compared with the range of 17.7 to 18.4 observed for other northern Kyushu). In addition, the correlation between Sr and Pb is broadly positive, suggesting binary mixing. Specifically, while Older Unzen dacite and andesite having generally high Sr and Pb isotopes, and higher than those of the Younger Unzen samples, indicating crustal involvement, Pre-Unzen andesite and basalt also show a large variation trending from low to high Sr and Pb isotopes. We suggest that continental crust may as well affect the Pre-Unzen lavas resulted in higher Sr and Pb isotopes relative to the more depleted, considered to represent or be closer to the mantle isotopic signature beneath the region that trended more toward N-MORB than the nearby northern Kyushu EM1-influenced mantle.

Intrinsic mantle isotopic signature of the region may be represented by the most depleted 0.5-2Ma Pre-Unzen samples, derived by melting of the mantle source. Whereas isotopic variation of the Younger and Older Unzen samples may be explained by interaction between the continental crust and mantle derived melts as mantle upwelling and lower crust erosion proceeding followed the Shimabara graben formation. Thus, the isotopic characteristics are viewed as results of a binary mixing between pervasively N-MORB and EM2-like components.