Arc evolution and continental crust formation at the Izu-Bonin-Mariana arc system

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The Izu-Bonin-Mariana (IBM) system extends 2800km from the Izu Peninsula to Guam Island and is arguably the most extensively surveyed intra-oceanic arc. Ambitious wide-angle OBS experiments at the (IBM) arc have documented the characteristic seismic crust and mantle structure, including a middle-crustal layer of Vp=6.0-6.3 km/s, an upper-most lower crust layer with Vp=6.8-6.9 km/s overlying a thicker lower layer of Vp=7.1-7.3 km/s, and the uppermost mantle having Vp=7.6-7.7 km/s, clearly lower than normal upper mantle (Vp=8.0 km/s). The presence of the 6.0-6.3 km/s mid-crustal layer throughout the entire IBM arc is remarkable because this velocity is similar to the mean velocity of the continental crust, thereby suggesting that the continental crust, having an andesitic average composition, may be directly created in IBM. We estimate the composition of the IBM arc crust based on the seismic structure and compositions of IBM arc magmas including the Tanzawa tonalite occurring in the arc-arc collision zone at the northern tip of IBM and likely representing the obducted portion of the IBM middle crust.

Two different processes of andesitic crust formation are assumed: (1) 30% melting of the pre-existing basaltic crust that was created by 20% fractionation of olivine from an inferred IBM primary basalt magma; (2) mixing of the differentiated basalt magma and the felsic magma produced by 15% melting of the basaltic crust. Both processes can reasonably explain compositions of the inferred andesitic middle crust. Partial melting of this andesitic middle crust produces both felsic magmas and less mafic restite; the latter corresponding to the uppermost lower crust layer.

Seismologically observed volume of the IBM upper and middle crust layers and the above petrologic model provide estimates for volume of dunitic cumulate and gabbroic restites, which may form the lower crust. The calculated volume is, however, ~2 times greater than the observed volume of the lower crust, suggesting that the mafic cumulate and resites, originally produced within the arc crust, would be transformed into the uppermost mantle, causing unusually low Vp in that region. This transformation may play the key role in creating the andesitic continental crust from the initial basaltic arc crust through evolution of the intra-oceanic arc crust.