Petrogenesis of tonalitic middle crust of oceanic arcs and its bearing on the continental crust formation

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Slab melting has been proposed for the formation of Archean TTG. However, the present study suggests that partial melting of lower parts of thicker Archean arc crust (>35 km) is an alternative process for the petrogenesis of these magmas. The REE modeling combined with density calculations for the felsic melt and eclogitic residue suggests that the eclogitic residue after subtracting felsic melt would be gravitationally unstable and sink into the mantle beneath the arc

Oceanic island arc crust is the fundamental building block of continental crust, and the juvenile continents formed by the coalescence of oceanic arc and other oceanic terranes. The bulk chemical composition of these accreted arc fragments is thus relevant to the composition of continental crust. Early models proposed that primitive additions to the continental crust by arc accretion in arc setting are andesitic, and consequent lateral growth of continents resulted in andesitic composition of the continental crust. Although more recent studies indicate that the parental magmas in arcs are basaltic, not andesitic, models of an intermediate bulk composition for the continental crust are still accepted based on geophysical, geological, and/or petrological evidences.

Recent seismic study of the northern Izu-Bonin-Mariana (IBM) arc reveals the mid-crust has seismic characteristics typical of felsic plutonic rocks (~6.0 km/sec P-wave velocities) at a depth ranging from 7 km to 12 km (about 30 % of the arc crust) overlying a mafic lower crust (7.1 - 7.3 km/sec P-wave velocities). This is interpreted to be tonalitic middle crust, an interpretation that is supported by studies of the Miocene Tanzawa plutonic complex (TPC, 7 Ma; K-Ar ages) distributed in the Izu arc collision zone and tonalitic xenoliths in some Izu arc volcanoes. Similarly, seismic surveys of the Kyushu-Palau Ridge, once conjugate to the IBM arc, has shown a presence of 6 km/s layer. The presence of thick tonalitic middle crust in the Izu-Bonin arc requires re-evaluation of models for arc crust composition, because previous models inferred a basaltic bulk composition for intra-oceanic arc system.

TPC provide a unique opportunity to examine the felsic middle crust of the IBM arc. Collision of the northern IBM arc system to the Honshu arc has been occurring since the mid-Miocene. One manifestation of this collision is uplift and exposure of TPC covering ~140 km2 in the Tanzawa Mountains of central Honshu. The Tanzawa plutonic rocks, mainly consisting of tonalite intrusions, belong to the calc-alkaline series and exhibit a wide range of chemical variation from 43 to 75 wt.% SiO2. They are characterized by relatively high Ba/Rb and Ce/Nb ratios, and low abundances of K2O, LIL and REE elements. Their petrographic and geochemical features are indicative of their derivation from an intermediate parental magma through crystal fractionation and accumulation processes, both involving hornblende, plagioclase, and magnetite.

The mass balance calculations, combining data from melting experiments of hydrous basaltic compositions at lower crustal levels, suggest that the TPC intermediate parental magma and pyroxenitic restite were generated by dehydration partial melting (~45 % melting) of amphibolite chemically similar to low-K tholeiitic basalt. Densities of the Fe-Ti oxides-bearing pyroxenite restites are calculated in the range 3.4 to 3.9 g/cm3, which are considerably higher than that of the upper mantle peridotite (~3.3 g/cm3). The pyroxenite restite could separate from the arc crust and sink into the mantle due to their relatively higher density during the arc collision. Slab melting has been proposed for the formation of Archean TTG. However, the present study suggests that partial melting of lower parts of thicker Archean arc crust (>35 km) is an alternative process for the petrogenesis of these magmas. The REE modeling combined with density calculations for the felsic melt and eclogitic residue suggests that the eclogitic residue after subtracting felsic melt would be gravitationally unstable and sink into the mantle beneath the arc during the coalescence of arc.