Melting conditions beneath island arc volcanoes and its tectonic implication

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Subduction zone is believed to be an important tectonic environment where surface materials return to the mantle, and plays an important role in martial recycling in the earth. Subduction zone magmatism is more complicated and diverse as compared to those of mid-ocean ridges and hot spots mostly because of the contribution of H_2O-rich fluid which is thought to be expelled from the subducting slab, and the complexity of thermal and flow structures of the wedge mantle. In order to understand such complex subduction zone magmatism, quantitative estimation of melting conditions and clarification of its tectonic controls must be made. In this study, melting conditions in mantle were determined by a newly developed rigorous approach.

The approach adopts a least-squares optimization with input from major element composition of a single volcanic rock, in which crystallization and melting parameters are simultaneously and consistently optimized. The optimized parameters are (1) degree of partial melting, (2) melting pressures, and (3) H_2O content in primary melt as melting parameters, and (4) pressure of fractional crystallization and (5) temperature of erupted magma as crystallization parameters. Melting temperature is also estimated from the relationship among the optimized parameters.

The method was applied to frontal volcanoes of world arcs. There is a good overall linear positive correlation between degree of melting and melting temperature as well as melting pressure and melting temperature. From a clear positive correlation between melting pressure and temperature, melting is inferred to be primary controlled by the decompressional melting of mantle with various potential temperatures as in the case of global correlation for MORB.

From the comparison with the estimated melting conditions and tectonic parameters, a major controlling tectonic parameter is specified, which is the difference between absolute velocity of subducting slab and convergence velocity (V_{abs} - V_c), which corresponds to trench retreat velocity if negative and trench advance velocity if positive. The V_{abs} - V_c show a positive correlation with melting temperature and melting pressure with a few exceptions. The existence of back arc volcanism and extensional tectonics are associated with arcs with highV_{abs} - V_c. The most critical factor that controls arc magmatism is thought to be temperature of the wedge mantle, which is strongly controlled by the return flow induced by slab subduction.