Forward modeling of P-T-deformation paths of regional metamorphic rocks at convergent plate boundaries

HIKARU IWAMORI

Department of Earth and Planetary Science, University of Tokyo (hikaru@eps.s.u-tokyo.ac.jp)

Regional metamorphic belts and rocks are thought to be products of remarkable geological events, such as collision and subduction of plates at convergent plate boundaries. Therefore, it is possible to extract the events and processes from the regional metamorphic rocks. Analysis of P-T(-time) paths of the rocks is one of the main approaches of metamorphic petrology, in order to understand ultimately the evolution of the Earth's crust (e.g., Spear, 1995). Regional and structural geology also provide fundamental information on flow and deformation of the crust, especially the forearc region of the arc and continent (e.g., Platt, 1986). In spite of accumulation of the information on physico-chemical conditions recorded in the metamorphic rocks, the corresponding global field to produce such conditions has been poorly constrained at present. In this paper, we will discuss forward modeling of such global field.

Results of modeling on the temperature field and the flow field of metamorphism and deformation of a forearc region (e.g., Iwamori, 2000; 2003) suggest that (1) high-P type metamorphism, together with high-T type, requires a high-T condition compared to the average thermal structure of forearc region in subduction zone, when both heat and water are supplied to the forearc region associated with ridge subduction, supporting "paired metamorphism" (Miyashiro, 1961), (2) a 3-D corner flow in a forearc wedge can account for observed deformation recorded in Cretaceous regional metamorphic belts in SW Japan, suggesting that a large-scale viscous flow and deformation of the forearc region occurred associated with the metamorphism. These results suggest that the P-T paths and deformation should be strongly coupled, hence combined analyses of P-T paths and deformation will provide tight constraints on the global temperature and flow field.

References

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Pressure and temperature controls on slab-derived fluid chemistry

MAUREEN D. FEINEMAN[1], FREDERICK J. RYERSON[2] AND DONALD J. DEPAOLO[3]

[1]Institute for Study of the Earth's Interior, Okayama University at Misasa, 827 Yamada, Misasa-cho, Tottori-ken 682-0193, Japan
[2]Lawrence Livermore National Laboratory, Dept. of Earth Sciences, L-206, Livermore, CA 94551, USA
[3]University of California, Dept. of Earth and Planetary Science, Berkeley, CA 94720-4767, USA

The composition of slab-derived fluid in a subduction zone is determined by the residual mineral assemblage following pressure-induced dehydration reactions in the subducted oceanic crust. The residual mineral assemblage, in turn, is determined by the trajectory of the slab through pressure-temperature space as it descends into the mantle. Recent experimental studies of phase equilibria in subducted oceanic crust have shown that the presence of zoisite in the residual slab following amphibole breakdown is strongly dependent on temperature (Forneris and Holloway 2003). We have combined new mineral-fluid trace element partitioning data for zoisite and mica with existing data for garnet, cpx, and rutile to generate bulk eclogite-fluid trace element partition coefficients for both zoisite-bearing (cold) and zoisite-free (hot) assemblages. We find that fluids in equilibrium with zoisite-bearing slabs are strongly depleted in Sr and Pb, and to a lesser extent Ba, Th, and U relative to fluids in equilibrium with zoisite free slabs. Rare earth and high field strength elements in the fluid are not affected by zoisite in the slab.

The cold and hot slab-derived fluids are numerically combined with sediment melts and added to the mantle, which is susequently melted 10-20% to generate arc basalt. We find that model arc besalts generated from cold slab-derived fluids have Sr concentrations of about half what is observed in natural arc basalts. Therefore, either most subducting slabs are at temperatures outside the range of zoisite stability beneath the volcanic front, or there is an additional Sr input to arc basalts not accounted for in our model. Our results help constrain thermal conditions beneath subduction zones and the processes responsible for determining arc basalt geochemistry.

Reference

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