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Growth of lower crust by magmatic intraplating

Takashi Yoshino [1]

[1] Geol. Inst., Univ. Tokyo

The Kohistan Arc of NW Himalayas represents widely exposed lower crustal section consisting mostly of metabasic rocks. High temperature metamorphism was triggered by subsequent gabbroic intrusion event after crystallization of basaltic magma at lower crustal depth. Metamorphic P-T path obtained from gabbroic rocks represents remarkable increase in pressure and constant depth at onset of each metamorphic path. They suggest that magmatic accretion at mid-crustal depth and subsequent crustal thickening are quite important processes of growth of the lower crust.

In the view of growth of continental crust, magmatic underplating caused by accretion of basaltic magma derived from mantle at the base of pre-existing crust is a significant factor. Although previous workers have considered magmatic underplating as an important mechanism of growth of basaltic lower crust, the process of magma accretion has not been documented. Because the Kohistan arc located in NW Himalayas represents no absence of lowermost crust, it is quite suitable to investigate the process of basaltic accretion to the crust. In present study, growth mechanism of lower crust is considered based on metamorphic P-T paths after crystallization of magma. In addition, the results of the Fiordland complex, New Zealand, which have similar petrological characteristics to the Kohistan arc will be also reported. From these results, a growth model of the lower crust is proposed.

In gabbroic rocks of the Kohistan arc, textures preserve evidence for pyroxene granulite facies metamorphism defined by mineral assemblage of two pyroxene-plagioclase. Relict pyroxene granulites in the Kamila amphibolite belt were used to estimate metamorphic P-T paths. Al zoning in plagioclase and clinopyroxene was analyzed to estimate metamorphic P-T path under high temperature condition, because diffusion rate is very slow. Based on similarity of Al zoning in both minerals, if growth surface of two minerals were equilibrated, it is possible to calculate the metamorphic conditions. Peak metamorphic temperatures are around 1073K at the pressure conditions ranging from 0.8 to 1.2 GPa. Inferred P-T paths show remarkable increase in pressure under high T condition (1073K). Initial metamorphic pressure condition is constant (around 700 MPa).

Pressure increase paths of the lower crust of the Kohistan arc suggest loading above these rocks. The path is probably caused by magmatic underplating rather than arc-continent collision. These phenomena can be considered by a following model. (1) Subduction-related magma is crystallized at mid-crustal depth (c. 20 km). (2) Preexisted gabbro undergo increase in pressure triggered by magma loading at mid-crustal depth. (3) Lower crust grows downward and undergo crustal thickening by the sequence.

Although magmatic underplating has been considered as a mechanism of magma accretion at the base of the crust, present study suggests that magma accretion occurs at mid-crustal depth. This physical process can be explained by density contrast between the rocks of lower crust and basaltic magma derived from mantle. Because gabbroic rocks at considerable depth are denser than the magma, the basaltic magma can move upward by buoyancy and then can reach the neutral depth. This process could give the heat source of crustal anatexis and metamorphism and cause generation of eclogite due to the crustal thickening. Because density (3.38-3.54 g/cm3) of eclogite is higher than surrounding mantle, lowermost crust could delaminate to the mantle. In this case, this type of magmatic underplating process is possible to become recycle mechanism of huge crustal materials.