The lower crustal Dasu Tonalite and its implications for the formation-reformation-exhumation history of the Kohistan arc crust

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Geological outline of the Kohistan block

The Kohistan block in northern Pakistan represents an exposed crustal cross section to near-MOHO depths of an ancient island arc which became sandwiched between the Eurasian and Indian continents. The Kohistan lower crust is composed of three geological units: south to north, ultramafic rocks and mafic granulites (Jijal Complex), banded amphibolite (Kamila Amphibolite) and a gabbronorite and ultramafic association (Chilas Complex). These units are geologically continuous, with no major tectonic breaks between them. The Kohistan block is tilted to the north due to uplift by subduction of the Indian continent from the south. Tonalite sheets intruding the lower crustal sequence of the Kohistan block provide key information on the dynamic history of the Kohistan arc crust.

Dasu Tonalite in the lower crustal sequence

A silicic melt pod which first appears in garnet pyroxenite of the Jijal Complex develops into granitic rock in the overlying Kamila Amphibolite. In the upper part of the Kamila Amphibolite it expands into kilometer-sized tonalite sheets, the Dasu Tonalite. The Dasu Tonalite is a weakly foliated epidote-garnet-muscovite-biotite-hornblende tonalite. It was emplaced as sheet-like bodies of various sizes layer-parallel to the structure of the host banded amphibolite, suggesting syn-tectonic intrusion. Based on geothermobarometry on the amphibolite, the tonalite is estimated to have been intrtruded at 20–30 km depth (Yoshino et al. 1998), implying that it was generated and emplaced into the lower crust of the Kohistan arc. This conclusion is consistent with the presence of magmatic epidotes in the Dasu Tonalite, an indicator of high-pressure crystallization.

Juvenile granitic magma in the lower crust

The Dasu Tonalite is extremely poor in K_2O (0.6–0.9 wt% at 65–70% SiO_2) and Rb (18–28 ppm), indicating that it contains no recycled upper crust. It is also depleted in Zr, Y, Th and Nb compared to common arc granitoids of similar SiO_2 content, such as the Cretaceous Circum-Pacific granitoids. The initial $^{87}Sr/^{86}Sr$ ratio of the tonalite is low, 0.7037–0.7038, similar to the lower crustal rocks of the Kohistan block and within the range of felsic rocks from the oceanic Izu-Bonin arc (Taylor and Nesbitt 1998). These features suggest that the Dasu Tonalite formed from juvenile granitic magma generated from mantle-derived lower crustal mafic components without interaction with the Indian craton, which presumably now tectonically underlies the Kohistan block.

Geochronology and tectonic implications

Two samples of Dasu Tonalite have given a SHRIMP zircon U-Pb age of 98 Ma. The euhedral shape of the zircon grains and absence of overgrowth or resorption textures in cathodoluminescence indicate a simple magmatic history starting at 98 Ma, with no secondary thermal event. The $^{40}Ar/^{39}Ar$ biotite age of the tonalite is 70 Ma. The 28 m.y. discrepancy between the two geochronometers is interpreted as a measure of the deep crustal residence time of the Dasu Tonalite. Tonalite magma generated and crystallized at 98 Ma probably remained at lower crustal temperatures of about 700–800°C (as indicated by geothermometry on the intercalated Kamila amphibolite) before cooling to ca. 300ÚC at 70 Ma, possibly when the Kohistan block was tilted, uplifted and exhumed due to the collision of India.

Dynamic processes in the Kohistan lower crust

The isotopic ages reported on the Kamila amphibolite and Chilas gabbro complex are remarkably scattered. Although this might be due in part to variation in the quality of the data, some of the scatter might also reflect a protracted emplacement and cooling history for these rocks. A long deep-crustal residence time could cause petrological reformation and isotopic re-equilibration after the igneous crystallization of the gabbros and conversion of those rocks to amphibolites. At least the upper half of the Kamila amphibolite consists of hydrated and recrystallized gabbro and gabbronorite equivalents of the Chilas complex (Yamamoto 1993). This interpretation is supported by the ubiquitous amphibolites in the Chilas complex. It would be reasonable to assume that the huge volume of the Chilas gabbro and gabbronorite was not produced in a single magmatic pulse, but formed by successive injections of mafic magma over a considerable period of time. This would have produced a mosaic of rocks frozen at various stages of the dynamic process from igneous crystallization to amphibolitization, which is what we now see.

References

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