Re-interpretation of progressive metamorphism, facies series, P-T-t path and exhumation model for the collisional orogenic belts

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Recent discovery of ultra-high pressure (UHP) mineralogy, and descriptions of geology, petrology, geochronology and geochemistry of the Phanerozoic collisional orogens have changed the basic concepts of metamorphic facies series, P-T-time path, progressive metamorphism, Barrovian-type metamorphism and tectonic model.

The Himalayan orogen has served as a world standard for the collisional orogenic belt for a long time, characterized by Barrovian-type metamorphism (intermediate-P type metamorphism within the stability field of plagioclase), tectonic overlapping of double-continental crust, and thermal relaxation with buoyant unroofing (England and Thompson 1984). Recent discovery of coesite-bearing eclogite in the western Himalaya and eclogites from the central to eastern Himalaya can not be explained by the previous models. In the followings, summarizing the new constraints on orogenic process, I try to explain the collision orogeny including Himalaya.

(1) Major structure as a sandwiched subhorizontal tectonic slice: a thin tectonic slice with P-T maximum at structural intermediate. The UHP-HP unit is a few km thick slice cut on the top and bottom by normal and reverse faults, respectively. It is separated from the underlying and overlying low-grade or low-P metamorphic rocks.

(2) The underlying unit is thermally metamorphosed to form andalusite-sillimanite metamorphic rocks in some cases by the hot tectonic intrusion of UHP-HP rocks.

(3) Metamorphic facies series ranges from greenschist/blueschist transition or blueschist, through epidote-amphibolite, quartz- and zoisite-eclogite, to dry eclogite facies with a sharp kink point, indicating anti-clockwise P-T path in the case of the highest-P and –T belt.

(4) The P-T-time path calculated by inclusion mineralogy in garnet combined with zoned garnet compositional profile shows the same P-T path with the metamorphic facies series.

(5) Extensive hydration at mid-crustal level obliterated the pre-existing UHP-HP mineralogy, except mineral inclusions in garnet, zircon and omphacite.

(6) Zoned zircons with UHP-HP minerals mantled by late-stage hydration with Barrovian minerals are dated as ca. 30 m.y. older from that of hydration stage at rim, indicating a slow tectonic exhumation.

(7) The mountain-building stage is not related to the exhumation of UHP-HP rocks to the mid-crustal level. The mountain-building, in the case of Himalaya, started at 9 Ma, ca. 16 m.y. after the Barrovian hydration at mid-crustal level.

(8) Combining above constraints, a tectonic extrusion model is the most probable process (Maruyama 1990, Maruyama et al. 1994, Maruyama et al. 1996). (9) Previous interpretation (e.g., England and Thompson 1984) of progressive metamorphism, facies series, P-T-t path are all quite different from those summarized here.

Most of present mineralogy exhibits the late-stage crustal metamorphism due to extensive hydration underneath. The role of water must be re-evaluated to mask the progressive nature of metamorphism during subduction.

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