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The relationship between continental collision process and metamorphic pattern in the Himalayan collision belts

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Both UHP and HP eclogites are reported from the Kaghan Valley and Tso Morari Massif in the western part of the Himalayan collision belt (Ghazanfar and Chaudhry, 1987; Thakur, 1983). UHP eclogites in the Kaghan record peak metamorphic conditions of 770 °C and 30 kbar (O'Brien et al., 2001) and was retrograded into the epidote-amphibolite or blueschist (580–610 °C, 10–13 kbar; Lombardo and Rolfo, 2000). Sensitive high-resolution ion microprobe dating of zircon reveals that the UHP eclogite formed at ca. 46 Ma (Kaneko et al., 2003; Parrish et al., 2006). The Tso Morari UHP eclogite had formed at 750 °C, > 39 kbar (Mukheerjee et al., 2003; Bundy, 1980) and underwent amphibolite facies retro-grade metamorphism (580 °C, 11 kbar) during uplift (Guillot et al., 2008). Peak metamorphism of the Tso Morari Massif was dated at ca. 53-55 Ma (Leech et al., 2005). Only HP eclogites have been reported from the mid-eastern part of the Himalayan collision belt (Lombardo and Rolfo, 2000; Corrie et al., 2010). The HP eclogite in the mid-eastern part may have formed at ca. > 780 °C and 20 kbar and was overprinted by high-pressure granulite facies metamorphism (780-750°C, 12-10 kbar) at ca. 30 Ma (Groppo et al. 2007; Corrie et al., 2010). HP granulite (890 °C, 17–18 kbar) is reported from the NBS, at the eastern terminus of the Himalayan collision belt; the granulite was subjected to retrograde metamorphism to produce lower-pressure granulite (875-850°C, 10-5 kbar), representing near-isothermal decompression (Liu and Zhong, 1997). The HP granulite metamorphism may have occurred at ca. 22-25 Ma. Along the Himalayan collision belt, peak metamorphism changes eastward from UHP eclogite facies through HP eclogite facies to high-pressure granulite facies, indicating a progressive eastwards decrease in the depth of subduction of continental crust and an eastwards increase in the geothermal gradient. The peak metamorphic ages also decrease from 53-46 Ma in the west to 22-25 Ma in the east indicating propagation of collision towards east. The following collision model of the Himalayan collision belt is proposed based on data published in previous studies. Collision between the Indian and Asian blocks started in the west before ca. 55 Ma. In the western part, the amount of oceanic slab subducted prior to continent collision was enough to pull the continental crust down to the depths of UHP metamorphism, as a wide ocean existed between the Asian and Indian blocks prior to collision. Following UHP metamorphism, oceanic slab break-off started at ca. 55∼46 Ma in the west due to the very strong buoyancy of the deeply subducted continental block. In contrast, the subduction of continental crust continued at this time in the middle and eastern parts of the belt. The zone of break-off migrated eastward, initiating a change from steep- to low-angle subduction. Final break-off may have occurred in the easternmost part of the belt at ca. 22-25 Ma. The depth of slab break-off decreased toward the east due to the westward decrease of the amount of subducted oceanic crust along the Himalayan collision belt, resulting eastwards decrease of an uplifting rate due to a decrease in buoyancy of the continental slab. The slower uplift resulted in a longer period of thermal relaxation and a higher geothermal gradient. In the west, the high rate of uplift resulted the epidote amphibolite facies (580–610°C) retrograde metamorphic overprint on the UHP eclogites, whereas the relatively slow uplift in the mid-eastern part caused high-grade granulites (850°C) retrograde metamorphic overprint on the HP eclogites. The study indicates that the metamorphic pattern along the collision belt is strongly related to the amount of subducted oceanic crust between continents before collision and the depth of slab break-off. Therefore metamorphic pattern can be used to interpret both the disappeared and ongoing tectonic process during continental collision.