

# Discovery of granulitized eclogite in North Sikkim expands the Eastern Himalaya high-pressure province

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Eclogite occurrences are very few in the Himalayas and mainly consist of two types (Lombardo and Rolfo 2000): the coesite-bearing eclogites of the western Himalaya (Kaghan valley: O'Brien et al. 2001; Tso Moriri: Sachan et al. 2004) and the granulitized eclogites of the eastern Himalaya (Ama Drime range: Lombardo et al. 1998).

Unlike the "western type" eclogites, where post-peak decompression under constant to decreasing temperature suggests exhumation favoured by thrusting associated with accretion of the metamorphic pile onto the base of the over-riding plate, the "eastern type" Ama Drime eclogites were probably exhumed relatively slowly and were subjected to thermal relaxation in the thickened continental crust producing a strong granulite-facies overprint at intermediate crustal levels.

A new finding of granulitized eclogites in North Sikkim, east of Mount Kangchendzonga and some 120 km southeast of the Ama Drime, extends the eclogite province in eastern Himalaya.

Mount Kangchendzonga sits at the western flank of the Ranjit Tectonic Window (RTW), a regional structure cutting deeply through the Himalayan nappe pile. At low structural levels, the RTW exposes low grade Lesser Himalayan schists overlying unmetamorphosed Permo-Carboniferous sedimentary rocks of Gondwanian affinity. At higher structural levels, the northern end of the RTW shows an increase in metamorphic grade through the Main Central Thrust zone up to migmatites with garnet-bearing leucosomes in the Higher Himalayan Crystallines (HHC). In north Sikkim, along the Zemu Glacier east of Kangchendzonga, HHC main lithologies are granite to granodiorite orthogneiss with intercalations of biotite-rich paragneiss and very rare metabasites. Rolfo et al. (2006) gave a preliminary description of this geologic transect, where the main fabric is folded by two systems of later folds trending NNE-SSW and WNW-ESE with steeply dipping axial planes. The RTW can be the result of the interference pattern between these two later system of folds. Compressive and extensional shear zones with a top both to the SW and SE sense of shear respectively affect the main foliation. Top to the SE shear zones can be correlated with normal shear zones recognized in the nearest western Bhutan (Carosi et al. 2006), developed during the extrusion of the HHC.

The lithological associations of the HHC in the Zemu Glacier area are comparable to those described south of Mt. Kangchendzonga by Vezzoli et al. (2005). Among metabasites collected in the drainage of Zemu Glacier, a few samples are very similar to the granulitized eclogites first described in eastern

Himalaya by Lombardo et al. (1998) in the Ama Drime range, southern Tibet.

Microstructure of the North Sikkim granulitized eclogite is medium grained, granoblastic and little deformed. It is characterised by the occurrence of well preserved porphyroblastic garnet crystals several mm across, surrounded by a thick plagioclase + orthopyroxene corona, and a matrix mainly made of brown amphibole and plagioclase together with minor quartz, biotite and opaque minerals. Primary omphacite is not preserved, but is replaced by a distinctive symplectite of plagioclase + amphibole. Compared to the Ama Drime eclogite, the typical plagioclase-biotite intergrowths replacing pristine phengite occur very rarely and ilmenite aggregates and minor magnetite are locally abundant.

Though strongly re-equilibrated to granulite and amphibolite facies, the North Sikkim eclogite is clearly comparable to the Ama Drime eclogite. Bulk rock composition is analogous, showing a moderately high SiO<sub>2</sub> content (from 52 to 53 wt%), medium K<sub>2</sub>O (0.54 wt%) and low MgO (5.47 wt%) contents. Ti content is relatively high (TiO<sub>2</sub> = 2.77 wt%) as well as the Fe content (FeOtot = 14.79 wt%), suggesting Fe-rich basalt as protolith. Most minerals of the high-pressure peak assemblage are not preserved, save for the eclogitic cores of garnet (Grs18-20, Alm55-56, Prp08-09, Sps08-09) very similar in composition to those of Ama Drime eclogite (Groppo et al. 2007). As a whole, chemical compositions of the North Sikkim eclogite main assemblage (garnet, pyroxene, amphibole) are strongly similar to those of Ama Drime eclogite, suggesting a comparable metamorphic evolution.

Mineral assemblages, reaction textures, geothermobarometry and isochemical phase diagram P-T sections suggest that at least three superposed metamorphic events have been recorded in the North Sikkim eclogite. The first event was eclogitic, with T > 600°C and P > 1.5 GPa, but is poorly constrained because of the nearly complete lack of eclogitic mineral relics. The second event was granulitic and is represented by the plagioclase + orthopyroxene corona around garnet, with medium P (> 0.4 GPa) and high T (ca. 750°C). The third event at comparable P and lower T (< 720°C) is marked by the growth of brown amphibole and plagioclase in the matrix.

The discovery of strongly overprinted eclogite in North Sikkim extends significantly the high-pressure province of the eastern Himalaya and confirms the duality in tectonic style of exhumation along the Himalayan chain.

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