ROLE OF FORBIDDEN METAMORPHISM IN HIMALAYAN OROGEN

The metamorphism occur in less than ($<7°C\ km^{-1}$) geothermal gradient considered a 'forbidden' condition within Earth and defined as forbidden metamorphism. The UHP metamorphism can also be termed as forbidden metamorphism because the geothermal gradient normally encountered in UHP terrains $<7°C\ km^{-1}$.

The recent discovery of UHP minerals in eclogites of Kaghan and Tso-Morari areas of Himalaya has assumed great significance. Both locations lie south of the Indus Suture Zone (ISZ) in the Indian continental crust, and represent the zone of continental subduction in the Himalayan belt.

These eclogites, which occur as boudins in kyanite/sillimanite-grade rocks of the Puga Formation, contain essential mineral assemblages (garnet, clinopyroxene-omphacite, phengite, rutile, epidote-zoisite/clinozoisite and quartz), as well as coesite, talc, kyanite, magnesite, aragonite, dolomite, and Mg-calcite. Coesite, magnesite, and dolomite occur as inclusions in zoned garnet. The carbonate-bearing coesite eclogite underwent three stages of metamorphism—prograde, peak, and retrograde. The prograde assemblage is characterized by the presence of magnesite and a SiO_2 polymorph, which is stable throughout the metamorphic process from the prograde to retrograde stage. At ultrahigh-pressure (27 kbar) and a temperature of 650ºC, quartz transforms to coesite. Peak metamorphism was characterized by the development of coesite in garnet coexisting withhigh-Si phengite, clinopyroxene, magnesite, aragonite, dolomite, zoisite/clinozoisite, kyanite, and talc at a pressure of >39 kbar and temperature of >750ºC. This is in good agreement with the estimated peak pressure and temperature judging from the composition of phengite, jadeite barometry, and garnet-clinopyroxene, garnet-phengite thermometry. Enstatite formed with talc and kyanite at a pressure of >31 kbar and temperature of 750ºC. With a subsequent decrease in pressure, retrogression is constrained by the development of chlorite and chloritoid, which surround the garnet at a minimum pressure of 4–5 kbar and temperature of <500°C. Mineral assemblages in the carbonate-bearing coesite eclogite reveal that prograde metamorphism started with greenschist-facies conditions and reached the ultrahigh-pressure eclogite facies, passing through the intermediate blueschist facies. These coesite-bearing eclogites of the Tso Morari Complex (TMC), Himalaya, contains five major types of fluids identified by microthermometry and Raman Spectroscopy. (1) N_2 rich (2) CH_4 rich (3) high salinity brine (4) CO_2 rich and (5) Low salinity aqueous fluids. Trapping of N_2, CH_4 and high saline brine inclusions are remnant of pre-peak and peak metamorphic fluid, whereas, CO_2 and saline aqueous fluids appear to have been trapped late, during the process of uplift. These fluids were trapped during both deep subduction and exhumation processes. The CH_4 might have been formed by a mixed fluid that was released from calcareous sediments during subduction or supplied through subducted oceanic metabasics. The presence of CO_2 possibly of high density, is associated with the matrix material, and probably provides evidence for the granulite facies overprinting on the UHP eclogite. Whereas, during the formation of retrogressed amphibolite facies metamorphism, the low-salinity fluids have been produced and modified through external sources.

During UHP metamorphism, pressure abruptly doubled with a slight change of temperature, defining a geothermal gradient of 6–7ºC/km. The UHP material was brought back to the surface along a path by rapid and almost isothermal exhumation. The association of talc with carbonates also indicates low-temperature subduction in the Himalaya.In terms of the carbon cycle, this demonstrates that carbonate sediments can be subducted to at least 120 km depth without releasing significant CO_2 to the overlying mantle wedge.

WIHG, H.K. Sachan
Dehra Dun -248001

Gist of Lecture delivered on 31 December, 2008 at the monthy meeting of the Geological Society of India, Bangalore