

The Himalayas revisited*

The Himalayas are a complex, uplifted and deformed mountain range, brought about by tectonic activities, culminating in a series of plate collisions, most of which are still currently active. The Indo-Eurasian Plates' collision event of the Tertiary times finds expression in intense deformation and associated metamorphism and magmatism in the Himalayan regions, and to mid-plate deformation of the Indian plate. Additionally, ceaseless creation of new crust at the Indian Ocean Ridge System results in generation of compressive stress on the Indian plate. All these make the Indian subcontinent a geodynamically unstable land mass, experiencing frequent earthquakes, especially along the foothills of the Himalayas, the Indo-Gangetic plains and the reactivated ancient faults of the Indian Shield.

To synthesize our understanding in this direction, and to address related problems, a national seminar on the 'Structure and tectonics of the Indian plate' was held recently in Chandigarh.

The seminar was inaugurated by K. N. Pathak, the Vice-Chancellor of the Panjab University, and H. K. Gupta delivered the Presidential lecture on an overview of the earthquakes in the Himalayan region. Out of a total of 87 extended abstracts, 72 were presented. Lectures under each theme commenced with a keynote address. Based on their contents and subject treatment, the papers presented during the seminar could be divided into four broad aspects – (a) Timing and tectonics related to collision of India and Eurasia; (b) Evolution of Tertiary basin, metamorphism and magmatism; (c) Himalayan metallogeny; and (d) Geology of predicting natural hazards.

The most significant geological event, India–Eurasia collision, is marked by the

Indus-Tsangpo suture zone that runs for 2500 km from Nanga Parbat to the eastern most extremity of Arunachal Pradesh. Interestingly, the time of occurrence of such an important event is shrouded in mystery. The age of initiation of the collision ranges between Late Cretaceous (> 65 Ma) to latest Eocene (< 40 Ma).

The presentation of S. D. Iyer and R. Mukhopadhyay on the nature of crenulation of the Indian Ocean seafloor south of the equator, as a fallout of collision event, set the tone of discussion. It was suggested that the nature of crenulations is the direct result of a collision episode which occurred in two phases: ca. 58 Ma ('soft' collision or 'first contact') followed by the first hard collision at ca. 51 Ma. These events are directly related to compressive stress regime, and the rate of seafloor spreading, which fell from 95 mm/yr (half rate) at 58 Ma to 28 mm/yr at 51 Ma. Interestingly, the bio-stratigraphic evidence offered by N. S. Mathur and K. P. Juyal during the deliberation also confirms the initiation of the collision event around 50.6 Ma.

Ram Sharma, in his keynote address, described a new collision mechanism and the formation of Main Central Thrust (MCT) and Main Boundary Thrust/Fault (MBT/MBF). It is believed that the collision brought the convergence rate down to 5 cm/yr. This caused crustal shortening, thickening of the crust, initiated Himalayan metamorphism and formation of MCT at 30 Ma. The MBT, dated as 10 Ma, brings lesser Himalayas over the Tertiary sediment of foreland basin. V. C. Thakur suggested that the Himalayan Frontal Thrust (HFT), evolved during quaternary time, demarcates the Siwaliks from recent alluvium.

K. K. Sharma suggested that MCT emplacement be initiated around 30–35 Ma, resulting in leucogranitic magma generation and their emplacement at 28–20 Ma. Another episode of thrusting (MBT) occurs (after 15 Ma) during mid-Miocene, when lesser Himalayan crystallites thrusted over lesser Himalayan sediments. V. K. Gairola reported dynamic re-crystallization and grain boundary migration occurring simultaneously in different minerals from several regions in the Himalayas; the process appears to be repeated in cyclic order during progres-

sive deformation. R. Islam and others found ophiolitic melanges, similar to seamount lava (alkaline basalt or oceanic island basalt, high Nb/Y enriched) in two distinct zones in Ladhak area, Shergol (Nidar) and Zildat.

The aspect of inverted metamorphic 'Barrovian' sequence all along its 2000-km length, in which the younger higher-grade rocks appear at successively higher structural levels towards the north, is a puzzling and controversial phenomenon in the Himalayas. Ram Sharma suggested that the leading edge of the diving Indian plate suffered plastic deformation and thrusted the Lesser Himalayan Crystallites (LHC) over Archaean–Proterozoic basement and overlying sediment along the MBT. Possibly Higher Himalayan Crystallites (HHC) thrusted over LHC along the MCT, through a similar procedure of melting of the leading edge of the subducting Indian plate. However, S. Ghosh *et al.* suggested that MCT has no genetic relation to Barrovian metamorphism, which occurred much before the MCT was emplaced, although the MCT may have fine-tuned the geomagnetic inversion of the metamorphic sequence, advocating the theory of post-metamorphic tectonic modification.

Considering the large-scale tectonic activities and associated metamorphism, it is but natural that those conducive conditions must exist for metallogenesis in the Himalayas. D. Kumar reviewed the occurrence of a variety of minerals in the Himalayan region – atomic (U, Rb, Zr, Th), metallic (Fe, Co, Cr), non-metallic (clay, kaolin, phosphate) and even petroleum, natural gas and coal. B. S. Dorka and S. Parasher suggested that tin and tungsten mineralization near Himachal Pradesh may have precipitated when hydrothermal solutions came in contact with the cal-silicate country rocks. Pandey and others suggested the possibility of the occurrence of stratigraphic trap for the presence of hydrocarbon between the Gangetic alluvium and outer Himalayan region. The importance of structure and tectonic environments in governing mineral disposition is recognized. R. Verma suggested that the NW-SE and E-W trending lineaments have played a major role in controlling the diamondiferous horizon of the Bastar craton.

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An interesting and well-timed aspect was to relate natural hazards, such as earthquakes and landslides to the tectonics of the Himalayan region. Some case studies as well as the possibility of predicting such calamities were described. A total of 14 major earthquakes (magnitude > 7.5) occurred between 1897 and 1952 in the Himalayan region. Of these, there were five 'great' earthquakes. These are: 1897 quake in Shillong-Assam Plateau, 1905 quake of Kangra Valley, 1934 quake of Bihar-Nepal, 1950 quake of Assam-China and its aftershock in November 1951. V. C. Thakur identified the epicentral area with maximum intensity of these quakes to be located close to the MBT and MCT. The 1999 Chamoli, 1998 Uttarakashi, 1979 Pithoragarh and 1964 Dhar-chula earthquakes occurred within or close to the MCT zone. R. K. Verma and others suggested that the mid-plate earthquakes of Latur in 1993 (magnitude 6.5) and in Jabalpur in 1997 (magnitude ~ 6) occurred due to release of accumulated stress along east-west trending reactivated Tirana river and Narmada-Son lineaments, respectively.

Detailed seismo-tectonics and slip rate studies, associated with ^{14}C dating of the Shillong Plateau, suggest that great earthquakes of magnitude > 8.0 occur at an interval of nearly 500 years, and those of major earthquakes (magnitude > 7.0) with rupture length of 300 km at nearly 200–270 years. With the increase in population

and change in use of building materials, V. C. Thakur quoted Arya's observation (1992) that if the 1905 Kangra earthquake, which killed 20,000 people is to happen today, it could claim more than 300,000 lives.

K. S. Bist and M. P. Sah described the MCT as of about 6–7 km wide, and with highly crushed and pulverized weathered rocks, coupled with periodic seismic events. Its steep slope condition, several joints and seepage, and reduced forest cover, make it the most vulnerable area for landslides, especially during rainy season. Two devastating landslides occurred in August 1998, separated by a week's time along the MCT in Garhwal region. A. K. Mahajan and N. S. Virdi presented a unique case study of Dharmasala, where unplanned development and urbanization, in addition to the presence of the MBT and MCT very close-by are threatening the very existence of the town.

As far as the prediction of earthquakes is concerned, some geological measurements as presented by H. S. Virk and V. Walia, could be of much use. For example, fault zones which are the major shock/stress-release areas, are also known to act as preferential pathways for a variety of fluids, including gases, to the surface. Concentration of radon, helium and He/Rn ratio in thermal springs surfacing along these faults seem to be predictive tools for earthquakes.

An effective post-seminar field excursion to examine the geological features along the Dehradun-Mussorie section was arranged. Several unique sections of the two major members of the Himalayas, the Siwalik Group and the Lesser Himalayas were visited. A visit to the splendid museum at the Wadia Institute of Himalayan Geology in Dehra Dun was an additional gain.

It can be said that such seminars do serve the useful purpose of interaction among established academicians, students and scholars. It is time that a Round-Table or Panel discussion on a couple of thrust areas is arranged during each seminar, to facilitate intense interaction among the researchers, assessment of the know-how, and suggest ways to appreciate the lacunae. As usual, the quality of presentation left much to be desired, since the speakers tried to cram in a number of slides and transparencies and their thoughts in an allotted time of 10–15 minutes. Probably one should conduct a workshop regarding how to present a paper at seminars and symposia!

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