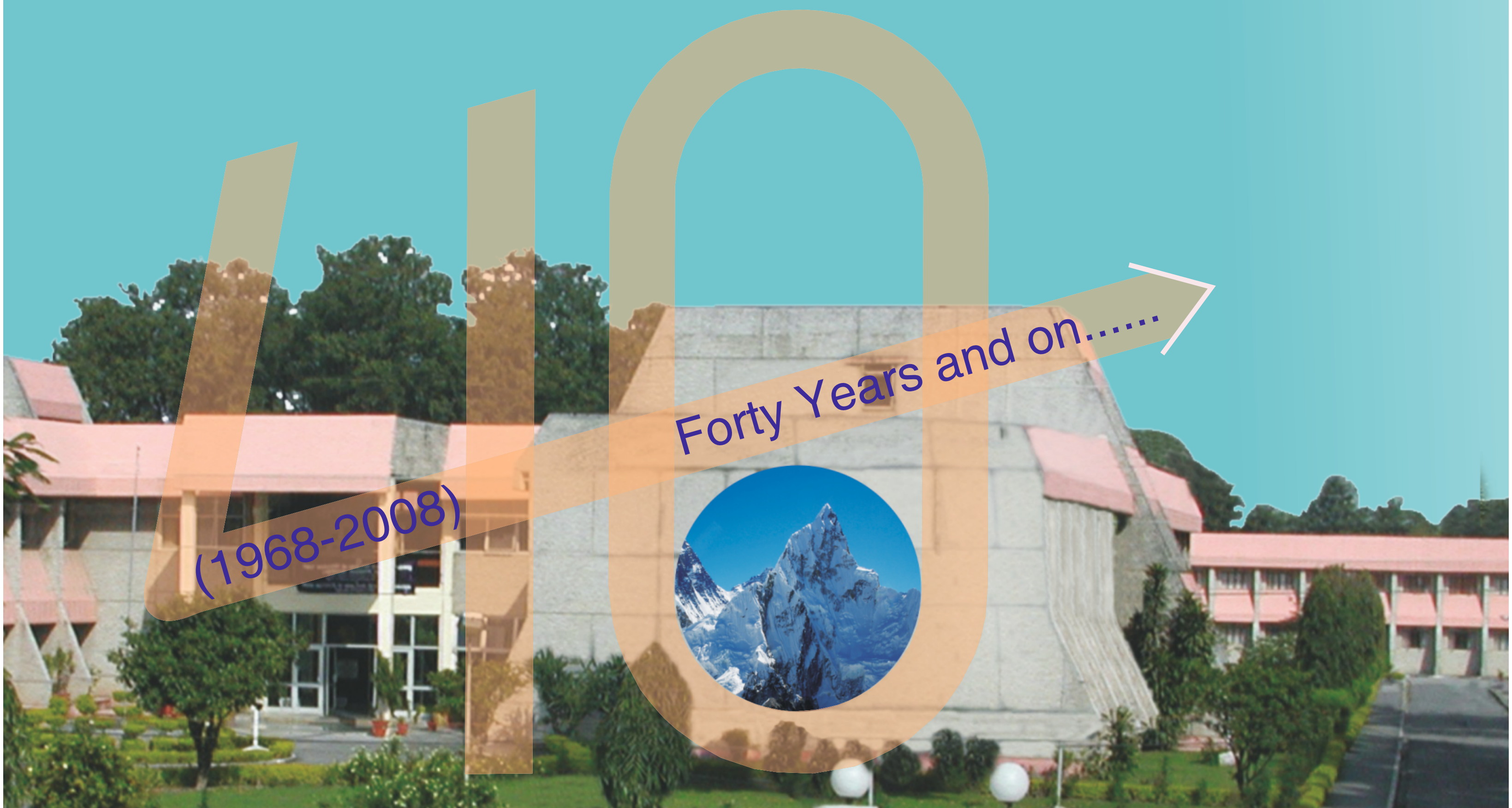
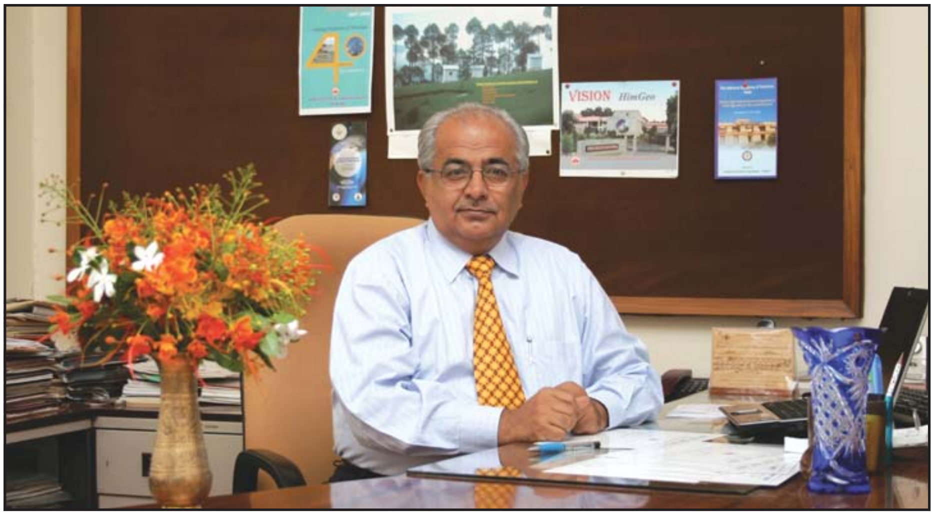
Annual Report
2007-2008

Probing Evolution of Himalaya



WADIA INSTITUTE OF HIMALAYAN GEOLOGY
DEHRA DUN

Introspection and Perspective



It is a matter of great pleasure to place on record an abridged account of scientific activities and achievements of Wadia Institute of Himalayan Geology (WIHG) during the year 2007-2008. In the geochron of the Institute, it has been a landmark year as WIHG completed *'four decades'* of dedicated service to the Nation. All through the years, the Institute has been continuously striving to unravel the geological truth related to building of majestic Himalaya and improve upon understanding of geodynamic processes, climate-tectonic interactions, evolution and extinction of life, processes of ore formations, glacier dynamics as well as assessment and mitigation of natural hazards for fostering sustainable and secured living in the Himalayan region. The multitude of data collated and synthesized by unstinted hard work of the WIHG scientists has greatly enhanced our knowledge on the geodynamic evolution of the Himalaya, in particular the processes and timing of subduction and exhumation in relation to India-Asia collision. Studies on pre- and post-orogenic sediments from the Himalayan terrain have enabled us to identify stratigraphic gaps and to place chronological constraints on the basin evolution. Also, improved images of deep crustal structures by geophysical methods coupled with source mechanisms of earthquakes have helped to develop sesimotectonic model explaining the earthquake occurrences in the Himalayan region. In the period when the impact of global climate change is at centre stage of discussions at different forums, the scientists at WIHG have prepared themselves to study environmental geology, climate change and the geomorphic responses. Glaciers, lakes and their geological archives are being used for deciphering annual, biannual and centennial scale changes in climate with its impact on the resource development of the region. The contributions are widely recognized and the Institute has acclaimed reputation of internationally known center of excellence for research aimed to unravel the orogeny of the world's youngest and loftiest mountain system.

In more recent years, specially crafted program of upgrading the Institute's analytical laboratories for mineral identification, geochemistry, image capture, rock magnetism etc and recently inducted state-of-the-art field monitoring networks have posted the research output to new heights. The research publications in reputed SCI Journals have witnessed the growth of 180% in the last five years (Plate 1). Motivated with this growth, the Institute with its multitude of expertise and interdisciplinary infrastructure has taken a fresh initiative of introspection and has drawn up a long term vision to frame future areas of research. The Vision HimGeo motivated by the pursuit of sciences for discovery and applications of emerging knowledge of deep dynamics for the benefit of the society has drawn well lit road map of research for the 11^{th} Five-year plan. The Vision HimGeo giving the rationale and action plan to achieve tangible output in time bound manner was released by Prof R. Chidambaram, the Principal Scientific Adviser to the Government of India on the Foundation Day on June 29, 2008.

As part of its out-reach programme during the International Year of Planet Earth, Wadia Institute has launched a number of new initiatives to take up research pursuits which have direct bearing on the society. The real time monitoring of earthquakes with VSAT connected network of Broad Band Seismometers (BBS), the establishment of Multi-Parametric Geophysical Observatory

Plate 1: Chart showing the number of scientists, budget, research publications of the Institute during the (left panel) past five successive years and (right panel) overall growth in last two five-years plans. While the number of scientists have remained stagnated around 60, the increase in inflow of grants have enabled upgradation of laboratories and field monitoring instrumental networks, which have begun to make positive impact on the research output, both in quantity and quality, as evidenced by continuously growing numbers of publications in peer (SCI) review journals.

(MPGO) for earthquake precursory research are some of the outstanding examples. The MPGO established at Ghuttu, Uttarakhand became fully operational since April 2007 and is equipped with India's first super-conducting gravimeter, overhauser magnetometer, tri-axial fluxgate magnetometer, ULF band search coil magnetometer, radon data logger, water level recorders and is backed up by the dense network of BBS and GPS. The simultaneous recording range of parameters is ideally suited for identifying characteristic space-time variation in micro-seismicity, seismic wave velocity changes, crustal deformation, small-scale changes in gravity, resistivity, magnetic field intensity, electromagnetic and radon gas emission as well as by fluctuations in hydrological parameters expected during the earthquake preparatory cycles. The present exercise to search earthquake precursors in an integrated manner is first of its kind anywhere in the world.

Recognising the likely impact of global warming on Himalayan glaciers, and its far reaching consequences on Indian economy, the Institute is geared to *"Mount a coordinated research initiative on Himalayan glaciology to understand the factors controlling the effects of climate on glaciers in order to develop strategies for climate change adaptability for sustained growth of the society"*. A proposal to establish Center for Glaciology at WIHG is at an advance stage, which will eventually usher the establishment of the dedicated National Institute of Glaciology. The mission is in compliance to the policy decision taken by the Council on Climate Change, under the chairmanship of Hon' able Prime Minister, Government of India, to create research capacity in the field of glaciology. Detailed Project Report and Memorandum for Standing Financial Committee for the establishment of the Center for Glaciology has been completed and awaiting the approval of the Government. of India. The two way strategy has been drawn to understand the impact of climate change on the health of glaciers in the Himalaya. Establishment of field stations at representative glaciers equipped with automatic weather stations for basin level mountain metrology, optically sensed water discharge measurement for melt water contribution to hydrology of the region, particle size analyser and automatic sediment sampler for estimating of sediment transfer, ground penetrating radar for mapping for bed rock geometry, internal structure and thickness of glaciers coupled with GPS and total stations will be helpful in characterizing of glacier dynamics and mass balance. Long term horizon for such multi-disciplinary high quality data capture would enable quantification of the factors influencing climate-glacier inter-linkage. In the second phase, ice cores, glacier sediments and other proxies will be used for reconstruction of palaeoclimate on various time-scales to answer whether present accentuated rate of glacier receeds are affected by anthropogenic induced global warming or form part of long term transitory behaviour.

Research orientations and progress of on-going research programs

With the continuous growth of analytical and field observational facilities as well as in-house expertise for undertaking integrated geoscientific research, the major scientific programmes being persued under the 11th Five Year Plan are aimed to address special scientific themes in the form of Mission Mode Projects (MMP). The Mission Mode Projects are grouped in the following five categories:

- Himtransects
- Climate - Tectonics Interactions
- Biostratigraphy & Biodiversity-Environment linkage
- Sustaining Natural Resources
- Real Time Geology for Society: Coping with Natural Hazards

The advances in each of the mission mode themes during 2007-08 are discussed in detail in the subsequent sections, the basic rationales and some salient achievements are summarized below.

Himtransects

One of the challenging problems of the Himalaya is the development of geodynamic model of the orogenic belt that can not only explain the archetype of the collision tectonics but can also trace the metamorphic history, constrain processes controlling high rate of erosion and exhumation, extent and nature of crustal shortening, kinematics of the crustal deformation, effects of superposed deformation as well as can provide clues to the space-time distribution of seismicity. The numbers of co-ordinated studies undertaken are expected to address one or more of the above fundamental issues.

- The resistivity images of crustal section inverted from magnetotelluric investigations along Bijnaur-Mallari of Garhwal Himalaya provide first geophysical evidence on the geometry of down-going Indian plate beneath outer Himalaya.

- First ever passive seismology experiment around the Eastern Himalayan Syntaxis shows presence of Moho at a depth of 47 km beneath Brahmaputra valley that gradually increases towards east and attains depth of 62 km at the Suture zone.

- Minerlogical assemblage of mafic rocks present in the

Tangtse area in Karakoram zone favour upper amphibolite or granulite facies metamorphism. The predominance of such high dense CO_2 inclusions in mafic bodies corroborates a granulite facies metamorphism.

- Initial comparative studies of the isolated Leo Pargil and Tso Morari gneiss domes located between South Tibetan Detachment System (STDS) and Indus Suture Zone (ISZ) of NW Himalaya support subduction related metamorphism but their differing grades suggest different rates and paths for exhumation up to subsurface levels.

- Geochemical volume strain and elemental mobility studies on the mylonitized and extremely deformed phyllonitic quartzite along the MCT in Bhagirathi valley predict a very high fluid/rock ratio during development of the MCT zone.

- Incompatible elemental concentrations including REE in the basic and metabasic rocks of Siang valley warrant mantle source for the origin of these rocks, perhaps involving low to moderate melting accompanied by an influx of K,Ti, Rb, Sr, Ba, Zr, H_2O and CO_2.
- The Anisotrophy of Magnetic Susceptibility (AMS) data from the Uttarkashi area, Garhwal Inner Lesser Himalaya lead to an important conclusion that the hanging wall of the Munsiari Thrust is characterized by stress conditions favourable for normal faulting with some oblique-slip component. The data suggest locking of the Munsiari Thrust.

- The structural and geomorphological studies in combination with OSL dating revealed that the landform of frontal part of the major Siang antiform/window, eastern Arunachal Pradesh evolved between 15-3 ka whereas the prominent transverse Ranaghat Fault running parallel to the hinge zone of Siang antiform was activated between ~13 and 10.5 ka. The deformation structures (psuedonodules, dish, pillar, folds and convolute structures) in the Subansiri Formation are inferred to have formed by earthquake activity that occurred during the deposition of the Middle Siwalik sandstone (~ 5 Ma to 10 Ma).

- In the hinterland region along the Main Central Thrust zone the analysis of morphometric parameters of some part of east-west trending Bomdila-Tamen Fault Lineament suggests the recent rejuvenation of landscape with rapid incision and uplift of the Kamla River in the Quaternary times.

- The widespread occurrence of soft sedimentary deformation (SSD) in the comparable sections of the Chakarata formation in Lesser Himalaya and their association with 1.8Ga penecontemporeneous mafic volcanics point towards a regional triggering mechanism for their development like frequent earthquakes.

- The carbon and oxygen isotopic analysis of some representative Palaeocene algal - foraminiferal Lakadong Limestone from the Mawsynram section suggest a shallow marine (tidal flat) environment for the deposition of the Lakadong Limestone since the C isotopic value of the shallow sea water is nearly zero per mil.

- GPS data from Himalaya in conjunction with regional GPS velocity estimation covering entire India, Asia, Europe, Africa and Australia were studied to understand the interactions between different plates, and manifestation along plate boundaries, specially segmentation of the convergence along the Himalayan arc.

Climate-Tectonic Interactions

Centuray scale palaeoclimatic history and its responses on Himalayan palaeoecology was evolved using the (1) lacustrine deposits in Spiti River valley, (2) proglacial lake near Chorabari glacier (3) peat deposits located in Bhagirathi, Pinder valleys and Nanda Devi bioreserve of Kumaun and Garhwal regions and (4) Cave speleothems, (5) fluvial archives in Alaknanda, Bhagirathi river valleys and Soan Dun, (6) Ziro lake in NE Himalaya, (7) Interfluve sequences of Siwalik Foreland.

- Results from Spiti valley indicated warm and moist conditions at 8370 yr BP, 6880 yr BP, 5620 yr BP, 3160 yr BP, and 400-1000 yr BP.

- Peat sequence revealed that the upper catchment of Bhagirathi Valley, with respect to its present climate, was warmer and wet around ca. 5900 and 2400 cal yr BP. The tree-line trend inferred from the quantitative pollen data indicated that around these times, the snout of Gangotri Glacier was probably retreated much beyond its present position (i.e. 4120m amsl).

- The past 2000-year multi-parameter climate records from the well-dated Dhakuri peat deposit in Pinder Valley revealed four major (ca. 100 cal BC–100 cal AD, 285-360, 1250-1370 and 1570-1700 cal AD) and two minor (around 900 and 1750-1850 cal AD) dry climate events in Kumaun Himalaya.

- Mineral magnetic studies form proglacial lake of Chorabari suggested that variation in magnetic parameters is probably controlled by transportation energy related to the activity of the glacier.

- Sahastradhara, Brahmkhal, and Pratapnagar caves in Garhwal and Mawsmai and Mawsynram in Meghalaya were studied. Based on the petrography of thin sections coupled with carbon and oxygen isotopic ratios of individual carbonate laminae indicated that these deposits hold high resolution Late Pleistocene-Holocene history of climate change.

- The morphostratigraphic studies on the fluvial archives located in mountain catchments of Alaknanda, Bhagirathi valleys and Soan Dun at the mountain front of Garhwal Himalaya suggested that the region responded to large-scale global climatic changes. The valleys experienced aggradation during the drier conditions of 36-10 la and subsequently incised in response of enhanced precipitation shortly after 10 ka. In the NE Himalaya the morphostratigraphy of Ziro lake in Subansiri Valley also suggested river incision ~10 ka and aggradation during 22-10 ka.

- The detailed sedimentological studies on Siwalik foreland sediments reflected that variable rock uplifts along the strike of Himalayan thrust-folds-belt was primarily responsible for contrasting fluvial architecture during the Late Cenozoic. However, several cycles of aggradation and degradation seems to be associated with variation in precipitation.

Biostratigraphy & Biodiversity-Environment Linkage

In the mission mode projects searching Biodiversity-Environment Linkages, some significant findings emerging from the Himalayan palaeontological studies are:

- The identification of ancestral form of the whales from a huge faunal collection from the Kalakot area of J&K; study of the fossil material demonstrates that change in diet gave rise to earliest cetacean taxon. The results of this study have also been successful in demonstrating that whales evolved from an aquatic group of mammals living in freshwater bodies rather than on land, necessitating the revisions in the views held so far that whales had land-dwelling ancestors.

- The latest discovery of an European rodent taxon belonging to the cosmopolitan family from west Indian early Eocene has opened a new debate regarding Tethys Sea serving as barrier in the passage of smaller mammals from the neighboring landmasses to the Indian sub-continent.

- Small shelly fossils of PЄ-Є affinity reported earlier from the Vindhyan Supergroup, affirmed afresh, are now much more curious subject of study regarding the earliest phase of organic evolution.

- Evidence of well-preserved uvigerinid foraminifera and pteropods in the Tertiary horizons of NE sector signifies that hydrocarbon producing Upper Disang Formation was deposited at a depth of ~500 m well above the aragonite compensation depth (ACD) in an open marine basin, an information crucial in oil exploratory activity in the region.

Sustaining Natural Resources

This mission mode projects under the theme 'Sustaining Natural Resources' are aimed at identifying the processes of ore formations and critical appreciation of glacial dynamics and its interaction with global climate change and growing anthropogenic emissions. Some significant advances in this directions are as follows.

- The homogenization experimental studies indicated more than 700^{0}C temperature for the melting of various granitic bodies of the Himalayan terrain. Both the syngenitic and epigenetic features and imprints of the Himalayan tectonics are present in polymetallic sulphide mineralization of the Uttarakhand. Further, the tectonic, petro-mineralogical geochemical condition and presence of crustally derived fluids in the Himalayan orogen provide setting favourable for the orogenises.

- A zone of sulphide mineralization in Chiplakot crystalline belt along North Chiplakot thrust and talc mineralization in Raiagar area near Berinag has been recorded in Kumaon region. The EPM analysis of pyrite grains, contrasting values of sulphur isotopes and presence of stromatolites from Raiagar area support the sedimentary syngentic pyrite formation due to biogenic reduction of seawater in shallow water environment.

- While lower concentration of Ca, Mg, Na, K, Ba, Sr, and Rb in comparison to UCCA (upper continental crust average) in stream sediments of Pinjaur Dun suggests their natural mobile nature, the enrichment of Cu, Ni, Pb, and Zn (in comparison to UCCA) indicate effects of anthropogenic activities.

- The major ion chemistry of Indus and tributary streams show mixture of carbonate (waters of Shyok and Nubra river) and silicate (waters of Indus river) weathering. A significant contribution of glacier melt has been observed in the major ion budget of the Nubra and Shyok rivers.

- The Gangotri glacier show some sign of decrease in recession rate from 46m/year (from 1962 to 1990) to 20m/per year (from 1990 to 2006). A negative mass balance of $4.54x10^6$ m^2 of water equivalent (0.77m specific balance) of Chorabari glacier was recorded in 2006-07. A newly installed AWS near snout of Chorabari glacier is providing inputs for long term glaciological studies. The diurnal variation in chemical constituents indicate sub-glacial source of meltwater during summer. The large growth (274mm) in thallium of *Acarspora* lichen is indicator of rapidly changing habitat and ecological condition associated with the deterioration of glacier.

Real Time Geology for Society: Coping with Natural Hazards

Frequent occurrences of natural hazards in the Himalaya pose a continual threat to the safety of the people inhabiting in and adjacent to this gigantic mountain system. It is therefore essential to enhance our knowledge base on the various physical and geodynamic processes causing natural hazards possibly in a real time mode for developing and implementing suitable mitigation measures. This line of fundamental research with serious societal implications forms the central focus of the mission mode projects under the real time geology for society.

- With the introduction of V-SAT Linked Network of 10 Broad Band Seismometers (BBS), earthquake monitoring programs in the NW Himalaya have attained new dimensions.
  - The dense network has brought down the detection threshold of local earthquakes from M=4 to less than 2. A prerequisite for long term monitoring of space time patterns of seismicity that will help in identifying zones of increased seismicity and/or zones of quiescence that invariably prevail before large earthquakes.
  - Given the closer spacing and better azimuthal coverage, accuracy of earthquake location parameters, both in space and time has greatly improved.
  - The space distribution of earthquakes clearly reinforces the earlier suggestions that major seismic activity is confined to a narrow zone centered just south of the Main Central Thrust, named Himalayan Seismic Belt.
  - The data of one year shows two clusters; one in narrow pocket centered around Adibadri-Gauri Kund and second in an extended zone stretching from Kharsali to Kotkhai with intervening sector showing only scattered seismicity.
  - In addition to dominating thrust tectonics in the collision zone fault plane solutions indicate evidences of mechanisms other than thrust in localized zones.
- During the last year, largest local earthquake recorded was a moderate earthquake of magnitude 4.9 near Kharsali in the morning of July 23, 2007.
  - Using V-SAT data of ten stations of WIHG network, earthquake parameters were located within few minutes of its occurrence. Given the closer spacing and better azimuthal coverage, main shock was located to an accuracy ± 3 km in the horizontal direction while the error in vertical direction was 4.5 km.
  - The seismic movement of the Kharsali main shock determined from the displacement spectra was 4.15×10^{16} Nm with source radius of 1.66 km. The stress drop obtained for the main event using spectral analysis of Brune's circular model was 41.5 bar, a value close to the expected value of 30 bar for the inter-plate region of Himalayan tectonics.
- M 4.9 Kharsali earthquake with epicentral distance of 59 km from MPGO Ghuttu provided testing ground to search pre-, post- and co-seismic changes.
  - The SG data, corrected for tidal effects, had showed bay like decrease of few microgal about four days before the occurrence of the earthquake.
  - The analysis of radon data shows perturbations more than 2ó confidence level in the radon values in both probes installed at 10m and 50m depths in the 68m borehole about 23 days before the earthquake.
  - Night time differential plot of total magnetic field for pair of stations, located on either of the epicenter across the MCT (Ghuttu-Bhatwari) showed sudden drop in magnetic field intensity 10 days before the

earthquake that recovered equally rapidly 4 days after the earthquake.

- Negative positional offsets were observed in all the three components of continuously operating GPS station in Guttu followed by the July 23, Kharsali earthquake (Mw = 5.5), Uttarkashi.

➢ A campaign mode seismic array in the source region of the 1905-Kangra Earthquake has enabled estimation of

- Optimum 1-D velocity model for this sector of the NW Himalaya.
- An anomalous layer in the depth range of 15-18 km, characterized by low S-wave velocity and higher Vp/Vs is viewed as fluid filled detachment zone that defines brittle-ductile boundary and serves as a cut-off depth of crustal seismicity.
- Further, a 3-D velocity model established for the Kangra-Chamba region allows to develop a tectonic model wherein a steep SW dipping fault running at right angles to the main strike of the Himalaya exerts stresses on the base of NE dipping MBT and detachment to account for the dense cluster of seismic events NE of the source region of the 1905 Kangra earthquake.

➢ Almost eight years of data from various satellites at various collection modes have been used to get the preliminary information of the regional geoid. Preliminary results suggest that :

- In the Western Himalaya, where anomalous crustal shortening, observed in Garhwal Kumaon Himalaya, is characterized by low density lithospheric mantle.
- Analysis of geoid anomalies over the Himalaya and its contiguous zone in the Indian plate are studied. Results suggest the existence of a strong density anomaly dipolar field in the Indian plate.

➢ A new program combining powerful InSAR and on-going GPS campaign surveys around the reservoir is taken up to constrain better the uplift/subsidence associated with annual loading/unloading of the reservoir. Long term monitoring GPS, total magnetic field intensity and radon emission are also in progress at 14 stable bench mark established around the Tehri reservoir.

➢ The site specific shear wave velocity measurements using MASW in and around Dehradun allows to division of the Doon fan deposits into *four broad* zones indicating varying influence of tectonics and climate in multiple phases evolution of the Doon fan.

➢ The two complementary techniques, namely the Nakamura technique and Multi-channel Analysis of the Shear Wave (MASW) are employed for seismic hazard assessment of Jammu city. This allows division of the Jammu city into three categories as per NEHRP classification i.e. class 'C'(360-760m/s) in the northern part, Class 'D' (180-360m/s) in Gandhi Nagar and Shastri Nagar and Class 'E' (<180m/s) in Talab Tila side or in Satbari area where thickness of sediments is very high. The results are in concordance with the site response analysis (Nakamura method) which indicates resonance frequency ranges from 0.432 to 3.369 Hz.

➢ Study on active faults and neotectonic activity in parts of Himalayan Front have revealed a new active fault oblique to the Himalayan Frontal Thrust (HFT) in Kala Amb area, once again negating the propagated opinion of HFT being a blind thrust. The active nature of part of the Himalayan foreland basin in Pinjaur Dun is clearly revealed in the perceptible faulting in the younger (Quaternary) sediments.

➢ Engineering geological mapping in the Alaknanda valley has revealed a positive linear relationship between density and acoustic wave properties and the mechanical strength of the rocks. The exponential relationship established between Schmidt hammer rebound (R-) values and the unconfined compressive strength (UCS) suggests that the former less expensive tool can be used as a substitute for strength parameter.

➢ The palaeo-mass movements recorded in the lower Spiti valley in Himachal Pradesh are attributed to periodic reactivation of the Sumdo Fault vis-à-vis structure related control on slope material movement. Similar evidence of slope instability in contemporary environment has been gathered in the Yamuna valley and is attributed to crushing of the material by activity of the Main Boundary Thrust.

Academic Pursuits

Under the on-going research programs pursued during the year, the Institute has published 79 research papers both in international and national journals and nearly equal numbers are in press/communicated. In addition to this 69 papers were presented in the international and national seminar/

symposia/ workshop by the Institute scientists, many of these included invited/keynote review talks. Further two Ph.D. theses have been awarded and two submitted for the award of Ph.D. Degree. WIHG has signed a Memorandum of Understanding with Kumaun University to have joint research projects for mutual benefit of the two institutions, share infrastructural facility for mutual benefit, recognize and accept WIHG scientist for supervising research leading to Ph.D, help each other in preparing common observational/research programmes/sharing of data/publications etc. The Institute continued to provide laboratory facilties to academic institutions of the region, particularly the students.

The Institute brings out regular Himalayan Geology publications. During the year volumes 28(2) 2007, and 29(1) 2008, were brought out with volume 13 of the in house Hindi magazine Ashmika. Apart from this Abstract volume 28(3) for the workshop on 'Collision Zone Geodynamics' was also brought out.

To promote geoscience research in the Himalaya, the Institute organized two days workshop on 'Collision Zone Geodynamics' during September 20-21, 2007.

Other Highlights

In keeping with the annual program for implementation of the official language policy of the Union of India, various steps were taken to promote use of Hindi in routine work as well as in scientific research. Hindi magazine Ashmika was published by the Institute. Hindi noting-drafting and Hindi typing were implemented, also day-to-day work, general circular, notices etc were issued both in Hindi and English. Hindi fortnight was celebrated from 14th September to 30th September 2007, during which various competitions like poetry, essay and debate were organized.

Financial Resource Management

Institute received a total grant of Rs.14.61 crore, this coupled with carried forward amount from the previous year and miscellaneous receipts, a total sum of Rs.16.51 crore was available for expenditure. Institute successfully operated the grants on almost zero budget with total expenditure to the tune of Rs.16.04 crore. In addition Institute mobilized a sum of Rs.1.10 crore by way sponsored projects which contributed significantly to build the infrastructure and achieve the targeted objectives for the year 2007-2008.

PROGRESS IN RESEARCH PROJECTS

MMP 1 : Himtransects

1.1 Tracking Collision Tectonics in Himalaya through Magnetotellurics

(B.R. Arora and Gautam Rawat)

This year data from magnetotelluric (MT) investigations at eighteen sites along Bijnaur-Mallari profile is analyzed. This profile passes through major litho-tectonic units of the Himalaya starting from Indo-Ganga Plain, Siwalik, Lesser, Higher Himalaya and Tethys Himalaya (Fig.1). Frequency dependent transfer functions are estimated using robust processing of time series for single site and remote reference as well. At few stations electric field recordings were very noisy perhaps due to unbalanced power network of the region. This is reflected as large error bars in estimated impedance tensors. Skewness and other dimensionality parameters indicate the validity of 2-D regional model. Robust impedance decomposition for the period band of 10 Hz-1000 sec of thirteen stations reveal that EM strike coincides with the geologic fabric.

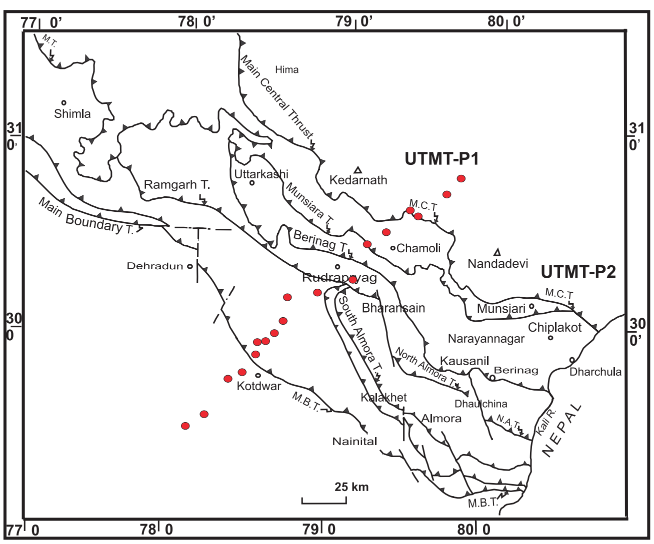


Fig. 1. Location map of MT sites along Bijnaur - Mallari profile, Uttarakhand Himalaya.

Considering the regional strike, EM field were decoupled in TE, TM mode and then inverted for frequency dependent conductivity distribution along the profile. The most conspicuous feature of the inverted resistivity section is the low resistivity zone at a shallow depth of 10 km beneath the Indo-Ganga Plain that dips down at a low-angle and extends as a continuous plane right up to the MCT. The geometry of this layer is correlated with the basement thrust separating the top of the underthrusting Indian Plate from the overriding sedimentary wedge of the Lesser Himalaya.

High resolution images of electrical resistivity distribution thus forms the first geophysical evidence on the geometry of down going Indian plate beneath the Sub (Siwalik) Himalaya. The data collected along parallel profile along Kali river valley is being analysed to obtain generalized picture of the down- going Indian plate.

1.2 Lithospheric Structure and Dynamics of the Eastern Himalayan Syntaxis - Mishmi Hills

(V. Sriram, D. Hazarika and B.R. Arora)

Investigations were carried out to map the crustal and upper mantle structures of the eastern Himalayan syntaxis using broad band receiver functions. A network of 12 broadband Trillium 240 seismometers with Taurus digitizers were put along an E-W profile in the Lohit district of Arunachal Pradesh. The stations were placed at an average separation of 12 kms along this 150 km long profile. The experiment started in April 2007 and would continue for atleast 24 months. Based on the preliminary analysis of the data obtained for the first 8 months, a strong azimuthally varying lithosphere exists in the region. The eastward subduction of the Indian plate can be clearly seen as thickening of the crust east of the Tidding suture zone. Also, the Moho depth of 47 km at the Brahmaputra valley (Near Mahadevpur) increases gradually towards east and reaches 62 km at the suture zone.

1.3 Structural vis-à-vis a Crustal Evolution in the Trans-Himalayan regions of Tso-Morari, Indus and Shyok Suture Zones

(S.K. Paul and H.K. Sachan)

In the Indus Suture Zone (ISZ) study was undertaken to map the geological transect between Nimu and Chilling in the Zanskar valley, Northwestern Ladakh Himalaya. The southern part of the ISZ is characterized by back thrusts within the northern passive margin of deep sea sediments of the Lamayuru Formation. These back thrusts have possibly been formed by reactivation and inversion of early rift related normal faults during the Himalayan orogeny. The Lamayuru Formation comprised of black pyrite bearing shale followed by fore arc volcanoclastic sediments including greywacke of the Nindam Formation. In Suru valley further west of the study area, the contact zone between the Lamayuru and Nindam formations is emplaced by Shergol Ophiolitic Melange during post-Paleocene time. In Zanskar valley, the Indus Formation of the fore arc basin is broadly divided into Miru Member, Red Bed Member and Hemis Member. In this valley, the Nindam Formation is overlain by marine Miru Member (Sumda and Jurutze formations of Searle, 1990) and the contact plane between them is emplaced by a thin band of ophiolite and ophiolitic (serpentinite) mélange noticed at about one kilometer north of Chilling village named as Chilling Ophiolitic Melange. Previously, this ophiolitic body was named as the Northern Shergol Ophiolitic Melange (Thakur, 1981; Thakur and Misra, 1983). This ophiolitic melange is younger than post-early Eocene since it cross cuts the Red Bed Member (continental flysch and molasse of post -early Eocene). The Miru Member is overlain by Red Bed Member which includes Chogdo and Nummulitic Limestone formations of Searle (1990) and the Hemis Member (Gongmarula-Nurla-Choksti formations) and form the parautochthonous sedimentary sequence to the south, whereas the Kargil Formation as an autochthonous sedimentary sequence to the north together constitute the fore arc basin of the Indus Suture Zone. The fold and thrust belt between the Chilling Ophiolitic Melange to the south and Kargil Formation to the north exhibit a broad pop-up structure.

It is inferred that the Shergol Ophiolitic Melange emplaced earlier than the Chilling Ophiolitic Melange support the idea of diachronicity of India-Asia collision.

Detailed fluid inclusion study of mafic bodies present in Tangtse area has been carried out. These mafic bodies contain clinopyroxene–pargasite–scapolite–spinel–quartz–plagioclase, orthoamphibole– garnet– biotite -spinel–rutile assemblage. The presence of scapolite (meionite variety) imposes high temperatures above 800°C. The jadeitic content of clinopyroxene (9 %) in the presence of plagioclase yields a pressure of 7.5 kbar at 800°C. The mineralogical thermobarometry indicates the maximum temperature of 675±20°C and pressure of 7 Kbars. These mafic bodies are believed to represent upper amphibolite or granulite facies metamorphism?

Three types of inclusions identified are: pure carbonic inclusions, carbonic-aqueous inclusions and aqueous–rich inclusions. The carbonic inclusions occur as isolated with typical negative crystal shape. These inclusions are primary in nature and hence represent earliest generation fluid formed during the peak stage of metamorphism. The carbonic-aqueous inclusions are biphase in nature. These inclusions show some co-existence with aqueous inclusions. The aqueous inclusions are of biphase in nature and occur in the form of trails as well as isolated.

The CO_2 in the carbonic inclusion melting between -56.5 to -57.3 °C has revealed that the trapped fluid has approximately pure CO_2 composition. Whereas, melting carbonic-aqueous inclusions melting between -56.5 to -57.5 °C indicates more or less pure CO_2 composition. The homogenization of CO_2 in both types of inclusions took place in liquid phase. The homogenization temperature in carbonic inclusions varies between -25 to -32.4 °C which indicates the maximum density of 1.08 gm/cm^3. Whereas, in carbonic-aqueous inclusions it varies between -2 to -10 °C. The temperature of total homogenization of CO_2 and H_2O phases in CO_2-H_2O inclusions is in the range of 275-290 °C. The eutectic temperature in aqueous inclusions varies between -20 to -22 °C revealing the composition of aqueous inclusion to be NaCl-KCl-H_2O. The final melting temperature is between -2 to -6 °C corresponding to a salinity of 5 to 8.5 wt.% NaCl. The predominance of such high dense CO_2 inclusions in mafic bodies also indicates that they have suffered a granulite facies metamorphism?

1.4 Comparative study of Himalayan Gneissic Domes

(Barun K. Mukherjee, R. Islam and K. Sachan)

The Tethyan Himalayan region between South Tibetan Detachment System (STDS) and Indus Suture Zone (ISZ) is occupied by a series of isolated gneissic domes. These domes are deformed and partly metamorphosed, which show marked differences in terms of genesis and metamorphism. The preliminary studies of the Leo Pargil and Tso Morari domes show contrasting behavior as compared to the other north Himalayan domes. The metamorphic petrology reveals that the Leo Pargil shear zone divides the high grade metamorphic rocks from the alternating sedimentary rock of the Tethyan sedimentary sequence. The high grade rocks of the Leo Pargil dome are para- and ortho- gneisses, which are composed of mica-garnet-quartz-feldspar and mica-quartz-feldspar simultaneously. The para-and ortho- gniess bodies often surround the decimeteric size of metabasics boudins. These boudins are cored by high grade of metamorphism, whereas the marginal part of boudins shows progressive decrease of metamorphism. The mineralogy of the metabasics is dominated by garnet, amphiboles, clinopyroxene, kyanite, epidote, carbonates, etc. Cursory estimation of P and T of the Leo Pargil para-gneisses and metabasics supports the amphibolite facies metamorphism up to epidote and garnet grade. Surprisingly, the signature of eclogitic composition within few boudins is also noticed. However, the clear reaction texture for eclogitic composition is yet to be studied properly. Combined field observations and petrography indicate that the high grade rocks could have been exhumed through the Leo Pargil Shear Zone. However, the exhumation of such high grade rock could be the end product of multi exhumation phenomena. In turn, the adjacent Tso Morari dome shows the metamorphism significantly subduction related, which has gone up to the ultrahigh-pressure grade. The development of these two gneissic bodies seems to have been linked with crustal metamorphism up to subsurface level. The preliminary fluid inclusion study shows that these two bodies are being dominated by (secondary) saline–aqueous fluids. These secondary fluid phases reflect the last stage of entrapment during the development of domal structure. Though the history of dome evolution could be understood through the detailed study of microthermometry statistically. The pragmatic approach could be seen by the element modeling of each mineral especially to focus on zircon and monazite.

1.5 Magmatic and Metamorphic Studies of Kumaon Region, Uttarakhand

(Rajesh Sharma and D. Rameshwar Rao)

Two weeks field work was carried out in the crystalline rocks of Dobat-Tawaghat-Khet- Sobla-Garbadhyar-Shantivan area in Kumaon Himalaya. Variation in the gneissic rocks, and the contact zone of augen gneiss/granitic gneiss/late granodiorite veins were observed and samples were collected. Fluid inclusions study was carried out in (i) early quartz which is present as inclusions in feldspar and in (ii) late quartz that is coarse-grained in nature, from some of the collected samples from the crystalline rocks of Munsiari Formation. Fluid inclusion petrographic studies and limited microthermometry were conducted on the gneissic rocks with cofolded quartz veins from Chiplakot Crystallines and the Munsiari Formation, Kumaon Himalaya. Efforts were made to look for the fluids of various stages trapped during syn to post metamorphism and deformation. The textural evidences for the thrusting and the exhumation are available in the oriented intragranular fluid inclusion planes and the annular fluid inclusion decrepitation features. These textures are present in the quartz veins showing cofolding with the gneissic rocks of the central region of the Chiplakot Crystalline Belt. Unlike gneisses of the Askot Crystallines, the studied samples from central part of Chiplakot Crystallines do not entrap any boiling hydrothermal fluid, and at the regional scale carbonic-aqueous fluid appears to have shared most of their evolutionary history. The fluid inclusions in the metapelites from the Munsiari Formation were studied in (i) early quartz present as mineral inclusions within the garnet grains, (ii) garnet grains and (iii) late quartz. Fluid inclusions trapped in early quartz are monophase carbonic and biphase liquid–vapour inclusions. Primary fluid inclusions in garnet are predominantly monophase carbonic and are associated with biphase aqueous–carbonic inclusions; they petrographically represent growth of garnet during metamorphism. Limited Laser Raman Spectroscopy carried out on the fluids of Munsiari Formation agrees with the CO_2 composition of the dominant fluid in arrays without any other carbonic fluid species therein. However, a separate flux of high saline fluid during fluid migration through micro-shears is marked, which is unusual to the earlier observation from MCT zone. The re-equilibration morphology of the fluid inclusions is not seen in the quartz grain enclosed within the garnet and may be because of the small inclusion cavities. Whereas, the recrystallized matrix does consist of evidences of an excess internal pressure indicating continued uplift even after quartz recrystallization.

1.6 Exhumation history of the Higher Himalayan Crystallines, Western Uttarakhand Himalaya

(T. N. Jowhar)

Field work in Uttarkashi-Gangotri area (Bhagirathi valley) was carried out for two weeks with reference to mineral chemistry and petrogenesis of Gangotri granite and P-T estimates of Higher Himalayan crystallines. Representative samples were collected for detailed laboratory investigations. The EPMA data on tourmaline, K-feldspar, plagioclase, garnet, biotite and muscovite were obtained by utilizing Cameca SX 100 microprobe at WIHG. A review of significance of chemical zoning in garnets was also done.

Compositional zoning of silicate minerals has been recognized as a common feature in numerous geological environments. Compositional zoning which is a disequilibrium feature is most frequently observed in metamorphic garnets where the relatively slow diffusion kinetics prevents complete chemical homogenization across the grain. Chemical zoning preserved in zoned garnets can be utilized to infer metamorphic P-T paths. Diffusion modeling of zoned garnets is an easily accessible, fast and efficient means of accessing durations of thermal and tectonic processes in metamorphic rocks.

Work regarding P-T estimates and Exhumation history for Higher Himalayan Crystallines along Bhatwari-Gangotri region is in progress.

1.7 Study of Thrust/Nappe geometry, their tectonic evolution in Zanskar-Lahaul regions, Northwest Himalaya

(Keser Singh)

The Tethyan rocks are generally placed over the Higher Himalayan Crystallines (HHC) along a tectonic contact, known as the South Tibetan Detachment (STD). It is referred to as Zanskar Shear Zone (ZSZ) in the Zanskar Himalaya, Trans Himadri Fault (THF) in Garhwal Himalaya, etc. The Tethyan rocks are also reported south of HHC as Chamba and Kashmir nappes in the northwestern Himalaya. The Tethys rocks of Zanskar-Spiti are continuous southward and connected to the sedimentary rocks of Chamba succession through a narrow strip exposed in Lahaul region. The Tethyan sequence in Lahaul and Chamba region is folded into kilometers scale folds. The thrust geometry and the folding pattern within these rocks are poorly known. Whether these rocks were translated from the Tethyan sequence occurring in Spiti and Zanskar region north of ZSZ, or were to the south and lying over the HHC.

Southwest to ZSZ and the HHC, the Tethyan rocks exposed as Chamba succession cover approximately 140 km length and 70 km width, and is made up of 8 to 10 km thick anchizonal grade sequence and exposed in regional synclines. The Tethyan rocks representing highest tectonic unit are translated over both the southerly underlying Lesser Himalayan rocks and the HHC. Incongruous opinions regarding the contact between the overlying Tethyan rocks with the underlying HHC and the Lesser Himalayan rocks still remain unsolved so far.

The trends and patterns of regional folds within the Tethyan rocks of Chamba succession present a complex picture. The vergence of Tandi Syncline toward NE, in overall SW vergent structures, has invited conflicting interpretations. A NE directed orogeny producing NE directed nappe stacking (Shiker Beh Nappe of which the Tandi Syncline and Mayar thrust as its part) predating the principal SW orogeny were proposed by earlier workers.

The structural analysis indicates that the folding and southward translation of the Tethyan rocks along the Chamba Thrust has occurred simultaneously during the same deformation episode and has produced the opposite vergence Chamba and Tandi synclines, and intervening Hadsar-Chobia Box fold. The Chamba succession was translated from the Tethys Himalaya southward over the Panjal Thrust Sheet as well as HHC. A back thrust developed with thickening of ductile substrate in the core of box fold is observed south of the Tandi Syncline. The amplification of the fold hinge as observed in the northern hinge of the Hadsar-Chobia Box fold is interpreted as the result of a blind thrust. The opposite vergent folds have developed as flanks of a box fold in a single deformation episode in a SW directed orogeny. Work is in progress to understand the kinematics of thrusting and folding of Tethyan rocks and how they occur south of ZSZ.

1.8 Thrust zone geochemistry and mineralogy: Implications for Tectonic evolution, fluid-rock interaction and associated mineralization along Uttarakhand Himalaya Geotransect.

(P.K. Mukherjee and K.K. Purohit)

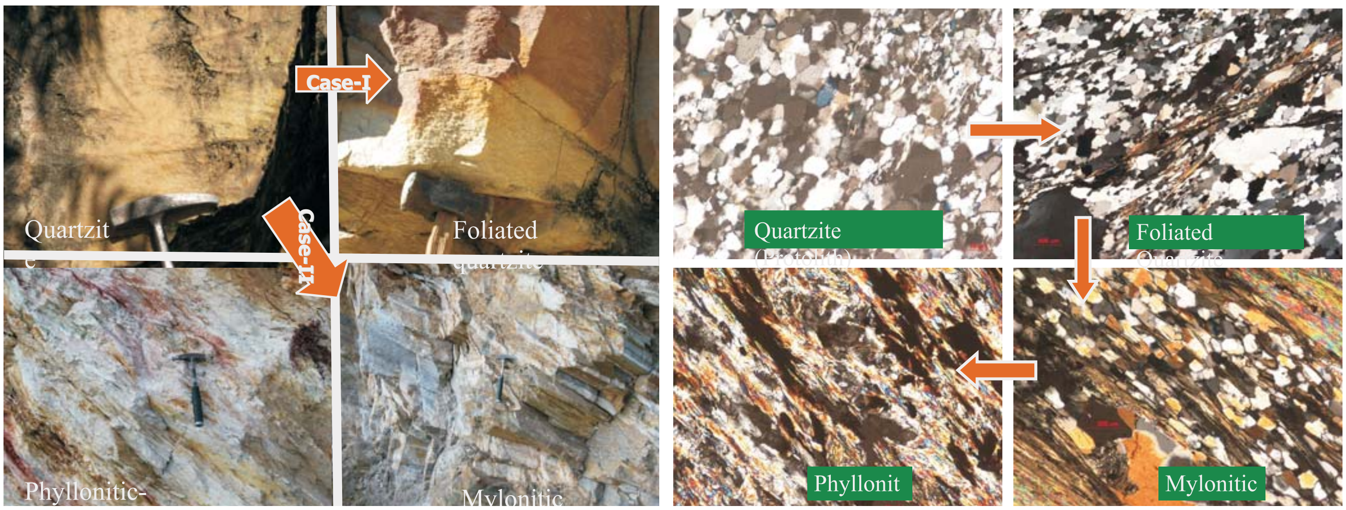
The MCT and MCT zone is differently defined by the Himalayan geologists. Some treat Munsiari as MCT while others mark Vaikrita as MCT. We prefer to retain the term MCT for Munsiari Thrust of Valdiya (1986) and the ductile shear zone to the north as MCT zone that comprise Lesser Himalayan Crystalline (LHC) and Higher Himalayan Crystalline (HCC). The rocks occurring between MCT and STD reveal that the grades of metamorphism increase from lower biotite-chlorite at lower structural level at the footwall of MCT (Munsiari Thrust) and reaches a peak metamorphic grade of sillimenite and even migmatitic stage near Sukhi village and then gradually decreases to staurolite and finally garnet-biotite grade at the highest structural levels demarcated by normal fault known as the South Tibetan Detachment (STD).

Thermochronological evolution of MCT zone

In view of the objectives of our study more emphasis was put on the thermochronological aspects. Our approach is based on the isotopic as well as chemical dating of monazites and xenotimes and their mineral chemistry and textural relationships. Preliminary investigations reveal that Monazite grains occur as inclusions with garnets and staurolite as well as in the matrix. The BSE image also reveals that they are zoned which suggests that these tiny grains preserve multiple thermal events. The grain size varies from $<20\mu m$ to as big as $200\mu m$. Larger grains are most appropriate for dating multiple events by EPMA and/or ion-probe technique. However xenotime grains are rather small and infrequent.

Geochemical volume strain and elemental mobility

The MCT zone consists of three major lithologies, i.e. granitic gneiss, metabasics and meta-sedimentary rocks including metapelite and quartzites. These rocks show progressive deformation and mylonitization all along the breadth of the shear zone (MCTZ). One such set of progressive deformation in quartzite was subjected to geochemical mass balance studies to infer the extent of volume strain and elemental mobility in the shear zone (Fig. 2a&b). With respect to the *quartzite protolith* the progressively deformed descendants are → *foliated quartzite* → *ultra-mylonite* → *phyllonitic quartzite*. It is noted that the LREEs show coherent abundance with respect to the protolith in the progressively deformed rocks. The LREE trends are essentially parallel to that of quartzite (Fig. 3). However, the HREEs trends show fan shaped pattern indicating differential mobility. This is further substantiated by the identical isochemical volume factors of LREEs suggesting their likely immobile behavior and their enhanced concentration with respect to protolith quartzite is due to residual enrichment owing to removal of sizable mass of other components from the system. Thus using LREEs as immobile reference frame and applying the MINMAS approach it is estimated that about 48% volume strain (loss) took place in the formation of the foliated



(a) (b)

Fig. 2. (**a**) Macroscopic (**b**) microscopic features of the protolith quartzite and its progressively deformed foliated, mylonitic and phyllonitic quartzites.

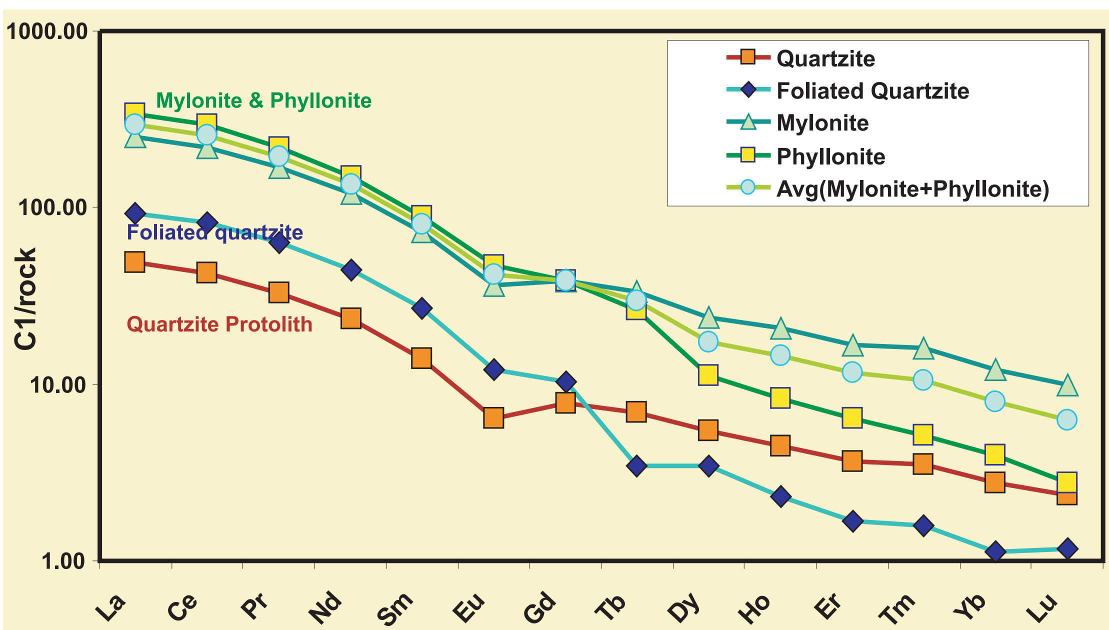


Fig. 3. REE pattern of protolith quartzite and deformed foliated, mylonitic and phyllonitic quartzite. The LREEs of deformed rocks are essentially parallel to protolith quartzite pattern indicating their immobile character and residual enrichment. HREEs show fan shaped pattern indicating their differential mobility.

quartzite while about 85% volume loss is required to explain the formation of ultra-mylonites and phyllonites. The mass balance equation for the alteration is as follows:

Case–I: Quartzite→Foliated quartzite: Volume Strain = 48.5% (Fv = 0.515)
100g Quartzite + *0.83g* Al_2O_3 + *0.24g* K_2O = *48.94g* SiO_2 + *0.03g* MgO + *0.06g* CaO + *0.18g* Fe_2O_3 + *50.82g* Deformed quartzite

Case-II: Quartzite → Phyllonite :Volume strain : 85.5% *(Fv=0.145)*
100g Quartzite + *0.12g* Na_2O + *0.96g* MgO + *2.34g* Al_2O_3 + *0.64g* K_2O + *1.06g* Fe_2O_3 = *88.89g* SiO_2 + *0.09g* CaO + *11.02g Quartzite-Phyllonite*

The major element geochemical mass balance estimates reveal that the bulk of the volume strain is accounted for by the removal of quartz in solution. Though a volume strain of about 85% seems unusual, but there are several references that talk about 60-90% volume strain. In view of the operative process, the entire thickness of the quartzite rock is not affected by the shearing, but it is only along a narrow plane (say about few meters) that experienced the maximum deformation.

Fluid rock ratio

The loss of silica in fluid phase can be utilized to estimate the fluid/rock ratio if the solubility of SiO_2 in aqueous hydrothermal fluid is known. The solubility of silica in hydrothermal fluid is about 0.3 gram per 100 gram fluid. Thus the amount of fluid required to remove 49 gram and 88gram SiO_2 is estimated to be at least 181 and 329. If the interacting fluid is partially saturated prior to entering into shear zone then it would be even more. Thus it is inferred that the shearing process produced deformed quartzite in the presence of plenty of aggressive fluid.

1.9 Kinematic history of the thrust sheets and metamorphic evolution of the crystallines of Subansiri and Siyom valleys, Arunachal Pradesh.

(B.K. Choudhuri and N.S. Gururajan)

The lithotectonic set up of the Lesser Himalayan sequence in Siang valley has been worked out to understand the nature of the crystalline rocks associated with the Lesser Himalayan sequence. On the basis of field study from southwest to northeast, the area comprises of four major lithotectonic units limited by NW/SE trending thrust faults. They are: the Lesser Himalayan unit; the Bomdila Crystallines, the Indus Suture Zone and the overlying magmatic arc or the Lohit Plutonic Complex.

The Upper Tertiary fluvial sediments of the Siwalik Group are overthrust by the Gondwana Group of sediments with marine and plant fossils of Permian age, along the Main Boundary Thrust (MBT). These groups of rocks do not extend to the eastern limb of the syntaxis where they are probably overlapped or cut-off by the Mishmi Thrust. The Lesser Himalaya consists of a non-metamorphic to low-grade (chlorite grade) sedimentary sequence and is thrusted over the Gondwanas. These rocks extend to the eastern limb where their thickness is considerably reduced. The crystalline rocks of the Higher Himalaya exhibit inverted metamorphism and are divided into two units: the lower is the Bomdila Group and the upper Sela Group (Verma and Tandon, 1976). Of the two groups, only the Bomdila Group extends up to the eastern limb of the syntaxis and they are known as the Mishmi Crystallines (Thakur & Jain, 1975).

The MCT in the eastern limb is located at garnet + straurolite grade that separates the greenschist facies Bomdila gneisses of the Lesser Himalayan Crystallines (LHC) from the garnet +straurolite+ kyanite bearing graphitic schists of the Higher Himalayan Crystallines (HHC) and the Main Central Thrust (MCT) corresponds to a definite lithological and metamorphic boundary. Earlier, these rock types were considered as part of the (LHC) and the MCT was marked at the base of the LHC (Gururajan and Choudhuri, 2003). The recent investigations in the Siang valley show that the Bomdila Crystallines extend towards NW and close around Singing-Anguing in Siang valley where the deflection of trend is observed from NW-SE in the east to NE -SW in the west and this conspicuous structure defines the Eastern Syntaxial Bend (Singh, 1993). Around this bend the rock types on both sides are disposed in the form of a major antiformal structure with development of mesoscopic scale anticlines and synclines.

The rocks belonging to the Indus Suture Zone (ISZ) occur as tectonic units that are thrust over the crystalline rocks. This type of lithology resembles the dismembered, metamorphosed ophiolite belt. The strong deformation style and development of down dip plunging lineation and oblique shear bands at the base of the unit suggest that this unit is thrusted over the metamorphic unit. This unit can be traced from the Lohit valley in SE and to the Siang valley in NW through Dibang valley. From Lohit to Dibang it occurs as a continuous belt and further NW it occurs as a discontinuous belt, but it is exposed near Tuting in Siang valley. Acharyya (1987) named this as Tuting-Tidding suture. Thakur and Jain (1975) regarded that this unit may be the continuation of the Indus Tsangpo Suture Zone. On the basis of tectonic set up Singh and Choudhury (1990) correlated this unit with that of the Indus Tsangpo Suture Zone. Bhalla *et al.* (1990) also supported this view and also correlated the overlying Lohit Plutonic Complex with that the Trans- Himalayan Ladakh batholith in NW Himalaya on the basis of isotopic studies. This unit is essentially made up of metabasics volcanics, bands of marble with thin horizon of graphitic phyllite and a fairly thick lensoidal block of serpentinite. Our field observations reveal that this is a separate lithotectonic unit bounded at the bottom by the Tidding Thrust and the top by the Lohit Thrust. This unit is predominantly comprised of metavolcanics and chlorite-actinolite schists with pyrites metamorphosed under green schist facies conditions. The serpentinite unit represents the altered peridotite namely the dunite. The serpentinite is dark green in colour, massive and foliated with two sets of lineations plunging NE and SE direction.The southeasterly lineation indicates the later strike-slip motion.

The Trans-Himalayan Units, namely the Indus Suture Zone rocks (locally known as Tuting-Tiding suture) and Lohit Plutonic Complex are thrusted southward over crystalline rocks of the Himalaya. The deformation and metamorphism in the Bomdila Crystalline Unit occurred due to collision related crustal thickening caused by the internal imbrication at different crustal levels. Based on field, structural and petrographic studies, the lower Lesser Himalayan quartzite unit is demarcated from the overlying Bomdila Crystallines by the Main Central Thrust. During post-peak metamorphism the continued compression uplifted and transported the thrust sheets as Lesser Himalayan Crystalline nappes further SW. Uplift and translation has reactivated the basal thrust, namely the Bomdila Thrust that climbed towards shallower levels at under reducing temperature conditions, attested by brittle deformation microstructures in the mylonites of MCT zone, superposed on the early crystal-plastic microstructures. Subsequently the Lesser Himalayan unit was metamorphosed under low-grade conditions and the Mishmi Thrust, which carried the Lesser Himalayan rocks over the Assam alluvium or over the sub-Himalaya (Siwaliks).

1.10 Geochemical and petrogenetic studies of basic and metabasic rocks of Lesser Himalayan sequence (LHS) in Siang and Subansiri valleys of Arunachal Himalaya

(A. Krishnakant Singh)

During the year various litho units were examined in the field and their interrelationships were investigated based on mode of occurrence, nature of contact, dykes/sills, etc. Samples of massive basalt, pillow basalt, agglomeratic basalt, acid rocks, metabasics, metasedimentary and dykes/ sills were collected for detailed petrographical and geochemical analysis. Moreover coal samples from the Gondwana Group of Arunachal Himalaya were collected for laboratory studies. Detailed petrographical and geochemical evidences confirm that basic volcanic rocks

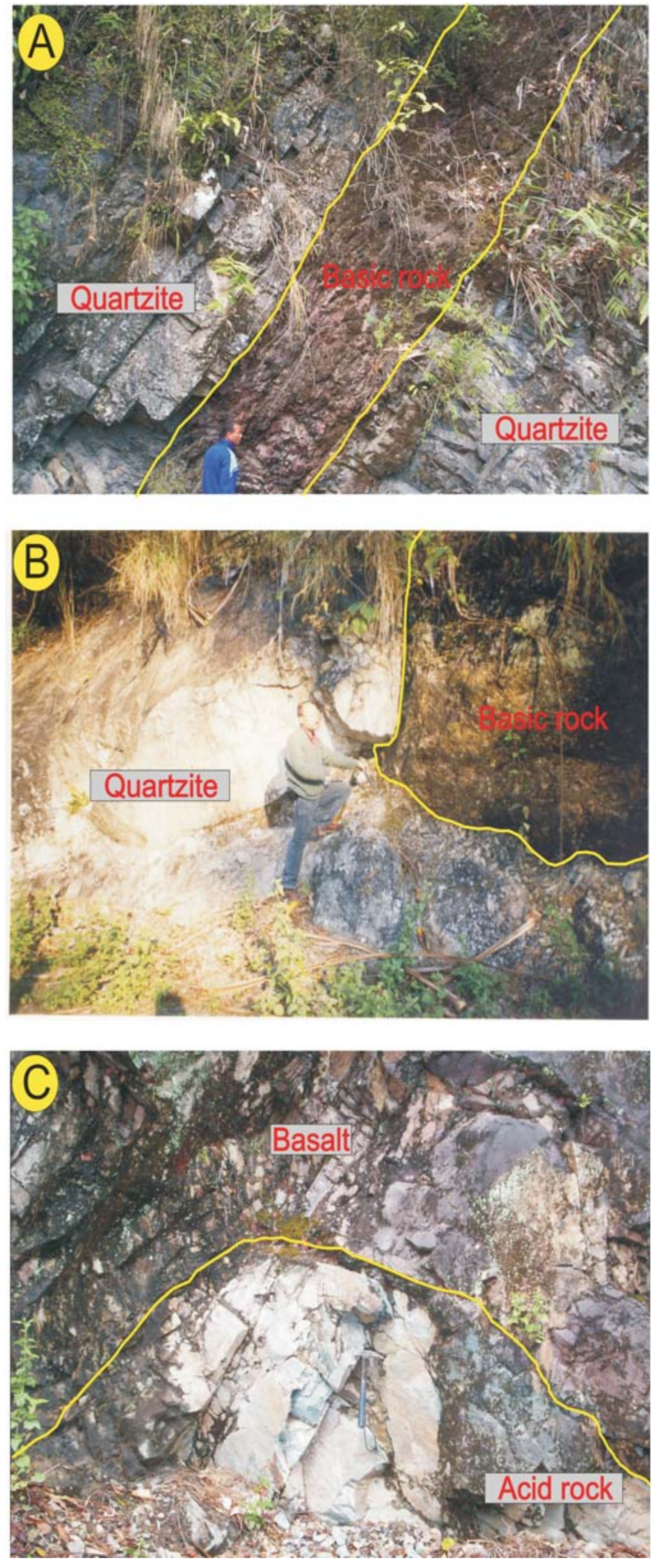


Fig. 4 (A) and (B) Basic dykes cutting across the quartzite (C) Acid intrusive within the basalt in Siang window of Arunachal Himalaya.

(high-Ti and low-Ti basalt) of Siang window have undergone multi-stage metasomatism by progressive transport of mantle fluids / or melts from deeper mantle. Relationship between incompatible element concentrations including REE and their ratios suggest enriched nature of these basic volcanic rocks and reflect a mantle source, probably formed by melting of mantle regions containing K-rich amphibole metasomatised veins. Modeling of trace including REE suggest that they are probably the result of a low to moderate degree (<30%) partial melting of source similar to picrite / komatiitic composition and the melting phase might have been accompanied by an influx of K, Ti, Rb, Sr, Ba, Zr, H_2O and CO_2.

Basic dykes of Siang window are characterized by depleted HFSE and Nb, P, Ti with low values of TiO_2, Ti/Y, Zr, Zr/Y (Fig. 4a&b). At place, intrusives of acid rocks are recorded and they range from dacite to rhyolite showing high SiO_2, Fe_2O_3, Na_2O+K_2O, Zr, Th, U, Nb, Y, Zr/Rb values and low in CaO, MgO, Ba, Sc values which suggest their crustal origin (Fig.4c). The coal seams are recorded (4 km in the NE direction from Garu IB in the BRTF road towards Basar and about 7km along the road from Garu IB to Gensi at the village Takso) in the Gondwana Group of Arunachal Himalaya. The seams are lenticular in form and are much crushed and show high ash content, may be due to the introduction of foreign matter on account of tectonic flowage. Nevertheless, these coal seams, though sporadic in nature, are important natural resource for the inhabitants in this region.

1.11 Structural evolution of the Uttarakhand Lesser Himalaya: A study based on field, model deformation, petrofabric and magnetic strains

(A.K. Dubey and S. S. Bhakuni)

Anisotropy of Magnetic Susceptibility (AMS) data from the Uttarkashi area, Garhwal Inner Lesser Himalaya has led to the following important observations regarding the neotectonic stress field.

- Most of the area is characterized by stress pattern that is favourable for formation of normal faults. The only exception is the southern part at the North Almora Thrust where the pattern is representative of thrust faulting indicating that the thrust is probably active because of low dips.
- The hanging wall of the Munsiari Thrust is characterized by stress conditions favourable for normal faulting with some oblique-slip component. The data suggest locking of the Munsiari Thrust.
- The Uttarkashi antiformal fold in the central part of the area may have been formed as fault propagation fold due to the displacement along the blind thrust (Thakur and Kumar, 1995).
- The area is deformed by a combination of simple shear and pure shear deformations.

A schematic model for the evolution of structures in the area is shown in Fig. 5. The first stage of the deformation (Fig. 5a) shows compressive strain (of the Himalayan orogeny) and displacement along a gently dipping thrust fault with the maximum extension in the vertical direction. With progressive deformation the fault surface rotates in a clockwise direction thereby resulting in increase in dip of the thrust (Fig. 5b). The model extends in the vertical direction and reaches up to the height of the compressing blades. The rotation of the fault continuing with increase in deformation and displacement along the fault may lead to formation of a fault propagation fold (Fig. 5c). The degree of asymmetry of the fold depends upon the dip of the thrust and the asymmetry decreases gradually with an increase in the fault dip. Once a fold is initiated, it can propagate along the layering by forming a series of anticlines and synclines. The upward extension of the model, after surpassing the height of the pistons, leads to extension of the model over the compressing blades (Fig. 5d). The extrusion and subsidence at the sides can result in extensional regime at the higher levels of the model providing conditions suitable for the formation of normal faults. This may be responsible for the formation of recent normal faults in several parts of the Himalaya where similar deformation conditions exist.

The three dimensional variation of the stress state demands a careful study for prediction of future seismicity in the Himalayan region. The observation is also important for the GPS study where only the surface displacements are measured (from far off stations in the Himalaya) and where the vertical displacements cannot be determined precisely.

The model explains the occurrence of recent seismicity along blind thrusts (e.g. Uttarkashi and Chamoli earthquakes). The active blind thrust cannot propagate to the surface because of prevalence of the extensional strains near the surface. Thus the proposed model brings a tiding for the regional habitants. The contrasting stress conditions can reduce the displacement along an active thrust fault thereby reducing the intensity of the resulting earthquake.

The stress orientations suitable for normal faulting at the hanging wall of a locked thrust may be generated by gravity gliding when the rocks reach a high topographic elevation as a result of thrusting. Gravity gliding of this type has been demonstrated in the Tethys Himalaya but no such normal faults were seen in the present study area.

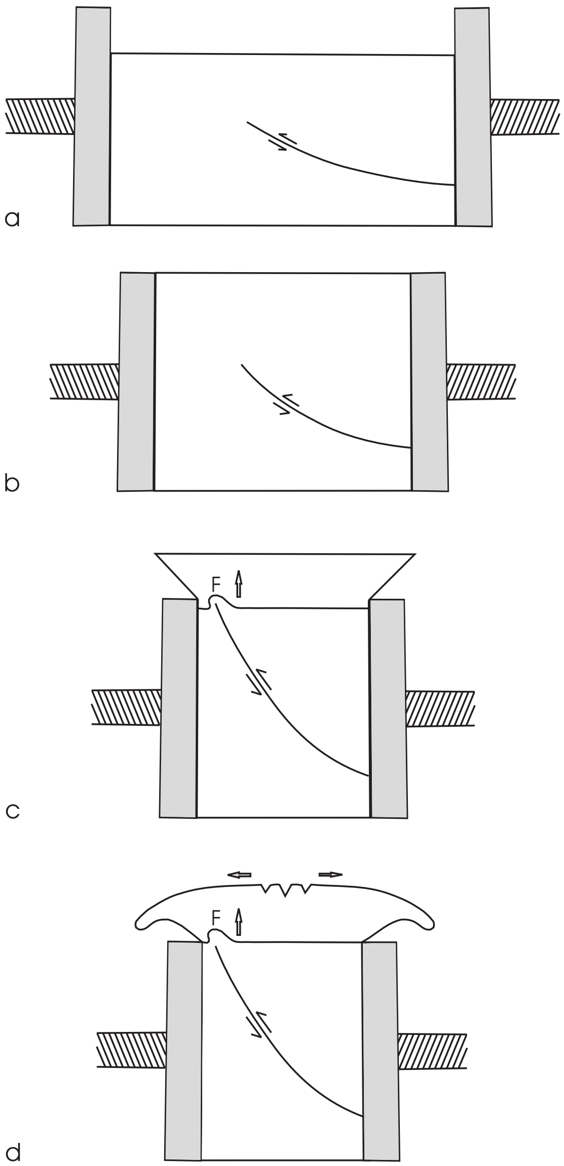


Fig.5. A schematic diagram showing thrusting at depth and extensional faults at the upper levels in a geological body. **a.** Compression of a geological body between two pistons, extension in the vertical direction and initiation of a gently dipping listric thrust fault. **b.** Rotation of the fault in a clockwise direction resulting in an increase in fault dip. The upper surface of the body reaches to the height of the pistons with extension in the vertical direction. **c.** Squeezing out of the upper part of the body above the pistons. The thrust at the lower level can form a fault propagation fold in a layer within the compressional regime. **d.** Collapse of the upper part and formation of extensional structures. The new location of the fault propagation fold is in the extensional regime.

1.12 Neotectonic study of eastern Himalaya, Arunachal Pradesh

(S.S. Bhakuni, Pradeep Srivastava and Khayingshing Luirei)

The structural and geomorphological studies reveal that the frontal part of the major Siang antiform/window, eastern Arunachal Pradesh, is neotectonically active. The OSL dating of the morphostratigraphic sequence around Pasighat indicated that the landform evolution took place between 15 ka to 3 ka. It is interpreted that the transverse Ranaghat Fault running parallel to the hinge zone of Siang antiform was activated between ~13 ka and 10.5 ka. Restricted between two undeformed beds, the soft sediment deformation structures have been identified in the Neogene sequence that consists of salt and pepper textured, coarse to medium grained micaceous, thickly bedded massive sandstone with thin carbonaceous lamination belonging to the Subansiri Formation (equivalent to the Middle Siwalik). The structures developed are complex flame structures, psuedonodules, dish, pillar, folds and convolute structures. These deformation structures are inferred to have been formed by earthquake activity that occurred during the deposition of the Middle Siwalik sandstone (~ 5 Ma to 10 Ma).

In the hinterland region along the Main Central Thrust zone analysis of morphometric parameters of some part of east-west trending Bomdila-Tamen Fault Lineament suggests the recent rejuvenation of landscape with rapid incision by the Kamla river in the Quaternary times. The east-west trending sharp ridge-slope dips steeply (> 50°) towards SSW direction and is characterized by old and recent landslides. The rocks are characterized by brittle open fractures with relative displacements along them and are traversed by four joint sets; the most important set of which being 56° dipping towards S10°E that trends parallel to the Bomdila-Tamen Fault Lineament. The steep slopes across the nick points along the Kamla river and its tributaries show high values of river Gradient Index which suggest rapid upliftment.

1.13 Sedimentological and geochemical attributes of the Pre-Vendian (1600-600 Ma) clastic and associated volcanic succession of the northwestern Lesser Himalaya

(Sumit K. Ghosh and R. Islam)

The present study focuses mainly on the following aspects – i) measuring of litho- sections, lithofacies distribution and establishing soft sedimentary deformational structure as palaeoseismites mainly in the outer belt of the Garhwal Lesser Himalaya, and ii) geochemical characteristics of the argillite-siliciclastics package for provenance and weathering aspects.

Sedimentological attributes

Palaeoproterozoic Damtha Group of the Garhwal Lesser Himalaya, an argillite>siliciclastic shallow marine succession associated with mafic volcanics possibly represents the oldest sedimentary rocks exposed in the Himalayan orogen. The Damtha Group comprises older argillite dominated Chakrata Formation and younger siliciclastic dominated Rautgara Formation. Various soft sedimentary deformational (SSD) features are observed mainly in the Chakrata Formation at different levels bounded by undeformed sedimentary layers. Four litho- sections studied in detail for palaeoseismites aspects are: i) Chakrata-Thana, ii) Nainbag-Damtha-Sarigad, iii) Saknidhar, and iv) Satpuli. The undeformed intervals are constituted of fine-grained sandstone, siltstone and shale having lenticular and wavy laminae of varying thickness. Commonly observed features in the sediments are discontinuous laminae with sharp contacts, cross laminations, ripple drift laminations and round crested nearly symmetrical wave ripples on the bedding plane view. However, in the fine-grained part a combination of parallel, wavy, lenticular, and flaser laminations are discernable. In many of the silty lenses micro-cross laminations showing fading ripple with the silt laminae on the ripple crests fade into mud laminae towards troughs. In the deformed intervals the SSD features are of both types i.e. syn- and meta-depositional with stages from incipient to advance. SSD features including ball and pillow of varied dimensions (between W/L 5-35 cm/ 5-150cm), deformed mud/sand balls with dislocated laminae, contorted beds, load sag, bed collapse and flame features (Fig. 6) are noticed in abundance in the Nainbag-Damtha section along the Yamuna valley for about 20-25 km stretch and also in further east along the Shivpuri-Saknidhar section in Alaknanda valley but not in abundance.

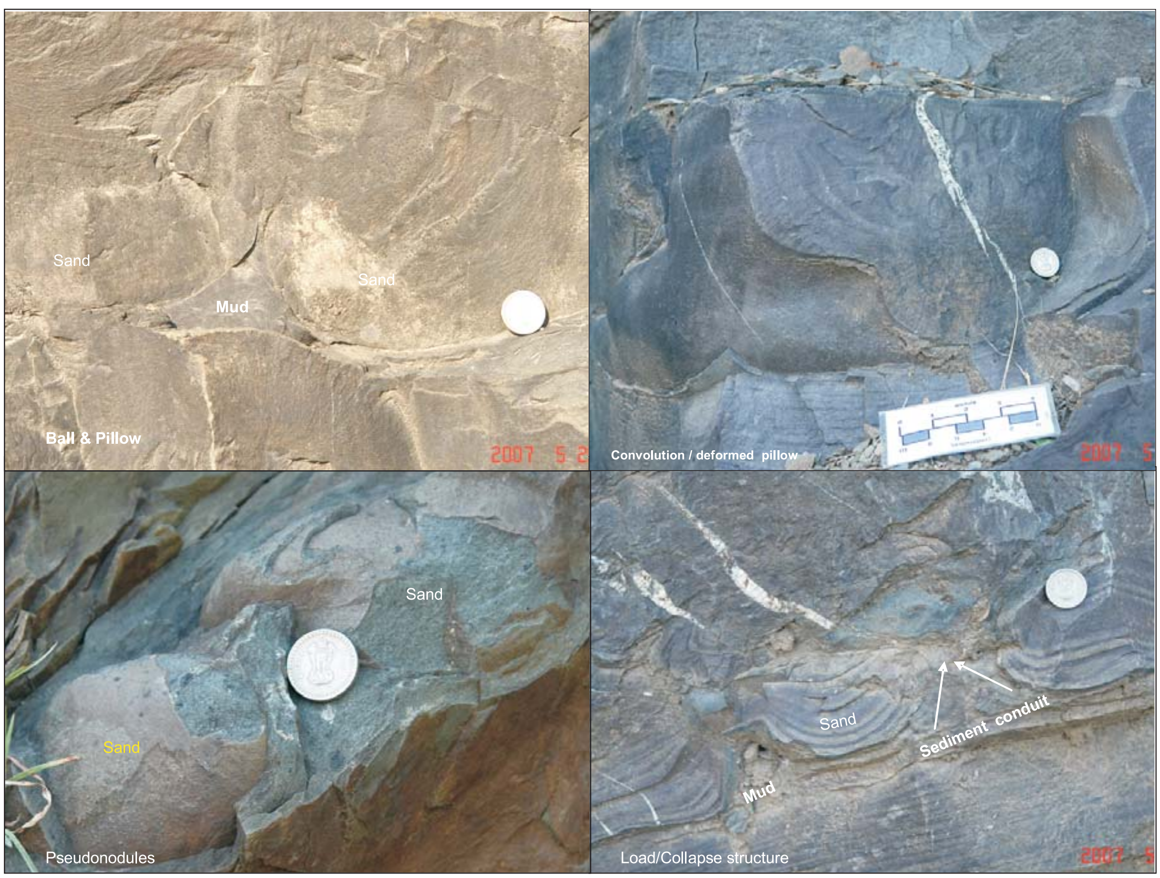


Fig. 6. Soft sediment structures (Seismites) in the Palaeoproterzoic argillite-siliciclastics succession of Damtha Group, Garhwal Lesser Himalaya.

These features are predominantly observed at fine sand-mud interface and are conspicuously absent in horizons having dominance of any single grain size facies. Size of the feature also varies with the bed thickness at the interface. Petro-textural behaviour of the SSD layers shows micro lobes particularly in two components i.e. clay and silt rich sediments. Widespread occurrence of SSD and their temporal distribution implies repetitive nature of causative process in the depocenter. The widespread occurrence of SSD in the comparable sections over large spatial distances (~ 150 km) and its association with 1.8 Ga penecontemporeneous mafic volcanics point to a regional triggering agent like frequent earthquakes. These features must have been developed by the seismic shaking of the basin floor by the earthquakes.

Geochemical Attributes

Sedimentary rocks are the only evidence of older crust that have been removed by erosion, covered by sedimentary deposits, ice or buried deep in the crust. A combination of petrography (detrital modes) and geochemistry of sedimentary rocks provides important information on the characteristics of provenance as well as tectonic setting. In the present investigation focused on petrographical and geochemical data set to understand the relationship between Pre-Vendian (1800-600Ma) argillo-arenaceous packages of the Lesser Himalaya an attempt has been made to decipher their provenance and weathering history. The bulk rock chemistry of the Lesser Himalayan sediments shows similarities with PAAS (Post-Archean Average Australian shale), NASC (North American Shale Composite) and UCC (Upper Continental Crust), but are slightly enriched in SiO_2 and K_2O and depleted in CaO, Na_2O, Ba, Sr, compared to PAAS. Chemical variations in these rocks are related to the chemical distribution within the different mineralogical phases and are produced by the grain size sorting during transport and deposition. The chemistry of these rocks shows illite control that gets diluted with increasing quartz content. The majority of the arenaceous sedimentary rocks exhibit presence of plagioclase, K-feldspar and clay minerals. But lack in ferromagnesium minerals which indicates decomposition of feldspar but greater decomposition of ferromagnesium minerals. The clastic sediments of the Lesser Himalaya are enriched in LREE with pronounced negative Eu anomalies; HREE patterns are moderately depleted in nature. Moderate to high CIA value, presence of illite and muscovite in most of the samples in A-CN-K plot is typical of non-steady state weathering condition where active tectonism permits erosion of all zones. The remarkable similarities in major, trace and REE chemistry and experiencing lower grade of metamorphism (up to green schist facies) and structural deformation, and still preserving the various primary sedimentary structures indicates a similar depositional set up throughout the Lesser Himalayan region. The penecontemporeneous (1.8 Ga) mafic volcanism and occurrence of palaeoseismites are suggestive of deposition in an unstable shallow marine basinal set up.

1.14 Cretaceous – Tertiary and Palaeocene – Eocene boundaries in Um Sohryngkew section, Meghalaya : interdisciplinary study and global correlation

(V.C. Tewari, K. Kumar, N.S. Siddaiah and Kapesa Lokho)

The Cretaceous-Tertiary and Palaeocene-Eocene boundaries represent global catastrophic and palaeoclimatic events well documented by the bolide impact evidence and faunal extinction. The rich concentration of rare earth elements such as iridium, osmium and other platinum group elements in the K/T boundary clay layer strongly support the asteroid impact. The mass extinction of planktonic foraminifera, nannofossils and dinosaurs may be related to this impact. The Um Sohryngkew River section (Fig. 7) and other sections in Shillong Plateau, Meghalaya are very promising areas to study these events in India for regional and global correlation. The stable carbon isotope studies from these sections will provide strong evidence of global cooling at the K/T boundary and Palaeocene-Eocene Thermal Maxima (PETM) at P/E boundary. An interdisciplinary approach is being applied to solve this problem. The main objectives of the project are to know the sedimentation history, facies variations and establish the Cretaceous/Tertiary and Palaeocene/Eocene high resolution biostratigaphy, palaeoclimatic events based on faunal extinction and diversification, carbon isotopic changes and PGE and REE geochemical changes through K/T and P/E succession in Meghalaya.

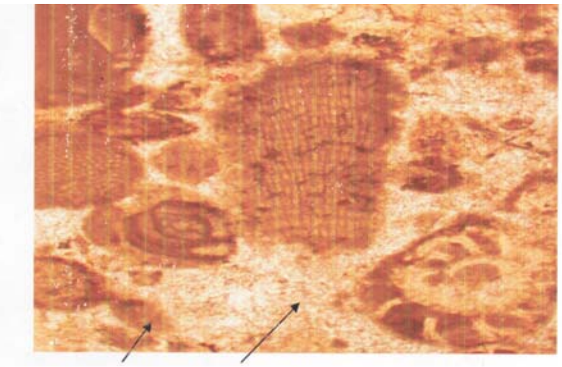
During the year field work was carried out along Cherrapunji (Sohra)-Shillong, Mawmluh Limestone Quarry, Um Sohryngkew River, Komorrah Limestone Quarry, Shella River, Mawsmai-Shella, Mawlong-Mashmak-Sohra, Ranikaur-Dirang and Mawsynram sections of the South Shillong Plateau in the East and West Khasi districts. All these sections were systematically studied. Detailed lithologs were prepared showing various sedimentary facies variations, sedimentary structures, bioturbation structures, trace fossils, larger and smaller foraminifera, bivalves, dinosaur bones,

Fig. 7. Um Sohryngkew River Section, Meghalaya showing Eocene Sandstone.

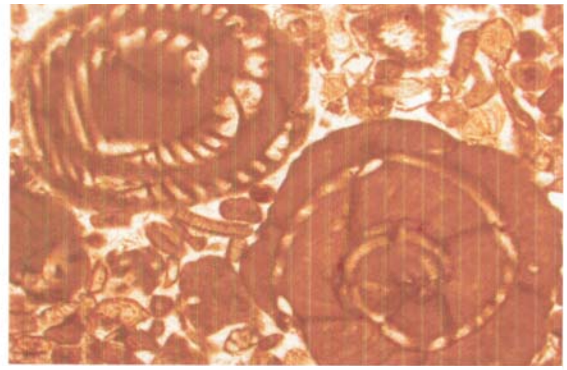
fossil wood, etc. Samples were collected in stratigraphic order from bottom to top of the sections. Different clastic/ sandy facies from the Jadukata Formation, Bottom Formation and the Mahadek/Mahadeo Formation (Late Cetaceous) were collected for the sedimentological studies. These rock formations show very good preservation of trace fossil *Thalassinoides*. The calcareous shales with limestone bands in the Langpar Formation (Early Palaeocene) have been collected for the microfossils, vertebrate fossils, carbon isotope and geochemical analysis. The Therria Sandstone is a coarse grained calcareous sandstone without foraminifera and contains a sandy dolomitic limestone with few foraminifera (Late Palaeocene) well developed in Um Sohryngkew river section. The Lakadong Limestone was sampled in detail in Mawmluh Limestone Quarry section. It is rich in larger foraminifera and trace fossils and Late Palaeocene in age. Microfacies, foraminiferal and isotopic studies of Lakadong Limestone will be done in detail for palaeoenvironmental and palaeoclimatic interpretations.

The Lakadong Sandstone overlies the Lakadong Limestone and is soft friable with coal lenses and without foraminifera. Umlatodoh Limestone is hard, massive foraminiferal limestone (Lower to Middle Eocene) and overlies Lakadong Sandstone. Nurpuh sandstone is ferruginous arkosic sandstone without foraminifera and shows good preservation of ripple marks and cross beddings near Duwansing bridge. The overlying Prang Limestone is a highly fossiliferous limestone with larger nummulitids and discocyclinids (foraminifera). It is Middle to Late Eocene in age. The top of the sequence is shale, sandstone and marl alternation, known as Kopili Formation. These sections were also studied in West Khasi Hills for vertebrate and other biotas across the K/T and P/E boundaries. Particular emphasis was laid on Late Cretaceous-Palaeocene sediments, which are represented by the Mahadeo, Langpar and Lakadong formations in ascending order. The sequences were found fairly rich in well preserved foraminifers, echinoids, mollusca, plant fossils, and trace fossils etc. Although no vertebrate fossils were noticed in the field except for some dinosaur bones in the Mahadeo Formation and fragmentary fish scales in the Lakadong Formation, maceration of test samples is expected to yield microvertebrate fauna, particularly marine fish remains. More systematic sampling will be done based on results obtained from test samples collected during the year.

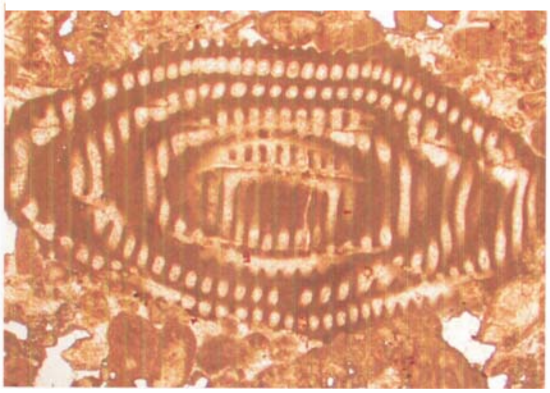
In the laboaratory, petrographic thin sections of the Lakadong Limestone from Mawsynram section were studied for microfacies analysis of the algal-foraminiferal limestone. The calcareous algae-foraminiferal assemblage recognized include coralline algae *Lithophyllum* , *Dasycladaceae* and *Discocyclina nummulites* foraminifera (Fig. 8). The Plaeocene-Lower Eocene age is indicated by these findings. The limestone is deposited in shallow marine conditions and tidal influence is recorded since reworked



Algae Solenopora sp. and *Miscellanea* sp. Foraminifera (equatorial section) SBZ 4, Palaeocene



Alveolina cf. *aramaea hottinger* (two sections), Ilerdian (SBZ 5)



Assilina cf. *vredenburgi* Davies and Pinfold, (ex Alv. cucumiformis)

Assilina sp. and *Discocylina* sp.

Fig. 8. Algal-Foraminiferal microfacies of the Lakadong limestone (Palaeocene) in Mawsynram section of Shillong Plateau (Tewari *et al.*, 2008).

clasts, oolites, intraclasts and broken shell fragments are intimately associated with algae and foraminifera. Marine transgression and continental environment was recognized in the Mahadeo Formation during Late Cretaceous period. Cretaceous anoxic event (reducing environment) is represented by the black shale-pyritic and fossil wood found in the Mahadeo Formation.

The carbon and oxygen isotopic analysis of some representative Palaeocene algal -foraminiferal Lakadong Limestone from the Mawsynram section has been done for the first time. The ä^{13}C ratio varies from – 0.05 % (PDB) to – 0.47 % (PDB) and ä^{18}O ratio varies from 21.543 % (SMOW) to 21.94 % (SMOW). The carbon isotope data suggest a shallow marine (tidal flat) environment for the deposition of the Lakadong Limestone since the C isotopic value of the shallow sea water is nearly zero per mil. The sedimentary facies, trace fossils, microfossils and carbon isotope profiles from the Southern Alps in Italy (Western Adriatic Tethys platform, Tewari et al. 2007) is tentatively correlatable with the South Shillong plataeau. The global events of cooling below the K/T boundary and the Paleocene-Eocene Thermal Maxima (PETM) are related to global carbon cycle perturbations and will be studied in detail for global correlation.

1.15 Kinematics of the India-Asia convergence process as manifest in Himalaya from GPS measurements

(P. Banerjee)

During the year repeat GPS measurements on Central Indian stations (Bhopal, Jhansi and Nagpur) were carried out. In the field campaign mode, 20 GPS stations were occupied for 4-5 days each. Eight new GPS stations were established and one Permanent GPS station was established at Badrinath. External data were collected from all permanent stations covering entire India, and processed. Also, data from published sources covering entire Asia, Europe, Australia, India and Africa collected and processed.

Thus a regional GPS velocity estimation covering entire India, Asia, Europe, Africa and Australia carried out and studied to understand the:

- Interactions between different plates, and manifestation along plate boundaries, with special emphasis on the Himalaya
- Strain estimation within stable Indian shield from the GPS derived velocities
- Segmentation of the convergence along the Himalayan arc

MMP 2 : Climate-Tectonic Interaction

2.1 Climo-tectonic studies in the Lahul-Spiti-Ladakh region with special emphasis on Quaternary environmental change.

(R.K. Mazari, M.P. Sah and A.K.L. Asthana)

During the year synthesis of data pertaining to glaciation and tectonics, Quaternary sediments exposed in trenches, radiocarbon dates, pollen and plant fossils was carried out to interpret the palaeoclimatic and environmental changes in part of the Spiti basin. Analysis of the data shows that the tectonics of the area has played a significant role in glacial entrenchment during the Quaternary period, particularly along the Chandra valley; this is evidenced by the presence of granitic boulders in the slopes of the upper Spiti basin which have extra-basinal origin. The glaciation seems to have been relatively more profound in the Chandra valley than the Spiti valley which may be due to contrasting geographical directions affecting the atmospheric circulation and hence the differential precipitation conditions. Field evidences show that at the present time the latter is relatively drier than the former.

The tectonic architecture of the region seems to have had profound influence in the drainage build up of the area. This, apart from leading to the entrenchment and sometimes disarray of the drainage lines has caused impoundment of the Spiti river along the axial fault which is evidenced by the development of a large palaeolake now displaying its sediments in discrete form. The development of the palaeolake seems to have coherence with a mega-regional tectonic movement around 45,000 year B.P. stretching from Lamayuru in Ladakh to some late Quaternary basins in Kumaon. The palaeolake study at Kioto in Spiti has revealed some climatic signatures of both terrestrial and marine equivalents in Tibet and Bay of Bengal respectively. Significant warm events in the Spiti valley have been noted at tentative ages (based on varve count) of ~43,000 yr BP, 32,000 yr BP 27,500 yr BP, 19,000 yr BP and 12,800 yr BP.

The sediment build up exposed in non-lacustrine environment in the upper Spiti valley has revealed periodic changes in facies development like fluvial, swampy, aeolian, etc. The swampy facies rich in radiocarbon material have been dated and also studied for the pollen assemblages. The sediments of these trenches bear a history of over 8000 years of development where changes in climatic pattern are evident. Warm and moist events in the Spiti valley through these proxy sediments have been noted at 8370 yr BP, 6880 yr BP, 5620 yr BP, 3160 yr BP, and 400-1000 yr BP. Broad leaved plant impressions collected from calcareous tufa indicate warm phase of climate in the Spiti region but the carbon dates obtained on the material being spurious the chronological setting is constrained at this time and will be refined with available proxy material adjunct to the calcareous tufa deposit.

In general, environmental change in the region is visible which has further been augmented by human colonization of the area. According to field observations collected earlier the alluvial fan pockets in the Spiti valley in particular were adequately vegetated but have been decimated since the dawn of inhabitation several centuries ago. The removal of forest cover in the alluvial fan terrain has led to depletion of water resources in otherwise cold and dry region. The temperature in the Spiti valley is showing changes with the minimum temperature reflecting diminishing trend. This may be due to the changes in the system at both the regional and global levels.

Apart from this, RKM carried out analytical studies on the landform development of the Kiarda *dun,* west of the Yamuna valley in District Sirmaur of Himachal Pradesh. The studies have shown a variety of landforms, the bulk being represented by the massive alluvial terrace, piedmont fans, flood plains and intra-basinal depressions filled with Quaternary deposits. Interplay of Quaternary tectonics is clearly visible in the area.

2.2 Environmental magnetic study in selected higher Himalayan paleo- and present-day glacial lakes

(Narendra Kumar Meena)

Field work was carried out in Chorabari Tal and BrahamTal where four cores and one trench profile was sampled. Field work was also undertaken near Samuder Tapu glacier (ChandraTal) and the Baralacha La region and a trench profile from ChandraTal and one exposed palaeolake section was sampled with a resolution 0.5 and 1 cm respectively. The collected samples were prepared for environmental magnetic measurements using parameters like Magnetic Susceptibility (Xlf), Isothermal Remnant Magnetization (IRM), Anhyteretic Remnant Magnetization (ARM), Partial Anhyteretic Remnant Magnetization (pARM) and Hysteresis

Loop involving VFTB. Grain size analysis was also done for selected samples of Chorabari Tal.

The Chorabari Glacier is located in the Mandakini basin, a subsidiary basin of the Alaknanda in Rudraprayag district of Uttarakhand. Chorabari Tal is a moraine dammed lake (Fig. 9) and the source of the water in lake is ice melt from a small catchment area. The dominant lithology in the lake is alternative layers of coarse sand and silt, plant roots and soil, found at the top of most layers. The value of the magnetic susceptibility ranges form 0.4 to 1.8×10^{-8} m^3/kg (Fig. 10), the upper 20 cm layer shows highest values that significantly decrease towards the bottom (below 20 cm). The Xlf suggest that the concentration of the magnetic fraction increases towards the surface that possibly is controlled by the sediment input in varying climate. The linear relation of Xlf with the fine material also supports that the magnetic fraction comes from fine grain material not from coarse grain (catchment rock). The SIRM values of the profile also follow the trend of the magnetic susceptibility and indicate low coercivity magnetic minerals (ferrimagnetic) at the top of the profile. The grain size dependent parameter ARM also shows higher values in the top most layer of the profile that clearly suggest domination of Single Domain (SD) fraction, while the bottom of the profile indicates Multi Domain (MD) fraction. The Hysteresis loop parameter also supports the presence of SD and MD grain fraction. Since the lake has a specified catchment, the magnetic property of the lake sediments is least contaminated by any other source. Therefore, variation in the magnetic parameters should be controlled by energy of transportation media that may be related with the activity of the glacier.

Fig 9. Photograph of moraine dammed Chorabari Tal (Chorabari Glacier) in Mandakini Valley.

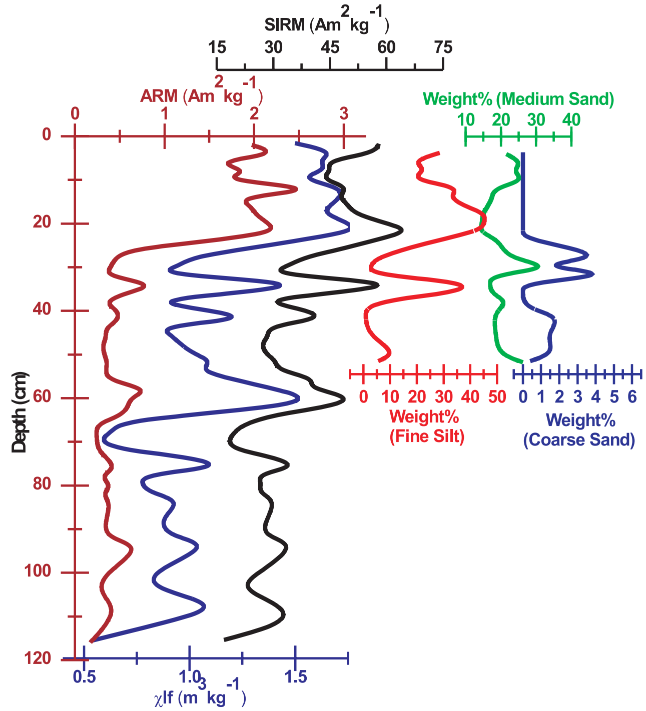


Fig.10. Depth profile of Magnetic susceptibility (Xlf), Saturation Isothermal Remanent Magnetization (SIRM) and Anhysteretic Remnant Magnetization (ARM) indicating large values in shallow section and a decreasing trend toward bottom part of the Chorabari Tal.

2.3 Tectono-climatic evolution of Alaknanda-Bhagirathi River system in NW Himalaya

(Pradeep Srivastava and R. Islam)

Studies on aggradational and incision processes of the Alaknanda river were carried out in and upstream of Srinagar. The terrace configuration at Srinagar indicates that five levels of terraces with distinct bedrock strata exposed in the form of a fossil valley at two levels, the T_6 and the T_1. The widths of the fossil valleys are comparable to the present day channel. This indicates that although the river has regularly and preferentially shifted eastward with continuous downcutting but the width has remained the same. The lateral shift of the channel has resulted in the formation of a wide valley around Srinagar. The other geomorphic indices like channel patterns of the first order tributaries indicate the role of North Almora Thrust in the tectonic uplift and formation of the terraces. The OSL dating constrained the processes of terrace formation between 36 ka and 13 ka. Similar studies from Gauchar indicated least tectonic uplift in the region. This aggradation phase lies between 37 ka and 12 ka. Chronologically same aggradational phase was observed in similar terrace types at Siroli, Nagrasu and

Gholtir. The river witnessed incision after 12 ka. These cut and fill type terraces represent regional aggradational events in the Alaknanda valley and are noticed downstream at Deoprayag and Byasi.

2.4 Palaeoclimatic and Tectonic study of the Quaternary – Holocene speleothems from NW and NE Himalaya

(V.C. Tewari)

The Quaternary and Holocene speleothems (cave carbonate deposits) have been used for determination of palaeoclimatic changes and palaeomonsoon study. Recent isotope signatures in microbial carbonates can distinguish between biologically and inorganically controlled precipitation and palaeoclimatic interpretation. Numerous caves are known in the Lesser Himalaya (Sahastradhara in Dehra Dun, Brahmakhal in Uttarkashi, Timta and Patal Bhuvaneshwar in Kumaon region, Mawsmai, Mawsynram and other caves in Meghalaya, Sikkim and Arunachal Lesser Himalaya). The main objective of the present study is to understand the Quaternary and Holocene sedimentation in caves (speleothems) and their palaeoclimatic and palaeomonsoonal (decadal scale seasonal variations) characteristics based on carbon and oxygen isotopic ratios and ^{230}Thorium dating of the speleothems (stalactites and stalagmites).

During the year field work was carried out in Sahastradhara, Brahmkhal, and Pratapnagar caves in Garhwal and Mawsmai and Mawsynram caves in Shillong Plateau, Meghalaya. Speleothem samples and dripping water from the cave stalactites were collected for the laboratory investigations. Petrographic thin sections were studied for carbonate mineralogy, microfacies and palaeoclimate. Speleothems show finely laminated carbonate and microbial laminations (Fig. 11). Carbonate minerals include aragonite and fibrous calcite formed in fresh water. Presence of microbiota was recorded from the organic dark laminae. Various types of light (carbonate) and microbial (dark) morphology is related to the microclimatic decadal scale seasonal variations. The Sahastradhara caves of Dehra Dun are made of stalactites and stalagmites. The stalactites show the presence of bacteria to form calcite precipitation. Carbon and oxygen isotopic variations in the Sahastradhara, Brahmakhal and Pratapnagar speleothems show negative

Fig. 11. Speleothem (cave stalagmites and stalactites) from the Garhwal and Meghalaya.

carbon and oxygen isotope values. The carbon isotopic ratios of of the Sahastradhara stalactites range from – 2.47 ‰ PDB to -6.06 ‰ PDB and oxygen isotope values range from 22.99 ‰ SMOW to 26.21 ‰ SMOW. In Brahmkhal caves the ä^{13}C varies from – 5.34 to -7.65 ‰ PDB and ä^{18}O varies from 20.67 ‰ to 22.84 ‰ SMOW. The ä^{13}C value of Pratapnagar modern calcite (stalactite) varies from – 4.85 ‰ PDB to – 9.23 ‰ PDB and the ^{18}O range from 19.50 to 21.57 % SMOW. The variation of ä^{18}O in stalagmites is related to the precipitation amount during the monsoon season. The oxygen isotopic composition of speleothem calcite from tropical and monsoon locations is primarily controlled by the ä^{18}O value of precipitation, which in turn varies inversely with rainfall amount. ä^{18}O values of regional precipitation and that changes in calcite ä^{18}O over time primarily reflect changes in the amount of monsoonal precipitation. Study of modern cave drip waters and stalagmites demonstrates that stalagmite was deposited in or very close to isotopic equilibrium. The ä^{18}O isotopic data of drip water from Sahastradhara cave in Dehra Dun measured during the months of August and September varies from -4.58 ‰ (V- SMOW) to – 5.14 ‰ (V- SMOW). Cave calcite also contains information about the isotopic composition of meteoric precipitation, is widespread and can be dated with ^{230} Th method. Thus the Lesser Himalayan caves may yield well dated record of palaeomonsoon history.

2.5 Late Quaternary climate changes and monsoon variability along the NW Himalaya

(N. R. Phadtare)

Dayara Peat Deposit (Bhagirathi valley, NW Garhwal Himalaya)

This peat deposit (3430 m altitude) situated in the upper Bhagirathi valley documents the past ca. 6000 year century-scale records of climate history around the Gangotri area. The multi-proxy data (pollen, organic matter and magnetic susceptibility) reveal that the upper catchment of the Bhagirathi valley, with respect to its present climate, was much more warm and wet around ca. 5900 and 2400 cal yr BP. The tree-line trend inferred from the quantitative pollen data (absolute pollen concentration per gram of peat sample) indicates that around these times, the snout of the Gangotri Glacier had probably retreated much beyond its present position (i.e. 4120 m altitude). The peat proxy data further indicate that the Gangotri area was extremely cool around ca. 5200 and 3600 cal yr BP, implying that the Gangotri Glacier might have experienced significant advancements around these times. These findings have significant implications in understanding the long-term climatic response of the Gangotri Glacier, particularly in context to its present retreating trend and climate change.

Dhakuri Peat Deposit (Pinder Valley in Kumaon Himalaya)

The past 2000 year multi-parameter climate records from the well-dated (six AMS ^{14}C and eight ^{210}Pb dates) Dhakuri peat deposit in Pinder valley revealed four major (ca. 100 cal BC, 100 cal AD, 285-360, 1250-1370 and 1570-1700 cal AD) and two minor (around 900 and 1750-1850 cal AD) dry climate events in Kumaon Himalaya. These dry events closely correspond with episodes of decreased summer monsoon strength over the Arabian Sea. The major dry events of Kumaon Himalaya appear to be sudden, and significantly amplified as compared to relatively weak monsoon phases of the Arabian Sea. Minor episodes of weak monsoon over Arabian Sea (e.g. 840-930 and 1080-1150 cal AD events), however, seem to have no apparent impacts on the regional climate and vegetation of Central Himalaya. This correlation evidently indicates that major dry climatic episodes in Central Himalaya during the last two millennia are the manifestation of long-term weak monsoon episodes over the Arabian Sea.

Bedni peat Deposit (Nanda Devi Bio-reserve)

The laboratory processing of samples collected from peat deposits and lake sediments of the Bedni meadow (ca. 3600 m altitude) has been completed. The AMS ^{14}C date obtained for one of the peat profiles (3635 m altitude) indicates that this site documents past 2500 year climate history of the region. The organic matter contents (LOI) and magnetic susceptibility data are generated; while the pollen analysis (identification and preparation of pollen diagram) is still in progress.

2.6 Evolution of late Quaternary Deposits in the Dun valleys, sub-Himalaya: implication for climate and tectonics

(Suresh. N. and Rohtash Kumar)

The Soan Dun, a longitudinal valley in the sub-Himalaya, is bordered by Siwalik hills which comprises Middle and Upper Siwalik formations in the south. The water in the valley is drained through two axial rivers, namely the Soan River and Sohan Nadi, originating in the hanging wall mountains in the north and flow in SE and NW directions respectively with the drainage divide falling close to the western margin of the dun. The tributary streams are originating either in the hanging wall mountains in the north or from the northern flank of the detached Siwalik hills.

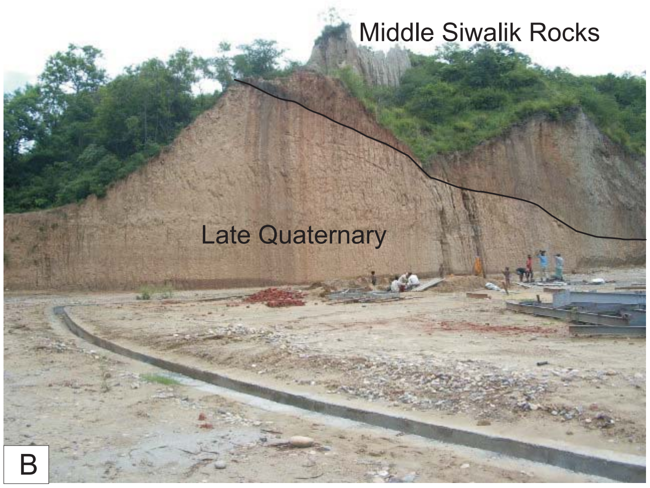


Fig. 12. Late Quaternary deposit in the Soan Dun showing (**A**) dominance of sand-mud litho-units and (**B**) the occurrence of coarse grained sand and pebbly sand units with thinly bedded gravels.

Studies were carried out in the Soan Dun to document the late Quaternary stratigraphic succession and associated lithofacies assemblage to understand the relative role of tectonic and climatic change in the evolution history. The late Quaternary deposit in the valley is exposed to the north and south of the axial Soan river. Both alluvial fan and fluvial deposits are observed, but the alluvial fan is dominant and is exposed to the north and south of the axial Soan river. The litho-stratigraphic succession, exposed in 10 to 25 m thick well-exposed sections between Daulatpur in the west and Una in the east, indicate that the deposits are dominated by sand-mud litho-units with rare occurrence of gravels. The sandy units are in general fine to medium grained but coarse to pebbly sand was also observed. The sandy units are grey to brownish grey coloured, massive, planar or cross stratified and poorly consolidated. The mud units were buff coloured and in general observed towards the bottom and top of the sections. The gravel units are common towards the basin margins as well as towards the top of the sections. The facies association characterized by fine-grained sand-mud alteration (Fig. 12A) is dominant towards the basal and top part of the section but pedogenic activity was more predominant in the basal part. Facies association characterised by thick, multistory, fine- to coarse-grained grey sand, having sheet geometry, with pebbly sand in between (Fig. 12B) is very common in the valley and occurs at various stratigraphic levels. In the upper part of the sections, the facies association is characterized by fine-grained sand-mud alteration but pedogenic activity was less. Gravel units having erosional contact with the underlain units characterise the topmost part of most of the sections.

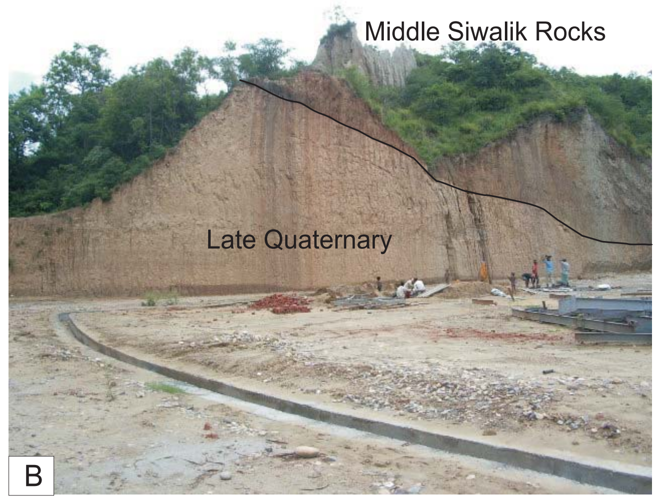


Fig.13. (**A**) Late Quaternary deposit showing titled beds and (**B**) the late Quaternary sedimentary succession over thrust by Middle Siwalik Formation along Soan Thrust.

In general, the aggradation phase is characterized by 3 or 4 facies assemblages. To the south of the axial Soan river, close to the southern margin of the valley, the late Quaternary deposit is dominated by gravel units derived from the detached Siwalik hills. At places, the beds are titled towards the northeast (Fig. 13A). Luminescence chronology was carried out to constrain the various events. The aggradation phase in the Soan Dun was initiated well before 36 ka and terminated around 9 ka. The late Quaternary depositional phase in the Soan Dun was terminated by prolonged stream incision. Presently, the surface is cut off from any further deposition due to stream incision and the active stream channels are about 15-25 m below the surface. In the northern margin of the Dun, the late Quaternary sedimentary succession is overthrust by Middle Siwalik Formation along the Soan Thrust (Fig. 13B). Detailed work is in progress.

2.7 Tectono-climatic studies in Quaternary sediments along the Eastern Syntaxial Bend, Arunachal Pradesh.

(D.K. Misra and Pradeep Srivastava)

Geological investigation in the Siang valley of Arunachal Pradesh reveals the existence of eight distinct thrust bound litho-tectonic units. From SW to NE, in ascending structural order they are: 1. Siwalik Group, 2. Gondwana Group, 3. Yinkiong Group, 4. Miri Group, 5. Bomdila Group, 6. Sela Group, 7. Tidding Formation, and 8. Lohit Plutonic Complex. Field studies coupled with interpretation of topographic maps resulted in the identification and delineation of a large number of NNW to WNW-SSE to ESE, N-S, NNE to NE-SSW to SW and E-W trending active faults which post-date the boundary thrusts and shear zones. Recent movement on the faults has caused not only pronounced deflection of rivers and streams but also forming loops of a variety of shapes and present-day ponding. Movements along faults and thrusts are also responsible for the abrupt rise of mountain front, occurrence of a planar scarp and triangular facets devoid of gullies or with a few straight furrows, huge landslides, debris fan, abrupt narrowing down of wide meandering rivers, uplifted fluvial terraces, etc.

West of Siang, in the central part of the Subansiri valley, the 16 km long NW-SE trending Joram Fault lies within the Bomdila Group. Movements in the geologically recent time on this fault have caused blockade of the river Kale and resulted in the formation of a lake at Ziro. The lake has now vanished due to the neotectonic activity. The NNW-SSE trending Ziro paleolake deposits are exposed at an altitude of 1600 m above the m.s.l. and extend for nearly 15 km and have a width of about 5 km. The lake valley is drained by a ~2 m wide low gradient stream known as Kale river, a tributary of Subansiri river. Steep rising mountains where the Kale river cuts a deep gorge mark the southern end of the lake. The morphostratigraphy of the lake suggests presence of older alluvial fill exposed along the margins of the lake followed by the incision and formation of the lake. The sedimentary character of the alluvial fill suggests an existence of high energy channel system during the past. The sequence exposed in the dug pits of the lake bed indicates presence of another lacustrine sequence below the exposed fill. The peat associated with the carbonaceous layer in the lower lake sequence has earlier given ^{14}C age of 40,000 years (Kar *et al.* 1997). The exposed part overlying fluvial sequence, using OSL technique is dated between 22 ka and 10 ka. The fluvial fill was incised post 10 ka after which second phase of lake formation commenced. The sequence indicates that initially the lake was formed in the area followed by a local tectonic uplift leading to increased gradient and drainage reorganization and the lake valley was occupied by high energy river; however drier climate between 22 ka and 10 ka led to the valley aggradations and the fill was incised in response to increased precipitation and water budget after 10 ka. The uplift along the southern margin of the lake reduced the gradient and valley converted into a lake again. The tectonic uplift is younger than 10 ka.

2.8 Cenozoic Fluvial Deposits in Himalaya between Ravi and Ganga Rivers: Interaction of Tectonic and Climate

(Rohtash Kumar and Suresh N.)

Potential linkage of climate with tectonics is an ongoing debate whether rock uplift is in response to tectonics or prevailing climate. Given an intense monsoon during Mio-Pleistocene, topographic variation and rapid tectonic deformation in the Himalayan foreland basin provides an ideal site to address this debate. The Himalayan foreland sedimentary belt has interacted with its hinterland by consecutive re-entrant and salient structures besides the transverse thrust stacking and lineaments. The Late Cenozoic sedimentation in this basin indicates contrasting sedimentation pattern and facies distribution. This variability across re-entrant suggests differential thrust loading in response to the irregular indentation margin has greatly influenced the basin sedimentation in the foreland. The hinterland-foreland sediment transfer is further governed by the characteristic drainage patterns, accommodation space and topographically controlled climatic differentiation between the re-entrant and salient structures. Variable rock

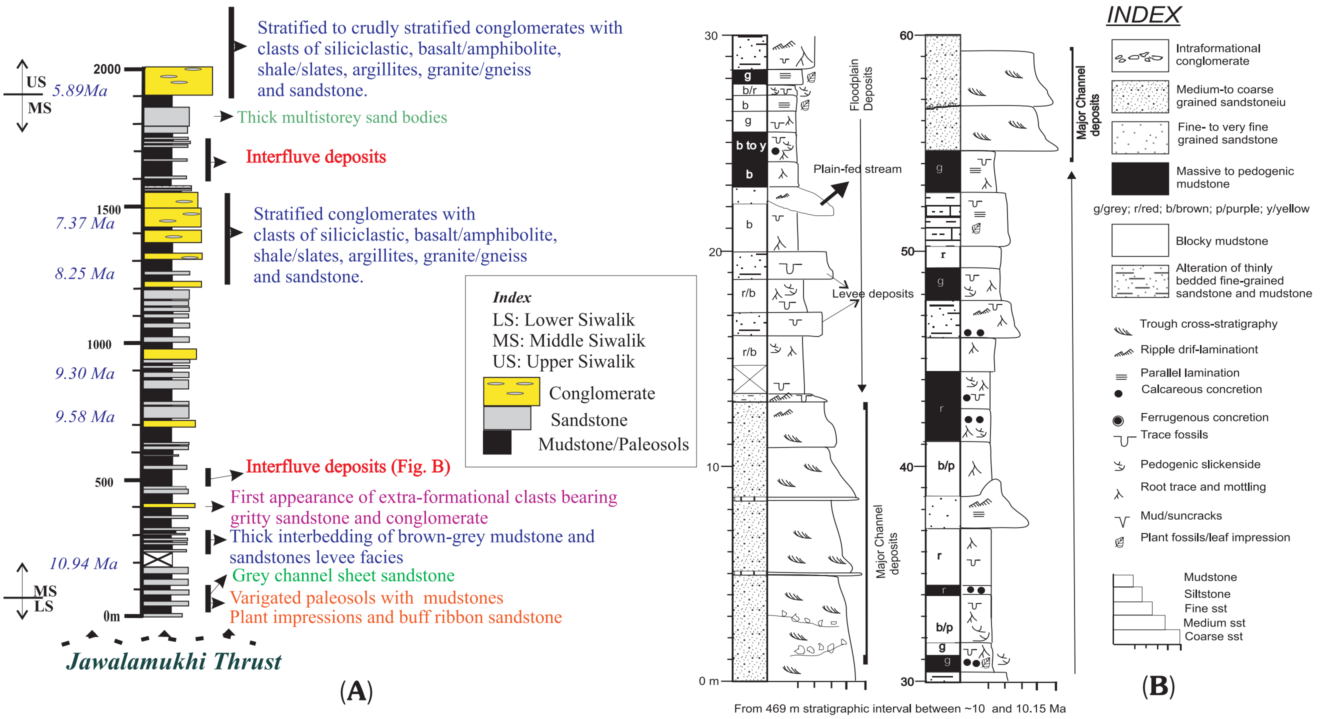


Fig. 14. (**A**) Magnetostratigraphically constrained litholog along Ranital-Kangra section showing important sedimentological features, north of Jawalamukhi Thrust. The first interfluve deposits it observed around 10 Ma coincide with intensification of Indian monsoon, (**B**) Detail of thick interfluve deposit, bounded by thick multistoried, grey sandstone. It comprises overbank mudstone, levee and plain - fed stream deposits.

Fig. 15. Thick overbank deposits punctuated by crevasse splay and levee deposits.

uplift along the strike of Himalayan thrust fold belt is responsible for contrasting fluvial architecture in the Late Cenozoic fluvial sediment succession in the Himalayan foreland basin. However within this tectonic process, climatic variability played an important role on shaping the landscape. For understanding the climatic variation in the tectonic regime, thick pile of overbank or interfluve deposits (in the order of 40 to 80 m) will provide decoupling of these two end members because these are generally subject to sediment starvation, soil formation and moreover deposit on the stable landform.

The interfluve deposits show temporal variation in facies and pedogenic activity (Fig. 14 A&B). These interfluve deposits are bounded by thick sandstone of major trunk river. The interfluve comprises overbank mudstone, levee and crevasse splay (Fig. 15), laccustrine and plain-fed minor stream deposits. This temporal variability in facies and their architecture suggest several cycles of aggradation and degradation which are associated with variations in precipitation. For understanding the temporal climatic fluctuation, detail work is in progress.

MMP 3 : Biostratigraphy & Biodiversity-Environment Linkage

3.1 Evolution - Radiation and Extinction of Bioevents in the Cambrian –Ordovician successions of the Zanskar – Spiti Himalaya, their relation to Global Event Stratigraphy

(S.K. Parcha)

Through fieldwork in Pin section of the Spiti valley and in the Lesser Himalayan regions, data was collected and sections were measured to prepare the litho- and biostratigraphic columns.

Spiti: The entire Paleozoic succession is well exposed in Spiti region of the Tethys Himalaya. The Kunzum La (= Parahio) Formation of the Cambrian succession consists of siliciclastic deltaic deposits. Many thin carbonate beds with abundant trilobite fossils directly overlie the fluvial facies and represent transgressive systems tract deposits. The cycles are interpreted to have resulted from delta-lobe switching, based on a lack of systematic stratigraphic changes in cycles and facies thicknesses. Trilobite bearing limestone beds represent thin transgressive systems tract deposits developed over marine flooding surface. The fauna indicates that the Kunzum La (= Parahio) Formation ranges from uppermost Lower Cambrian to middle Middle Cambrian. The presence of minor carbonate units within the dominantly siliciclastic Kunzum La (= Parahio) Formation suggests intermittent decrease in supply of terrigenous siliciclastic sediments. Trilobite and brachiopod fossils indicate deposition under marine conditions.

Trilobites: The fauna collected from the Kunzum La Formation of the Spiti region particularly in the Pin Valley is assigned to various genera and species. New faunal collections were recovered from the shale as well as from the Carbonate horizons; both the lithologies contain similar taxa. On the basis enlarged trilobite fauna including some new genera, the Kunzum La Formation (= Parahio) Formation ranges from Early to the early Late Cambrian in this section.

Ichnofaunal analysis

The presence of ichnofossils at this level is important since no body fossils have been reported so far from the Lower Cambrian to early Middle Cambrian successions of the Spiti valley except report of *Redlichia* from the Pin section by Hayden (1904) and latter by Parcha (1996).

The ichnofossil assemblage along with trilobite scratches and burrows recorded from the Cambrian succession of the Pin Valley of the Spiti basin range in age from the Early to Middle Cambrian. The ichnofauna can be assigned to the behavioral categories from Cubichnia, Domichnia, Pascichnia, and Fodochina. It seems that in the Early Cambrian succession of Pin section of the Spiti region there is a stratigraphic increase in abundance and diversity of ichnofossils. The ichnofossil assemblage indicates a high behavioural diversity ranging from suspension to deposit feeders.

3.2 Palaeobiology of the Neoproterozoic - Early Cambrian sequence of inner and outer carbonate belt with reference to its implications for evolution of life and global significance

(Meera Tiwari)

The animal evolution during the Neoproterozoic- Cambrian period is demonstrated by occurrences of microbiotic remains and molecular evidences. Different records of fossils including bilaterians, non- bilaterians and protists clearly indicate the root of the metazoans within the Proterozoic. Among these, bilaterians are significant for their diversity, non- bilaterians such as cnidarians and sponges for ecological tiering and protists as vital element of the food chain (Butterfield 2001; Lipps 2001; Clapham and Narbonne 2002; yuan *et al.* 2002). Soft bodied animals appear as Ediacaran fossil record in the Terminal Proterozoic (Glaessnner 1984). Animal phylogeny indicates that sponges or stem-group sponges must be among the earliest animals. McCaffrey *et al.* (1994) reported the presence of stem group sponges in the lower Neoproterozoic rocks. However, the fossils of crown group sponges occur much later in the geologic history. Earliest sponges of early Ediacaran age have also been documented from phosphorite of Doushantuo, south China (Li *et al.* 1998), whereas those of the late Ediacaran age have been reported from the lowest skeletal fossil horizon in Mongolia (Brasier *et al,* 1997), and from the Neoproterozoic Ediacara fauna of South Australia (Gehling and Rigby 1996). In India, sponge spicules of early Ediacaran affinity are known from Gangolihat Dolomite (Tiwari *et al.* 2000). Early Cambrian records of sponge spicules are known from South Australia, China, North America, Soviet Union, Siberia and India (Rigby 1987; Bengtson *et al.* 1990; Gruber and Reitner 1991; Brasier, 1992; Rozanov and Zhuravlev, 1992; Brasier et al. 1993; Steiner *et al.* 1993; Zhang and Pratt 1994; Tiwari, 1997, 1999; Mazumdar and Banerjee, 1998). These finds of fossil sponges with hexactinellid and monaxons spicules from Proterozoic and Cambrian rocks suggest that sponges with simple spicular morphology appeared in Proterozoic and then evolved into more complex forms during the Early Cambrian.

Exceptionally well-preserved but isolated hexactinellid and monaxon sponge spicules are described from samples collected from green shale and pink limestone of the Chhera Member of Gangolihat Dolomite exposed near village Chhera on Chandak- Chhera road in Pithoragarh area. Spicules in siliceous sponges occur either as fused spicules forming rigid skeleton or as scattered spicules forming non-rigid skeleton. The fossil record of non-rigid skeleton is poor because after the death of an animal scattered spicule drop out of the decomposing soft tissues and spread within the sediments as isolated spicules. Due to this, their phylogenetically interpretation is problematic. Besides, individual sponges produce more than one spicule form. In hexactinellid sponges, which are considered to be the most ancient metazoans, the skeleton consists of six-rayed siliceous spicules and an axial canal which is always square-shaped in cross section. In the present collection, the spicules are all hexactinellid with few monaxons. They are found as dense spicular accumulation looking like an accidental, dense accumulation of riotously arranged micro-hexactinellid and monaxons in a mat-like pattern with indefinite orientation. Some of the isolated spicules suggest that the mat-like structure is made up of micron –sized hexactinellids, polyactins and probably some monaxons. The spicule rays are slender and straight with pointed ends. Because two size ranges of spicules are present, it seems a differentiation into mega and microscleres might have been present at an early stage. Characteristically, these spicules are simple, small, and thin bearing straight rays, and spicular framework could not be build due to their scattered nature. Under the SEM these spicules clearly show hexactinellid morphology. Such small structures are unknown in the fossil record. A comparative study of sponge spicules recovered from the Gangolihat Dolomite and other Cambrian successions shows that the size range of isolated hexactines from Gangolihat Dolomite is much smaller (8 to 150μm). Their small size, perhaps, indicates that we are dealing with fossils of small ancestral sponges. Their occurrence as dense mats within the rocks, suggests that these mats may have formed immediately after decay and decomposition of sponges on the ocean bottom. As no such small hexactinellids were previously reported, the sponge spicules described here contribute significantly to the evolutionary history of the metazoans. Further, they provide an evidence for metazoan silica biomineralization in the fossil record and support the concept that hexactinellids evolved rapidly into more complex forms during the Early Cambrian; demosponges and calcareans diverged in the Atdabanian (Reitner and Mehl, 1995: Xiao et al. 2004). Hexactinellid sponges are exclusively marine and generally found in the deep ocean at 450 to 5000 meters depth.

3.3 Inner Lesser Himalayan Carbonate Belt: Biostratigraphy, Biodiversity and Time-Space-Environment relationship with the Krol Belt

(R. J. Azmi, S.K. Paul and D.K. Misra)

Micropaleontological investigations were carried out on samples collected during the field work from the Chamba Syncline (Muchhetar Magnesite of Chamba Formation, Salooni and Kalhel Formations), Dharamkot Limestone of Dharamsala) and Sataun Limestone near Paonta Sahib (latter two belonging to the *Inner Carbonate Belt*), and also from the Krol Limestone of Nainital Syncline and Tal Phosphorite of Mussoorie Syncline (*Outer Carbonate Belt*) of the Lesser Himalaya. In addition, a few samples from Birmania Phosphorite and Dhanapa Formation (Bilara Group) of the Marwar Supergroup (the Trans-Aravalli Vindhyan) and also from the Jhamarkotra Phosphorite of the Aravalli Supergroup were investigated for microfossils.

Microfossils recorded, for the first time, are as follows: 1) Pentacrinid crinoids stems and plates of possible Lower Triassic age from the Kalhel Limestone of Chamba Syncline, 2) PЄ-Є boundary SSFs, including the cleavage embryo, from the Sataun Limestone (=Deoban Limestone), 3) Numerous calcified *Girvan*ella algae from the Lower Krol of Nainital, 4) the earliest foraminifera Platysolenites, from the basal Cambrian Lower Tal Phosphorites of the Mussoorie Syncline, 5) PЄ-Є boundary SSFs Cloudina and Blastulospongia polytreta (possible radiolaria) from the Birmania Phosphorite of the Trans-Aravalli Vindhyan (Fig. 16).

It has been observed that the stratigraphic disposition of the Permo-Triassic platformal succession (Salooni-Kalhel Formations) on the Precambrian Chamba Formation (lowgrade metamorphics) is due to the Tethyan transgression in the autochthonous-parautochthonous Lesser Himalayan belt, and thus invoking a nappe mechanism to explain this disposition is not required. This transgression is similar to other short-lived transgressive sequences in the Lesser Himalaya (e.g., Vendian- Early Cambrian, Lower Permian and Late Cretaceous-Early Eocene sequences).

The micropaleontological investigations on the Lower Vindhyan samples of the eastern Vindhyan Basin jointly collected in November 2006 with Prof. Stefan Bengtson of the Swedish Museum of Natural History, Stockholm succeeded and yielded startling results. Almost identical Lower Cambrian shelly fossils have been recovered in both the laboratories: Swedish Museum of Natural History, Stockholm and the Wadia Institute of Himalayan Geology, Dehra Dun. Bengtson and his team have reported their findings in the *Geological Society of America* meeting held in Denver (*GSA Convention 2007*, Abstract, p. 331). The report confirms the occurrence of fossils resembling Ediacaran-Cambrian age in the Lower Vindhyan. However, they have stated, "In view of the strong geochronological evidence for a Paleoproterozoic age of the Lower Vindhyan we need to consider the mounting indications that Paleoproterozoic biota was more diversified than is generally assumed.". From this investigation by an international expert, one point is very clear that Azmi's 1998 Discovery of Lower

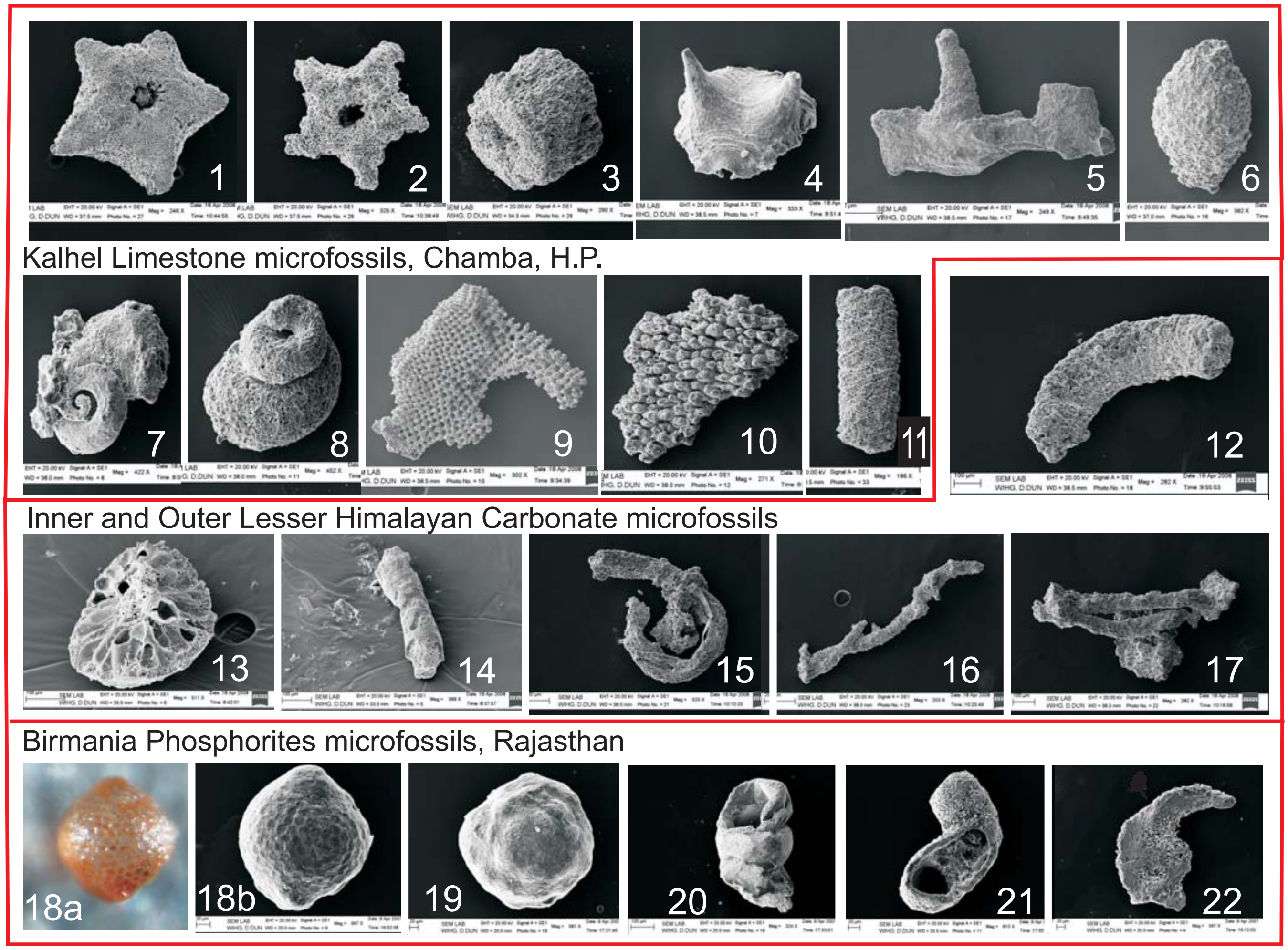


Fig.16. All SEM photomicrographs except **18a** as light photomicrograph. **1-3**, Pentacrinid crinoid plates and stem; **4-5**, conodontophorid elements; **6**, Legenodosarid foraminifera; **7-8**, microgastropods; **9-10**, Bryozoan zoaria; **11**, *Nodosaria* sp.; **12**, *Platysolenites*, the earliest Cambrian foraminifera, Lower Tal Phosphorite, Maldeota; **13**, Internal detail of a cleavage animal embryo, Sataun Limestone (=Deoban Formation); **14**, Annulated tube with a neck-like protrusion, Sataun Limestone; **15-17**, *Girvanella*-like calcareous algal tubules, Lower Krol, Nainital; **18a** & **18b**, cf. *Blastulospongia polytreta* (a possible radiolarian); **19**, *Archaeooides granulatus* (animal embryo); **20**, *Cloudina*, a double-walled flexible tube, **21**, Hollow tube with granular outer surface with initial bulbous chamber (a possible foraminifera); **22**, Internal mould of a *Mongolodus* protoconodont apparatus entirely consisting of hexactine sponge-spicules.

Cambrian fossils from the Lower Vindhyan and subsequent similar fossil reports by Azmi and his co-workers have substantial ground for thread-bare discussion on major disparity on the age of the Vindhyan Supergroup based on the geochronological and biochronological methods.

3.4 Terrestrial and aquatic biota from the nonmarine post – Subathu horizons of the Kangra Valley, Himachal Pradesh

(B. N. Tiwari)

Through study of a faunal collection from Subathu Group of Kalakot area, Jammu and Kashmir an aquatic artiodactyl *Indohyus* has been found to be closest sister-taxon, that is, ancestral form to the Recent cetaceans popularly known as whales; it was elaborated in an article in December 20, 2007 issue of *Nature*. This finding revises the earlier notion that whales are descendant of the land dwelling mammals and reveals that whales' clade originated on the northern sea shores of the Indian subcontinent that was transformed into the Himalaya in succeeding geological events.

Fossil fish assemblages from Siwalik (Mohand) and Dharmsala exposures, characterized by their otoliths and exotic cyprinids, were the subject matters of intense studies and presentations; while record of otoliths is their discovery from Siwalik Group of India, Dharmsala cyprinids reveal establishment of hydrographical link between south Tibetan region and Dharmsala Basin on southern flank via Ladakh Molasse area through a descending stram or a combination of streams from higher to lower altitude in early Miocene.

Ongoing study on fossils from Vastan Lignite mine enables to record and describe early Eocene Primates and Rodentia in two publications in national journals; dental morphologies being never-described-before category have been described as new taxon as per established norms of the vertebrate paleontology.

Chara gyragonites representing certain new form-genera (*Tectochara merianii*, *Chara pappi*, *Chara globularis* with a distinct unnamed *Tectochara* sp.) have been identified and thus added to the known chara assemblage from the Dharmsala Group.

3.5 Biotic, mineralogical and geochemical investigations of Early Tertiary sequences of the NW Himalaya with reference to India-Asia collision

(K. Kumar, N.S. Siddaiah and Kapesa Lokho)

The early Tertiary sediments in the Outer NW Himalaya are represented by the dominantly marine and richly fossiliferous Subathu Group and the overlying poorly fossiliferous Murree Group and its coevals. The Subathu Group consists of carbonaceous shales with coal seams, volcanic ash beds, carbonates, shales, evaporites, granulestones, ironstones, siltstones and sandstones. Richly fossiliferous coevals of Subathu group are also known in the western India. All these early Tertiary sediments are important for studying biodiversity-environment linkage.

The chert breccia and the host Sirban limestone that underlie the Subathu Group in Kalakot section (Jammu & Kashmir) were studied for their mineralogical and geochemical characteristics. The chert breccia is 2-3 m thick, occurs at the upper contact of the Sirban Limestone and below the silty and carbonaceous shales of the Subathu Group. It is bedded and shows fining upward nature. It consists predominantly of cherty pebbles in a siliceous and clay matrix. Both fragments and matrix consists of microcrystalline quartz and display undulatory extinction. The chert breccia consists essentially of 90-92 wt % SiO_2, and minor amounts of Al_2O_3 (3.0 wt %), K_2O (0.21 wt %), TiO_2 (0.21 wt %), Fe_2O_3 (0.59 wt %), CaO (0.15 wt %) and LOI (1.4 wt %), with very low concentration of trace elements (Zr = 91 ppm, Nb = 6.4 ppm, Sc = 3 ppm, Y = 22.5 ppm). The trace element compositions are typical of sedimentary rock, and the clasts are penecontemporaneous with the matrix. The host rock for breccia is limestone with minor silica (13 wt %) and high loss on ignition values (34 wt %), and high Sr (600 ppm) content. In the past there was a view that the chert breccia may be pyroclastic in nature. However, the mineralogy and geochemistry of the chert breccia does not support this view.

The ongoing study of evolution of underwater hearing in Eocene whales (cetaceans) was continued. Fossil data were compared with data on several families of modern mysticete and odontocete whales as well as non-cetacean mammals. Results showed that the outer ear pinna and external auditory meatus of land mammals were functionally replaced by the mandible and the mandibular fat pad in whales. Changes in the ear include thickening of the tympanic bulla medially, isolation of the tympano-periotic complex by means of air sinuses, functional replacement of the tympanic membrane by a bony plate, and changes in ossicle shapes and orientation. Pakicetids, the earliest whales (Archaeoceti), had a land mammal ear for hearing in air, and used bone conduction underwater, aided by the heavy tympanic bulla. Remingtonocetids and protocetids were the first to display a genuine underwater ear, where sound reached the inner ear through the mandibular fat pad, the tympanic plate, and the middle ear ossicles. Basilosaurids and dorudontids showed further aquatic adaptations of the ossicular chain and the acoustic isolation of the ear complex from the skull. The land mammal ear and the generalized modern whale ear are evolutionarily stable configurations, two ends of a process where the cetacean mandible might have been a keystone character.

Find of a new ailuravine rodent, *Meldimys musak*, sp. nov. (Ischyromyidae) from the lower Eocene sediments constitutes the oldest record of Rodentia from India. *M. musak* corresponds closely to the middle early Eocene species *M. louisi*, which lived about 52 Ma in Western Europe. *Meldimys* was previously known only from Europe and the ailuravine rodents only from Europe and North America. The occurrence of *Meldimys* in India allows the first direct correlation between the early Eocene land mammal horizons of Europe and India, and raises the possibility of a terrestrial faunal exchange between India and Eurasia close to the Paleocene-Eocene transition. Contrary to the earlier belief based on data from sub"Himalayan localities in India and Pakistan, the oldest fossil rodents from India belong to the cosmopolitan Ischyromyidae rather than to the endemic Chapattimyidae, and so far there is no evidence to know whether these two groups lived together at any point of time.

3.6 Himalayan Paleozoic Trilobites

(S.K. Parcha)

In the Cambrian successions of the Tethyan Himalayan regions, polymerids and agnostid are the main trilobite taxa which are of paleoecological significance for interpreting the depositional history of Cambrian sequences. In the Lesser Himalaya only Lower Cambrian successions yield substantial data. Kashmir and Spiti basins yielded good population of polymerids, whereas the Zanskar Basin contains good record of agnostids as well as polymerids. The trilobite fauna so far collected from the Tethyan and the Lesser Himalaya mostly belongs to Middle Cambrian. However, there appears a distinct difference in its spatial distribution in Kashmir, Spiti and Zanskar basins of the Tethyan Himalayan and the Lesser Himalayan regions. Although along the Cambrian successions of the Himalayan belt, trilobite faunal ranges are variable but a considerable percentage of similar taxa exist throughout the belt. The studies reveal that the faunal distribution is not uniform in all the Tethyan sub-basins; and some faunal gaps at different intrasystem boundaries have been recorded.

3.7 Biostratigraphy of Nagaland, Manipur, Mizoram and Arunachal Pradesh with special reference to Paleoecology and Paleogeography, and a comparative study with NW Himalaya

(Kapesa Lokho)

Collection of fossil pteropods (Thecosomata, holoplanktonic Mollusca) including some unidentified species, provisionally referable to the families Limacinidae, Creseidae, and Cliidae (?) is reported from the late Middle Eocene-Late Eocene beds of the Upper Disang Formation exposed near the town of Pfutsero in the Phek District of south central Nagaland (Assam-Arakan Basin, north-eastern India). This is the first record of fossil pteropods from this part of India. Although based exclusively on juvenile or incompletely preserved adult shells, the documentation of this collection is important from the viewpoint of biostratigraphy as well as palaeoecology (Fig. 17).

Various views on the palaeoenvironment of the Disang Group are published, with one school of thought regarding it as a deep water geosynclinal facies and another considering it a shallow distal shelf to deltaic facies. Recent reports on well-preserved uvigerinid foraminifera, from the same horizons and localities that yielded the pteropods, have provided definitive evidence on the depositional environment of the Upper Disang Formation. The combined assemblages of pteropods and previously reported uvigerinid foraminifers from the Upper Disang Formation indicate a palaeobathymetry of ~500 m, i.e., upper bathyal zone, and a tropical-subtropical climate. The interpretation as an anoxic set up was based on the morphology of some cosmopolitan uvigerinids and their dominance. The occurrence of pteropods in the Upper Disang Formation indicates deposition in an open marine basin above the aragonite compensation depth (ACD).

The ongoing microfossil investigation of Bhubhan Formation in Kolasib and Aizawl Districts of Mizoram is yielding a significant result in view of biostratigraphy and paleoenvironment.

Reconnaissance survey for microfossils has been carried out in parts of Changlang District in Arunachal Pradesh where Tertiary rocks are exposed.

MMP 4 : Sustaining Natural Resources

4.1 Mineralization and metallogeny in space and time in context of diagenesis, magmatism, metamorphism and tectonism: special emphasis on the role of complex fluids in the genesis and evolution of host rocks and ores in Uttarakhand and Himachal Himalaya.

(R.S. Rawat)

Petromineralogical and experimental studies were carried out (Homogenisation/ quenching Experiments) including experimental starting material preparation from natural rocks and minerals. Stress was given on homogenization-quenching experiments at 1050^0C for 48 hours duration and then their XRD studies.

Granites samples ranging in space and time with alkali feldspars of low structural state (intermediate to maximum microcline) were subjected to a variety of studies. The samples were subjected to melt temperature determination of the granites through homogenization-quenching experiments in the Experimental Petrological Lab. These samples were run through different conditions of slow scanning so that the peak separations were contrastingly seen in the diffractrogram i.e. the peak of internal standard and the homogenized alkali feldspar sample should be resolved properly so that a proper interpretation is carried out. In each experiment, it is observed that prior to the homogenization at 1050^0C in 48 hours duration, the white alkali feldspar (microcline) changed to flesh coloured (orthoclase) after the homogenization experiments, indicating the phase transformations in the feldspar i.e. from a low temperature (low structural state) to a high temperature (high structural state form i.e. triclinic to monoclinic phase-confirmed through XRD studies). The homogenization experimental studies were carried out on granites occurring in different lithotectonic setups (i.e. the granites ranging in

PROGRESS IN RESEARCH PROJECTS

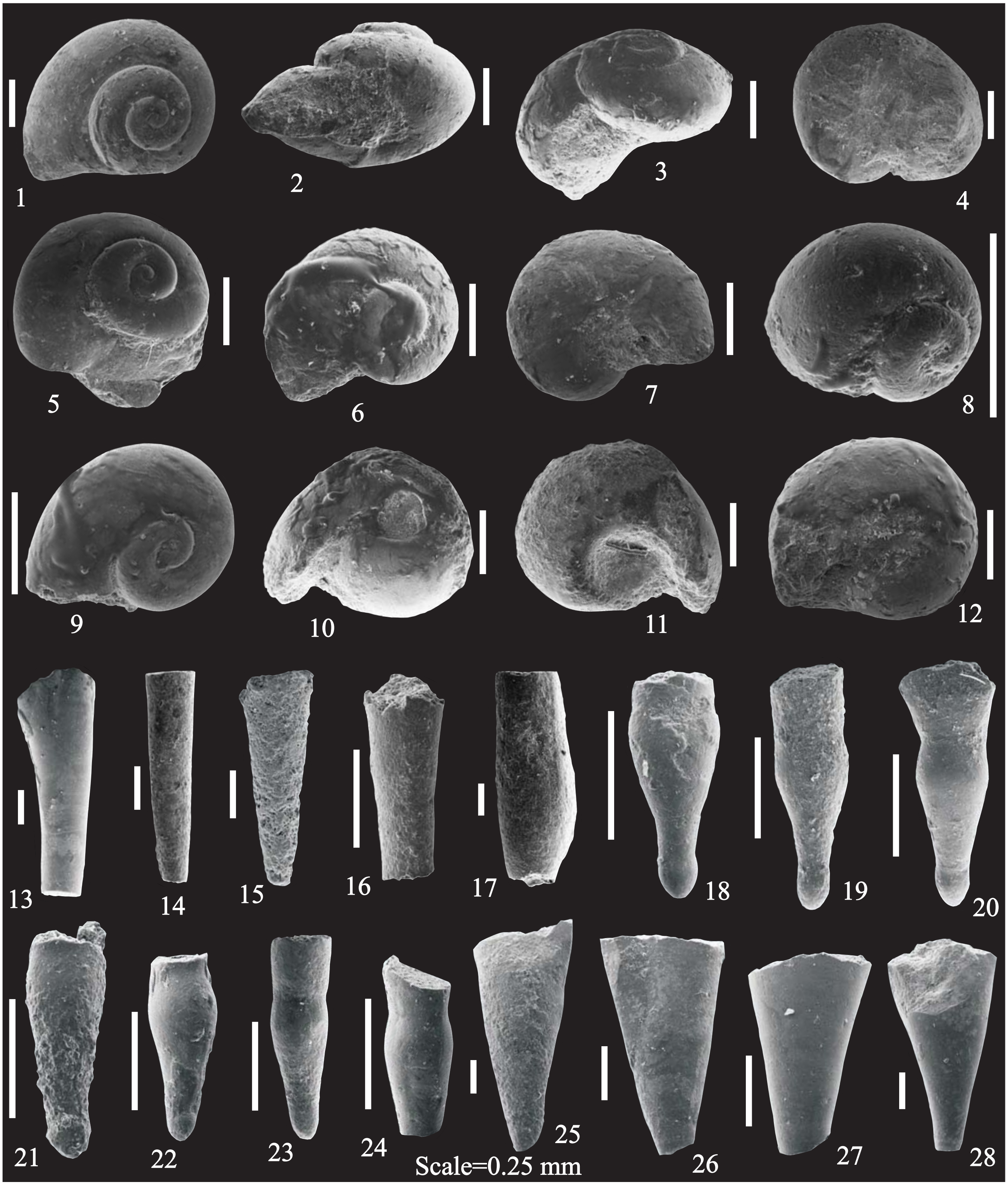


Fig. 17. Fossil pteropods from the Upper Disang Formation, Phek District, Nagaland (Lokho & Kumar, 2008).

space and time), from different Himalayan domains and their studies indicated a temperature of more than 700^0 C for the melt for various granitic bodies.

Further, the study of complex fluids vis-à-vis mineralization revealed that the lithotectonic set up of the area plays a vital role for the potential workable mineralization in a terrain as observed during the short field trip to the Garhwal Lesser Himalaya between Srinagar and Rudraprayag. The field and laboratory studies in the Garhwal and Kumaon Himalaya indicate that the area between River Sharda (Kali) and the rivers Yamuna andTons are potential areas for natural resources, where the mineralization is not only controlled by fluids but also by lithotectonic set up of these areas. In other words, while searching for new mineralization in an area, the relationship between the fluids, lithotectonic set up, deformation, magmatism, metamorphism and environment of deposition of minerals is to be known very well in advance and then only a proper model for exploration can be postulated; only then new mineralizations could be discovered in future. The present study on sulphide mineralization in Uttarakhand State clearly shows that both the syngenetic and epigenetic features as well as the imprints of the Himalayan tectonics are present in the polymetallic sulphides of the area, although the original depositional features are rarely well preserved in the mineralized zones. Further, the tectonic, petro-mineralogical, geochemical conditions, besides the presence of crustally derived fluids are suitable in the Himalayan Orogen and hence this region is a strong candidate to provide a rich store house of natural resources in future.

Field observations, lithotectonic setting, petro-mineralogy, experimental and geochemical characterization of the Amritpur granite series indicate a syn-collsional regime as a result of anatexis definitely in the Precambrian times say about 1880+40 MY) which also further remobilized under fluid rich conditions during 1330+40 M.Y.

4.2 Mineralization and Metallogeny in Kumaon Region, Uttarakhand

(Rajesh Sharma and D. Rameshwar Rao).

A zone of sulphide mineralization has been noticed recently along the North Chiplakot Thrust, about 100 m north of village Gasku. The North Chiplakot Thrust forms the boundary here between southerly located Chiplakot Crystalline Belt and the Berinag Formation occurring to the north of the thrust. Malachite, limonite and minor cuprite are seen at the outcrop over a width of about 300 m (Fig. 18a). The mineral assemblage observed under the microscope includes pyrite, chalcopyrite, pyrrhotite, sphalerite galena, secondary malachite, azurite and covelite, whereas quartz forms the ubiquitous gangue mineral. This mineralization is present in the intensely folded sericite-muscovite-talc-chlorite-biotite schists of the Chiplakot Crystalline Belt. Mineralized quartz veins, which occur both parallel to schistosity and cross-cutting/ oblique in nature are also present in these schistose rocks. In addition, amphibolites are present along the thrust, and the sulphide mineralization is observed in the quartz veinlets filling fractures in this amphibolite. Limited ore petrography shows exsolved blebs of pyrrhotite in chalcopyrite and the characteristic sphalerite stars in chalcopyrite, suggesting high temperature complex solid solutions of the sulphide minerals.

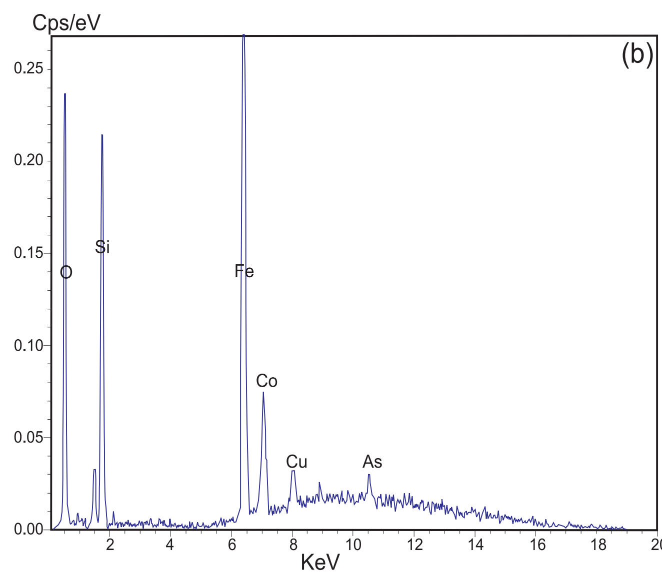


Fig. 18 (a) Field photographs showing occurrence of mineralized zone near Gasku, (b) The result of the SEM-EDS analysis of surface weathered sample from mineralized zone near Gasku. Presence of Fe, Cu, As and Co is evident.

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The SEM-EDS analysis of the surface weathered samples of host schist from near Gasku have been carried out using Bruker-make EDX equipped with LN_2 free SDD X flash 4010 detector and Zeiss EVO-40 EP microscope at the SEM laboratory of WIHG. The results show presence of Cu, Fe, Zn, Pb, and As in the weathered zone of sulphide mineralization (Fig 18b). Indication of the presence of minor Sn is also noticed in one record. Cu and Fe with distinct peaks are most frequent of these elements. The specks of sulphides are also noticed in the in-situ granitic gneiss of the Raunaq Nala area.

In Raiagar area near Berinag, talc mineralization occurs within Deoban carbonates and the sulphide occurrence was also known here in the carbonate host rocks. Distinct pyrite grains ranging from < 1 cm to about 12 cm collected from the open pits of talc of this area are useful for understanding depositional environment. EPMA analyses of the pyrite show high Mo and Ni and low Co in pyrite. Limited data of sulphur isotope composition of this pyrite present contrasting values of $ä^{34}$ S from -1.8 to +4.3 over short distance. Together with absence of wall rock alteration and the presence of stromatolites these values suggest that the sedimentary syngenetic pyrite was formed from the biogenic reduction of seawater which supplied sulpur for the formation of Raiagar pyrite in shallow water environment.

4.3 Geochemical investigation of soils and stream sediments in the south - east foothills (Pinjaur—Una Dun) of Himachal Himalaya

(P.P. Khanna, N. K. Saini and K.K. Purohit)

Quaternary alluvial fans in the tectonically active Pinjaur Dun, an intramontane valley in the Sub-Himalaya, were deposited in front of the Nalagarh Thrust and influenced both by tectonics and climatic fluctuation. The Pinjaur Dun (~750–280 m above mean sea level) is bordered by mountains (~1300–1800 m amsl) to the north along the Nalagarh Thrust (NT), an imbricate branch of the MBT. Bedrock in the mountains comprises the Cenozoic Subathu, and Dharamsala formations and the Siwalik Group. The Subathu and the Dharamsala formations comprise reddish brown shale, greenish-grey and reddish sandstone and minor limestone, whereas the Siwalik Group consists of brown mudstone, grey sandstone and conglomerate. The southwestern margin of the Dun is delimited by the Siwalik hills (~621 m amsl), which are separated from the Indo-Ganga Plain (_400 m amsl) by the HFT. The HFT is segmented by various NS trending transverse faults and is currently the most active thrust displacing Quaternary deposits (Nakata, 1972, 1989; Valdiya, 1993; Lave´ & Avouac, 2000; Kumar *et al.*, 2002).

46 soil and stream sediments samples covering nearly 80% area of Pinjaur Dun were collected from the Jhajra and Sirsa Nadi catchments. The sampling was carried out at varying densities depending upon varying geomorphic conditions as well as the accessibility. Samples were dried at 110 ^{0} C and screened through 80 mesh standard sieve. Part of the samples were finally ground to about 200 mesh using Tungsten Carbide Mill. Pressed powder pellets were prepared by mixing with 4-5 drops of polyvinyl alcohol as binding agent (Stork *et al.* 1987; Saini *et al.* 2000). Solutions of samples were prepared using acid mixture and open digestion process. Pellets were analyzed using XRF and solutions were analyzed using ICPMS for major, trace and rare earth elements. Few salient features observed are given below.

- Concentration of Ca, Mg, Na, K, Ba, Sr and Rb is much lower than UCCA (upper continental crust average) values indicating their mobile nature. This may also be due to weathering.
- Sediments are enriched in Cu, Ni, Pb and Zn in comparison to the UCCA value. Anthropogenic activity seems to be responsible for their enhancement.
- Concentration of Pb, Cu and Zn is much higher in samples of Jhajra drainage. This is envisaged due to the industrialization. However, mineralization in this area cannot be ruled out. The area needs detailed study.

4.4 Hydrochemistry of Water Sources in the Himalaya: an assessment of quality and chemical weathering

(S.K. Bartarya)

Hydrochemistry of Indus and its tributaries in Trans Himalaya

The Indus with its tributaries Nubra and Shyok are the major rivers draining through Trans Himalaya. The bed rock and tectonic control on the relative abundance of major ions in streams draining the Trans-Himalaya were investigated. The major ion chemistry of Indus, Shyok and Nubra has brought out the following results:

1. The TDS and TZ^+ (Total Cations) in Indus and tributary streams vary from 11 to 443 mg/L (averaging 117 mg/L) and 103 ìEq/L to 5333 ìEq/L, respectively. Both show spatial variations. The TDS and TZ variation demonstrates the significant role of glacier melt in contributing to the major ion budget of the Nubra and Shyok rivers.

2. The major cations trend in decreasing order is

Mg>K>Ca> Na. This trend is different from the source region of Ganga (Sarin et al, 1992) and Yamuna (Dalai et al, 2001) flowing through Higher and Lesser Himalayan region.

3. Unlike Ganga and Brahmaputra, the Indus samples show average Ca/Mg molar ratios of 0.4 much lower than the Ganga and Brahmaputra. The likely cause of low Ca/Mg ratio may be supply of excess Mg through dissolution of calcareous rocks like cherts and limestone present in the Indus, Nindam and Lamayuru formations in Indus valley, and limestone and dolomite in Margo formation, Saser Brangsa and Saltoro formation in Shyok and Nubra valley. Low Ca/Mg can also result from preferential removal of Ca from river by precipitation (as calcite).

4. Dissolution of pyroxene, amphiboles and olivine from basaltic and ophiolitic rocks may also support relatively higher Mg and SiO_2 concentrations particularly in Shyok and Nubra rivers where their concentration is ~ 25 to 30 % of the TDS.

5. The Na:Cl molar ratios suggest contribution of Cl either from marine salt and evaporite dissolution and that minor part of Na is derived from silicate weathering. The contribution from saline lakes and halite in the Indus water and excessive evaporation during summer may also contributete to Cl concentration.

6. The K:Na molar ratios is substantially higher in comparison to Ganga and Brahmaputra indicating weathering of K-rich feldspar present in granite rocks of Ladakh region .

7. The stream waters show mix of carbonate (waters of Shyok nad Nubra) and silicate weathering (waters of Indus river).

Water Quality of Doon Valley

The Bindal, Rispana and Suswa rivers in their lower reaches and bore wells, handpumps and tubewells lying close to these rivers show faecal contamination. Nitrate concentration an indicator of faecal contamination has been found more than 45 ppm, in some of the borewells/ handpumps and is an indication that water would be harmful for drinking. Out of 76 samples tested for total coliform and *Escherichia coli* bacteria, 48 samples turned positive. The total bacteria counts range from 3.1 to > 2400 MPN and E.coli from 1 to 225 and in Rispana it reached >2400 MPN. This indicates that the adjacent shallow aquifers recharged by these rivers are polluted.

4.5 Glaciological studies of Chorabari and Dokriani glaciers: An integrated approach

(R.K. Chaujar. S.K. Bartarya, D.P. Dobhal and P.S. Negi)

Geomorphology and Lichenometry

The work deals mainly with the climate change and its impact on the Himalayan glaciers on the basis of study of the landforms formed by the Chorabari and Dokriani glaciers in the Garhwal Himalaya, and dating of various cycles of their advance and retreat by lichenometry. Besides, satellite data are used to measure the shrinkage of the Chorabari glacier. Landsat and ASTER satellite data from the following years 1976, 1990, 1999 and 2003 have been analyzed.

Satellite data of Landsat TM (1990), ETM+ (1999), and ASTER (2006) were used to identify the terminus of the Gangotri glacier and measure its retreat with respect to the position of snout in a topographical map (1962) published by Survey of India. Position of glacier snout was estimated by comparing its relative position with other features in the field and in satellite images. In addition, position of the snout was also estimated using Global Positioning System during field work in October, 2007. The study has shown that the recession of Gangotri glacier, which was maximum during the period 1962-1990 (46m/year) has come down after 1990. The average recession rate has been found as 20m/year during 1990-2006. ASTER and Landsat Data appear useful to delineate glacier snout that is indicative of glacier recession and advance in remote terrains like the Himalayas.

Melt water Chemistry

The chemical characteristics of Chorabari glacier melt water show that temperature varies from 0.6 to 1.4 °C and average pH varied from 6.6 to 7.3. The electrical conductivity (EC) ranged between 30 and 64 $\mu S\ cm^{-}$. Sulphate and HCO_3 were the most dominant anions in stream meltwater followed by $Ca^{2+} > Mg^{2+} > Na^{+} > K^{+} > SiO_2$. Cl concentration was high in beginning of the measurement period and then decreased as the season progressed. Chloride concentration was at a maximum of 9.0 $\mu molel^{-}$ at the beginning and at a minimum of 1.4 $\mu molel^{-}$. Cl showed increase after rain fall. This pattern of solute concentration variation is consistent with the release of the ion-rich meltwater. The meltwater shows a low concentration of NO_3 and Cl, and relatively higher concentrations of lithogenic ions (e.g., Ca, Mg, K, SiO_2, HCO_3, SO_4). The result shows diurnal variation in TDS, conductivity and SO_4 concentration indicating subglacial water may be the major source of water during the summer.

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Hydrometeorology and snout monitoring

An Automatic Weather Station (AWS) was installed near the Chorabari glacier snout. Hourly meteorological parameters like air temperature, rainfall, relative humidity, wind speed, wind direction, incoming and reflected solar radiation, etc. were collected for the period 25 May to 4 November 2007. Preliminary results show that the maximum temperature recorded during the period was 15.8 ^{0}C (11 July), whereas the minimum temperature recorded was -3.8^{0}C (18 October). Seasonal rainfall is observed to be about 591mm with July recording the maximum rainfall (174 mm). The average day time wind speeds were measured as 1-3-m/s. The wind direction generally flows north to south in the morning and south to north in the afternoon; relative humidity fluctuated between 48% and 88%. Glacier discharge measurement was carried out for the period 1 June to 8 August. These data were analysed and interpreted. The average daily discharge during the study period was calculated as 1.3m^3/s (minimum) and 8.33m^3/s (maximum). The relationship between total discharge, air temperature and rainfall pattern during the study period is shown in Fig. 19. Study of snout retreat measurement was carried out in the last week of October when the melting processes is minimum or negligible and winter snow accumulation commenced. The study shows that the glacier retreated by 09 m in the central part and 7m and 3 m in marginal parts of the both sides of the glacier during the period October 2006 to October 2007.

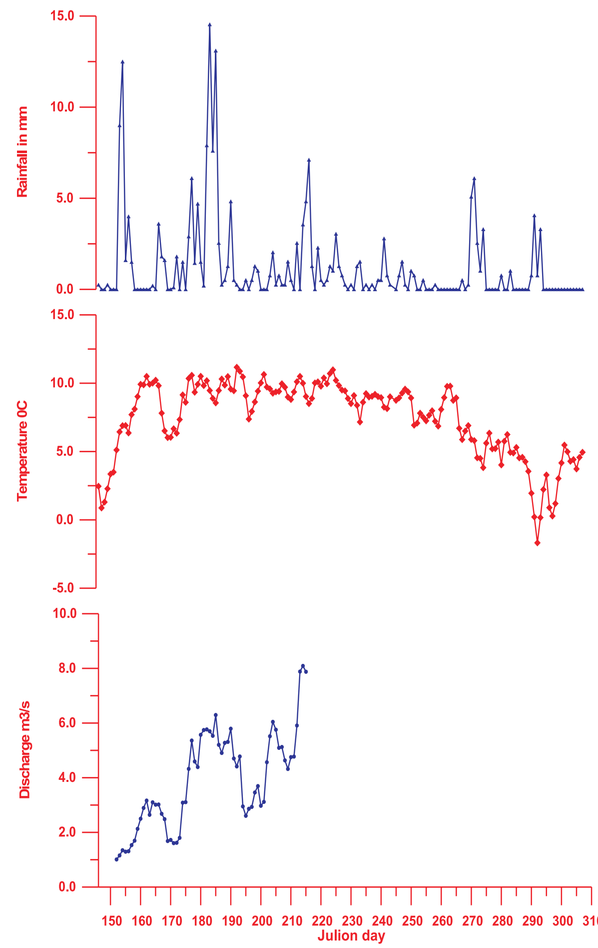


Fig. 19. Relationship between discharge, air temperature and rainfall during summer 2007 at Chorabari Glacier.

Lichenometry (ecological aspect)

Field work was carried out in the month of October 2007 in and around Chorabari glacier. In order to improve the accuracy and reliability of lichenometry, especially with reference to the alpine region of the Himalaya, ecological study of the lichens was carried out. Growth rate of lichens at different aspects of moranic deposits in the snout vicinity was measured and monitored. To explore lesser known lichens for sampling, gray colour *Acarospora* was identified due to its dominant spatial distribution and uniform growth pattern. The occurrence of largest, i.e., 274.32 mm thallium of *Acarospora* in snout proximity is suggestive of rapidly changing habitat and ecological condition associated with deterioration of glacier resource. The OSL technique based on quartz mineral dated same moranic deposit between 800 to 1100 years old before present; diversity in OSL data is attributed to the presence of deposits related to different temporal characteristics. During the year 2003- 2007 the variability in growth and development of lichen thallium at different aspects measured between 0.56 mm/year and 0.84 mm/year. The growth variation at Southern, Northern, Eastern and Western aspects is indicative of influence of microclimatic variability over a period of time. It is evident from above that aspect factor has a profound influence on lichen growth and needs to be considered for precise dating. It is a well known fact that lichen ecology is poorly understood globally, especially the alpine Himalayan terrain, and therefore refined knowledge of it is likely to improve the accuracy of the technique decisively.

4.6 Mass Balance studies of Dokriani and Chorabari Glaciers, Garhwal Himalaya

(D.P. Dobhal)

In continuation of mass balance study of Chorabari glacier, field measurement was carried out during the year. The net accumulation and ablation was measured by snow pits and stakes networking. These data were analysed and a mass balance map for the year 2006-07 prepared (Fig. 20). During the period 2006-07, net annual balance was calculated negative (-) amounting to $4.54x10^6 m^3$ of water equivalent with specific balance of (-) 0.77m. The ELA found at altitude of 5055 m was compared with ELA altitude 5050 m in 2006. The ablation processes in different surface features, thick debris, thin debris covered and debris free area show significant differences in melting over the debris layer. The total melting in the ablation zone during the entire ablation period is larger in the upper ablation area where the glacier surface is either thinly covered with debris or is debris free. It is believed that the presence of supraglacial debris strongly influences glacier ablation in similar climatic setting.

Mass balance measurement for Dokriani glacier was initiated in 2007. A network of 20 stake in the lower ablation area and 10 stakes along the centre of the glacier in upper ablation area were made. In October (end of the ablation period), the upper area of the glacier was entirely snow covered and it was not possible to measure ablation stakes in the upper ablation area as well as net accumulation for the period. Due to non-availability of adequate ablation and accumulation data, net mass balance of Dokriani glacier was not calculated during the year.

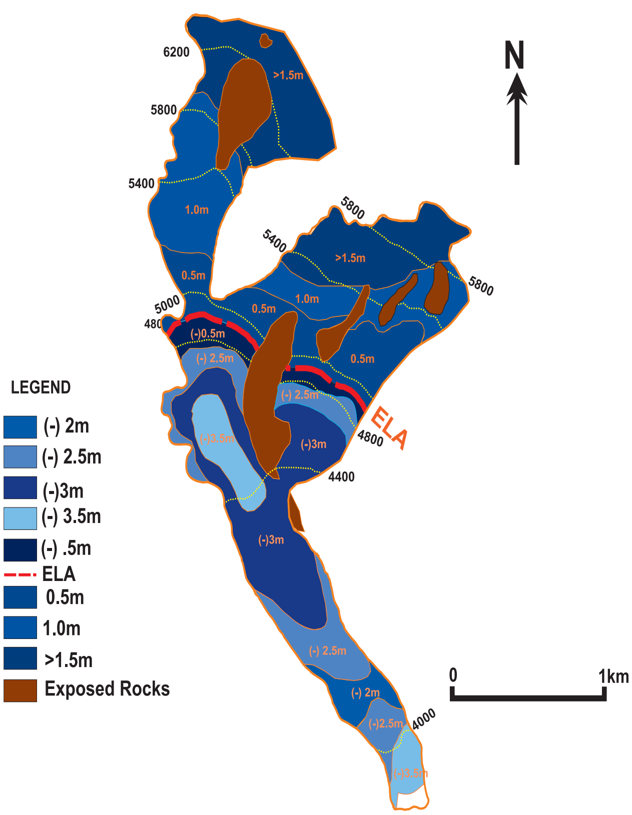


Fig. 20. Mass balance (accumulation and ablation) map of Chorabari Glacier, 2006-07.

MMP 5 : Real Time Geology for Society: Coping with Natural Hazards

5.1 Study of Active Faults and Neotectonic Activity in parts of Himachal and Uttarakhand Himalaya between Himalayan Frontal Thrust and the Main Central Thrust.

(G. Philip, S. S. Bhakuni, and N. Suresh)

During the year selected parts in the Himalayan Front, Pinjaur Dun, Western Doon valley, and Soan Dun were taken up for the study of active faults.

Frontal Himalaya

A new active fault, which is oblique to the Himalayan Frontal Thrust (HFT), has been recognized in the northwestern Frontal Himalaya near Kala Amb, Himachal Pradesh. Topographic features across the fault suggest long-term uplift/deformation history along the fault. The cumulative slip along the fault reflects the manifestation of normal faulting with a strike slip component. The fault is located west of the already reported active fault, Singhauli Active Fault, which traverses through the Middle Siwaliks exposed on the hanging wall of the Himalayan Frontal Thrust (HFT). This fault is traceable for over 4km, of which the western half trends NE-SW while the eastern half trends in E-W direction. The western half merges in the piedmont alluvium in the south while the eastern segment fades away further northeast in the Siwaliks. The fault is steeply dipping due N and its southern upthrown footwall is in contrast to the prevalent northside up movement along the HFT. The displacement along fault has also caused shifting of drainage channels of major and minor streams. Observation along a number of N-S oriented streams draining into the piedmont zone has revealed clear-cut exposures of the HFT on the surface. This observation once again negates the so far propagated opinion that the HFT is a blind thrust and no surface rupture is associated with major or great earthquakes that have occurred along the Himalayan Front.

Pinjaur Dun

Morpho-structural analysis using Indian Remote Sensing Satellite data and selected field investigations helped in delineating prominent traces of active fault systems in the area. Significant number of Quaternary deformation features is observed in the Pinjaur Dun. A trench excavated across one of the fault systems in the Pinjaur Dun indicates reverse faulting in the Quaternary sediments with a two meter vertical displacement which substantiates large magnitude

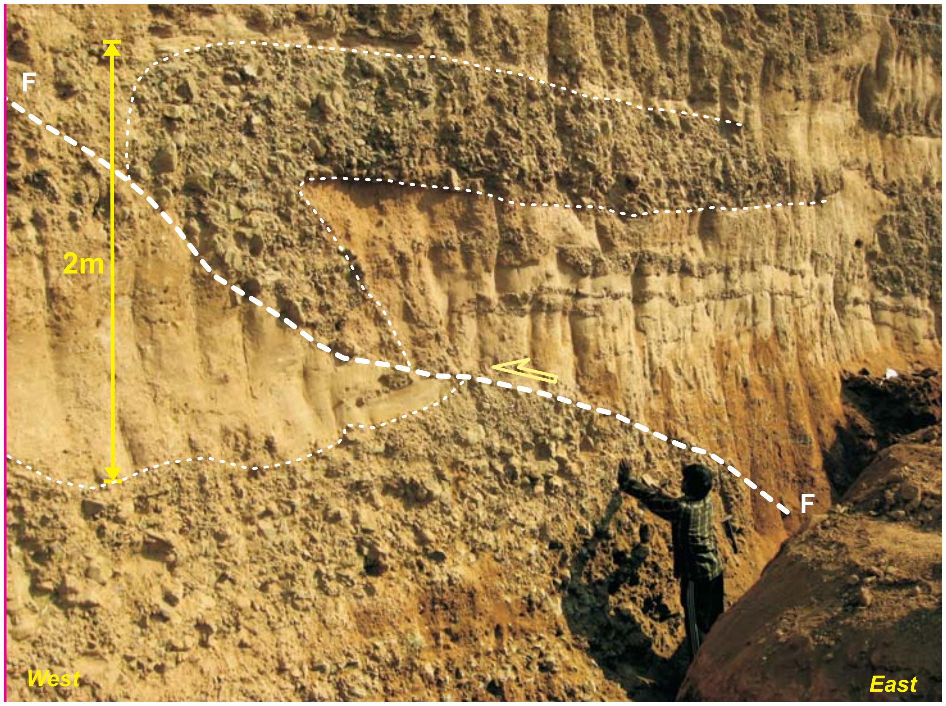


Fig.21. Reversely displaced (2m vertical) and folded Quaternary sediments in the trench wall of an active fault (F-F) in Pinjaur Dun.

earthquakes rupturing the Frontal Himalayan (Fig.21) region in the recent past. OSL samples are being dated to further establish the chronology of the Quaternary deposition and to infer their deformation history due to interrelated past seismic events.

5.2 Engineering Geological Characteristics of rock mass in the Satluj and Alaknanda valleys

(Vikram Gupta)

Engineering geological mapping of the Alaknanda valley was carried out using geological strength index, unconfined compressive strength, point load index and Schmidt hammer rebound values. Various physical, mechanical and acoustic properties of the different rocks were investigated and their interrelationships established.

In general, it was observed that there is a positive linear relation between density and the acoustic wave velocities and the mechanical strength of rocks. However, there are some anomalies that may be related to the anisotropy in the rocks. It has further been noted that the acoustic wave velocities are also affected by the weathering of rocks, rocks with high grade of weathering exhibit lower wave velocity than the rocks with low grade of weathering.

Schmidt hammer rebound (R-) values for all the rock types encountered in the valley between Badrinath and Rishikesh has been measured in the field and the R-value for each rock type were correlated with the unconfined compressive strength (UCS) measured in the laboratory. The preliminary results suggest that the relationship established between the R-value and the UCS is well correlated the results from other workers from around the globe. It was also observed that within the same lithology, the rocks exposed at higher altitudes exhibit lower R-value, thus indicating that the rocks located at higher altitudes are more weathered as compared to the rocks at lower altitudes.

The study further establishes the positive linear relation between density and UCS, R-value and UCS, R-value and ultrasonic wave velocities, and Young's modulus and UCS, and the negative relation between Poisson ratio and R-value. The study is continuing in order to establish the stochastic relationship among the various physical, mechanical and acoustic properties studied.

5.3 Study of palaeo-mass movements in relation to climate change and neotectonic activity in the Satluj valley, Himachal Pradesh

(M. P. Sah and Vikram Gupta)

In the Satluj valley between Rampur and Khab, and in the lower Spiti valley between Khab and Sumdoh, past river blockades have been identified. Morphological mapping of the Sumdo- Khab section along the lower Spiti valley was carried out and the emphasis given to know the control of Sumdoh Fault on the geomorphic evolution of the lower Spiti valley between Khab and Sumdo. The geomorphic evidences and Quaternary deposits in this section clearly indicate that Sumdo Fault has a major role in shaping the landscape.

Elongated and narrow drainage basin on the eastern half of the lower Spiti valley indicate fast vertical uplift of the Leo Pargil horst as compared to the rectangular and dendritic pattern developed on the western graben block. The rectangular pattern indicates the structural control on the drainage system. It was observed that Sumdoh Fault has oriented the channel course of river Spiti in north-south direction in this section of the Spiti valley.

An attempt was made to identify the facets developed due to the fault activity and development of lateral drainage basin along Leo Pargil horst. Analysing the topographic maps and field data, there are four major sets of facets occupied by four generations of drainage basins. The total relief of the oldest, i.e.,1st drainage basin is 3700 m while 2nd, 3rd and 4th have 2600 m, 1300 m and 600 m from the local base level taken at Khab, the confluence point of Spite and Satluj river. The four distinct slope brakes indicate the relative height of facets from 1st to 4th is 1300±170, 800±130, 1400±180 and 500±20 (Fig.22). The upper 1st and 2nd facets are relatively flat covered by glacial deposits brought down by valley glaciers from the Leo Pargil as compared to lower 3rd and 4th facets which are relatively steep and have sections of lacustarine and fluvial sequences of Quaternary age. Considering the total relief of 3rd and 4th facets and the presence of lacustarine and fluvial deposits in this section, the Quaternary uplift along the Leo Pargil horst is approximately 2000 m.

The occurrence of river terraces at Sumdo, Chango, Salkhar, upslope of Leo, downslope of Yangthang, Ka, and benches on the left bank of river Spiti indicates the sequence of shifting of channel course during the Quaternary period.

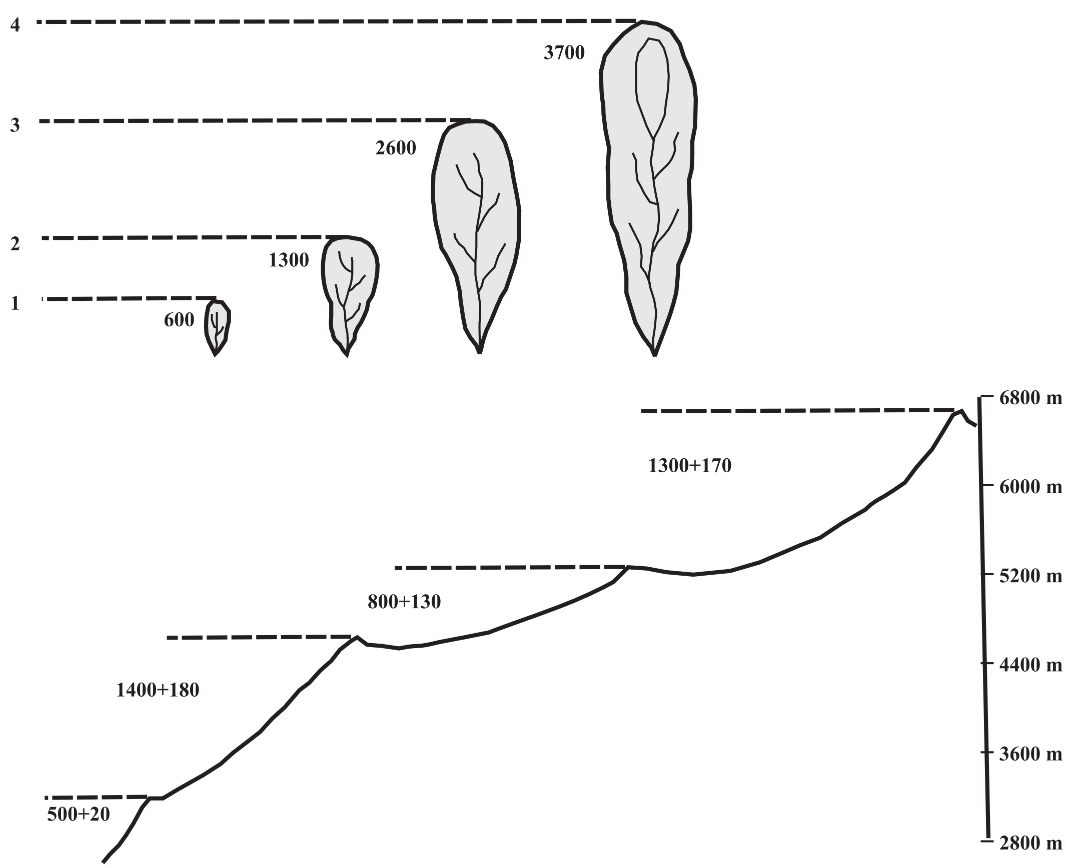


Fig. 22. Triangular facets in relation to Sumdoh Faults and the Channel development

5.4 Evaluation of structural features and their relationship with mass movement, Uttarakhand Himalaya

(*K.S. Bist*)

Studies were carried out in Yamuna valley for the Basan slip zone and adjoining region, a part of the Lesser Himalaya in Yamuna valley where two main lithotectonic units viz Lesser Himalayan sediments and Siwaliks and Doon gravels of Outer Himalaya are exposed. The Lesser Himalayan sequence is thrusted over the Siwaiks and Doon gravel towards south along the Main Boundary Thrust (MBT), the main regional tectonic feature in the area. The lithology of the area is mainly quartzites and phyllites of the Damta Group of the Lesser Himalayan sequence which is highly crushed and fractured due to its close vicinity to the Main Boundary Thrust (MBT). The general attitude of the rocks is N80^0 W – S80^0 E with their dip varying from 40^0 to 45^0 due North East. In general, the rocks are dipping into the hill against a moderate to steep southerly dipping hill slope of 50^0 to 70^0 towards the valley. The rocks are covered with thin Quaternary material consisting of pebbles, sand, silt and clay particles.

The area is having dissected hill and rugged topography with gully erosion on the slopes. Several first order streams / rills were developed during the monsoon season which brings the high amount of debris from the scarp as well as from the sides of the landslide zone and deposit the same on the Basan LMV road which break the frequent communication to the village Basan.

The width of the main land slide is about 500-550 m (along the Basan road section) lying at 600m above msl. The toe of the slide zone is ~ 80m down to the Basan LMV road where as the head /crown, is situated at 240m above the road level. The position of crown of the slide zone is at 840 m above msl and touching the main Yamunotri National Highway and a cause of worry in contrast to its past position in 1964 when it was about 40 m below to its present position i.e. at 800 m above msl. Thus the landslide is threatening the safety and stability of the main Yamunotri National Highway too besides the road to Basan village. The toe portion of the slip zone is lying at ~520 msl in the river bed where active toe erosion by Yamuna river is another cause of worry for the safety of the Basan LMV road and its embankment which could be treated with proper engineering measures.

The prime factor responsible for the slip zone is its vicinity to the MBT, which has caused the fragile nature to the lithology of the area. This along with the toe erosion by Yamuna river has further added to the problem in this zone. The bed rock exposed in the landslide scrap and in the surrounding region exhibits four discontinuity sets along with foliation joint with moderate to steep dip. During the rainy season with heavy downpour these discontinuities facilitate the debris flow of the eroded material down the slope towards south and southwest, creating the mini channels whic.h in turn form the brooklets on the slope causing damage in consequence.

5.5 Real time monitoring and Analysis of Seismicity, Seismotectonics, and Seismic Hazard of NW Himalaya

(Sushil Kumar, Ajay Paul, Naresh Kumar)

Strains resulting from the continued collision between India-Asia Plates are manifested in number of large earthquakes along the Himalayan Arc. Adjustments and activation of crustal blocks to accumulating/decaying strains trigger micro-earthquakes. The understanding of earthquake source processes and the medium characterization provides the base tools for the assessment, mitigation and reduction of seismic hazards. Towards these objectives the Geophysics Group of the Institute is operating a regional network of seismic stations, including 12 Broadband and 8 Short Period seismometers in the NW Himalaya. With the introduction of V-SAT Linked Network of 10 Broad Band Seismometers (BBS), the monitoring programs in the NW Himalaya have attained new dimension. In the first phase the data of these 10 stations has helped determination of earthquake locations in almost real time. Since its introduction in June, 2007, 417 local earthquakes were recorded in one year (Fig. 23). This dense network has brought down the detection threshold of earthquakes from M=4 to less than 2. The focal depths of most events range between 0.0 and 40.0 km, nearly 85% confined to upper 20 km. The local magnitude ranged between 1.3 and 4.9. The space distribution of earthquakes clearly reinforces the earlier suggestions that major seismic activity is confined to a narrow zone centered just south of the Main Central Thrust, named Himalayan Seismic Belt. However, the longitudinally seismic activity in this belt is not uniform. The data of one year show two clusters; one in narrow pocket centered on Adibadri-Guri Kund and another in an extended zone stretching from Kharsali to Kotkhai with intervening sector showing only scattered seismicity. Long term monitoring of space time patterns of seismicity will help in identifying zones of increased seismicity and/or zones of quiescence that invariably prevail before large earthquakes. The data of V-SAT linked stations are later

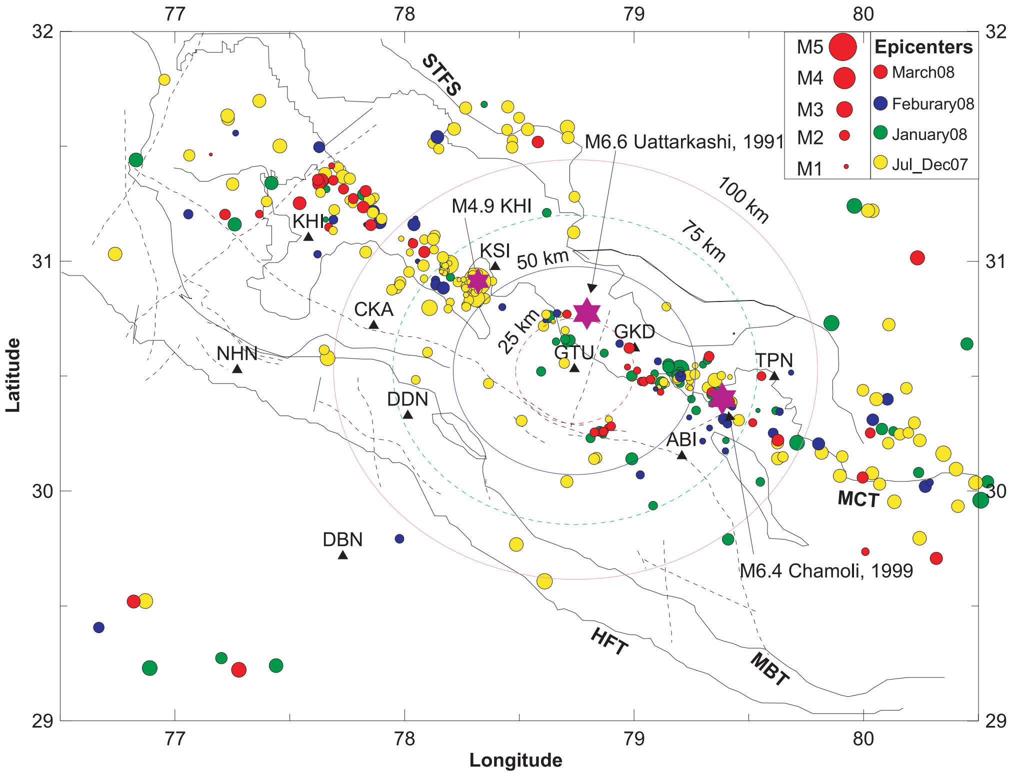


Fig. 23. Epicentral plot of earthquakes recorded by VSAT linked broad band seismometer in Garhwal Himalaya for the period of July 2007 to March 2008.

combined with other stations working in standalone mode to get complete picture of earthquake occurrences in NW Himalaya. Data of some of the well-recorded earthquakes are used to obtain the focal mechanism (Fig. 24). These results corroborate the present understanding that most of the seismicity is related with thrust tectonics, dominating in the collision zone. However, the evidence of mechanisms other than thrust tectonics is also evidenced by focal mechanisms. These data sets are being used to identify the localized active tectonic features.

During the last year, largest local earthquake recorded was a moderate earthquake of magnitude 4.9. It occurred near Kharsali in the morning of July 23, 2007. Using V-SAT data of ten stations of WIHG network, earthquake parameters were located within few minutes of its occurrence (Table 1a). The main shock was also located by other national (IMD) and international agencies (USGS) using WWSSN network. Given the closer spacing and better azimuthal coverage of the main shock, the accuracy of location was much better than that of other agencies. As given in Table 1a, the standard error for initial location in the horizontal direction was 4.5 km for WIHG network as against the 12.6 km estimated by USGS. The USGS estimates were based on the default fixed focal depth of 35 km while the error in vertical direction for WIHG was 9.5 km. Both groups revised the source parameters using data of more stations (Table 1b) leading to improves estimation of earthquake location parameters. It is noteworthy that error in depth has reduced to 4.9 km for WIHG network as against the 15.9 km provided by the USGS. In the past in the absence of suitable network in the Himalaya, the estimation of Himalayan earthquakes had largely relied on the data from outside the Himalayan belt. This not only affected the detection threshold of lower magnitude earthquake (minimum detection threshold was ~4.5) but large errors in hypocentral locations hindered their potential applications in constraining the seismotectonic model of the NW Himalaya. With the current lead to enhance seismic network in Himalaya, the improved location of earthquakes will open new vistas for developing and constraining the sesimotectonic models of the Himalaya as a whole. The present focus of seismological program at the Institute is to generate region specific velocity model, which will further reduce the errors in location parameters. Such an exercise accomplished successfully for the Kangra-Chamba sector of the NW Himalaya is a clear testimony where the new velocity model helped to locate the local seismic events to accuracy of ± 3 km and have been able to provide new seismotectonic model for the region.

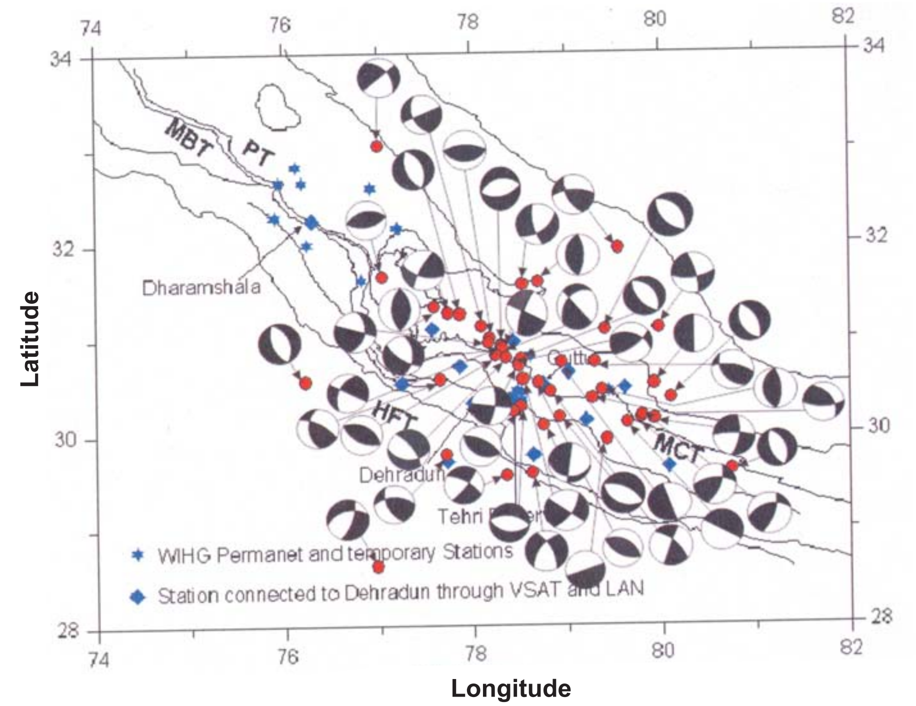


Fig. 24. Seismotectonic scenario of the NW Himalaya. Preliminary focal mechanisms of some well-located earthquakes shown as "beach balls."

Table 1a. *Initial Hypocentre parameters of the July 23, 2007 Kharsali Earthquake as estimated WIHG and USGS networks.*

	WIHG	USGS
Date	22/07/2007	22/07/2007
Origin Time	23:02:13.38 (UTC) Rms=0.54s	23:02:17.0 (UTC) Rms=0.94 s
Epicenter	30.915^0 N 78.315^0 E (± 4.5 km)	30.965^0 N 78.268^0 E (± 12.6 km)
Depth	15.1 km (± 9.5 km)	35 km (fixed)
Magnitude	4.8 M_L Gap=183°, Nst=9	4.9 Mb Gap=122°, Nst=29

Table 1b. *Improved Hypocentre parameters of the July 23, 2007 Kharsali Earthquake as estimated WIHG and USGS networks.*

	WIHG	USGS
Date	22/07/2007	22/07/2007
Origin Time	23:02:13.22 (UTC) Rms=0.61s	23:02:14.35 (UTC) Rms=0.94 s
Epicenter	30.910^0 N 78.316^0 E (± 2.6 km)	30.938^0 N 78.275^0 E (± 4.4 km)
Depth	15.0 km (± 4.9 km)	14 km (±15.7 km)
Magnitude	4.9 M_L Gap=97°, Nst=40	5.0 Mb

5.6 Subsurface Structure and Tectonic Deformation investigation in the NW Himalaya using local earthquake data

(Naresh Kumar, Ajay Paul and B.R. Arora)

The Institute has been engaged in operating a campaign mode seismic array in the source region of the 1905-Kangra Earthquake since 2004. The earthquake data collected from this 21 stations array have been used to obtain the optimum 1-D velocity model for this sector of the NW Himalaya. The results help to divide the upper crust (20 km) into three layers with anomalous layer in the depth range of 15-18 km (Table 2). This layer characterized by low S-wave velocity and higher Vp/Vs is viewed as fluid filled detachment zone that defines brittle-ductile boundary and serves as a cut-off depth of crustal seismicity. The new velocity model helped to improve the location of the local seismic events, which helped to trace the sub-surface extension of major tectonic features.

Table 2. *New velocity model.*

Depth (km)	Vp (km/s)
0.0	5.27
10.0	5.55
15.0	5.45
18.0	6.24
44.1	8.27

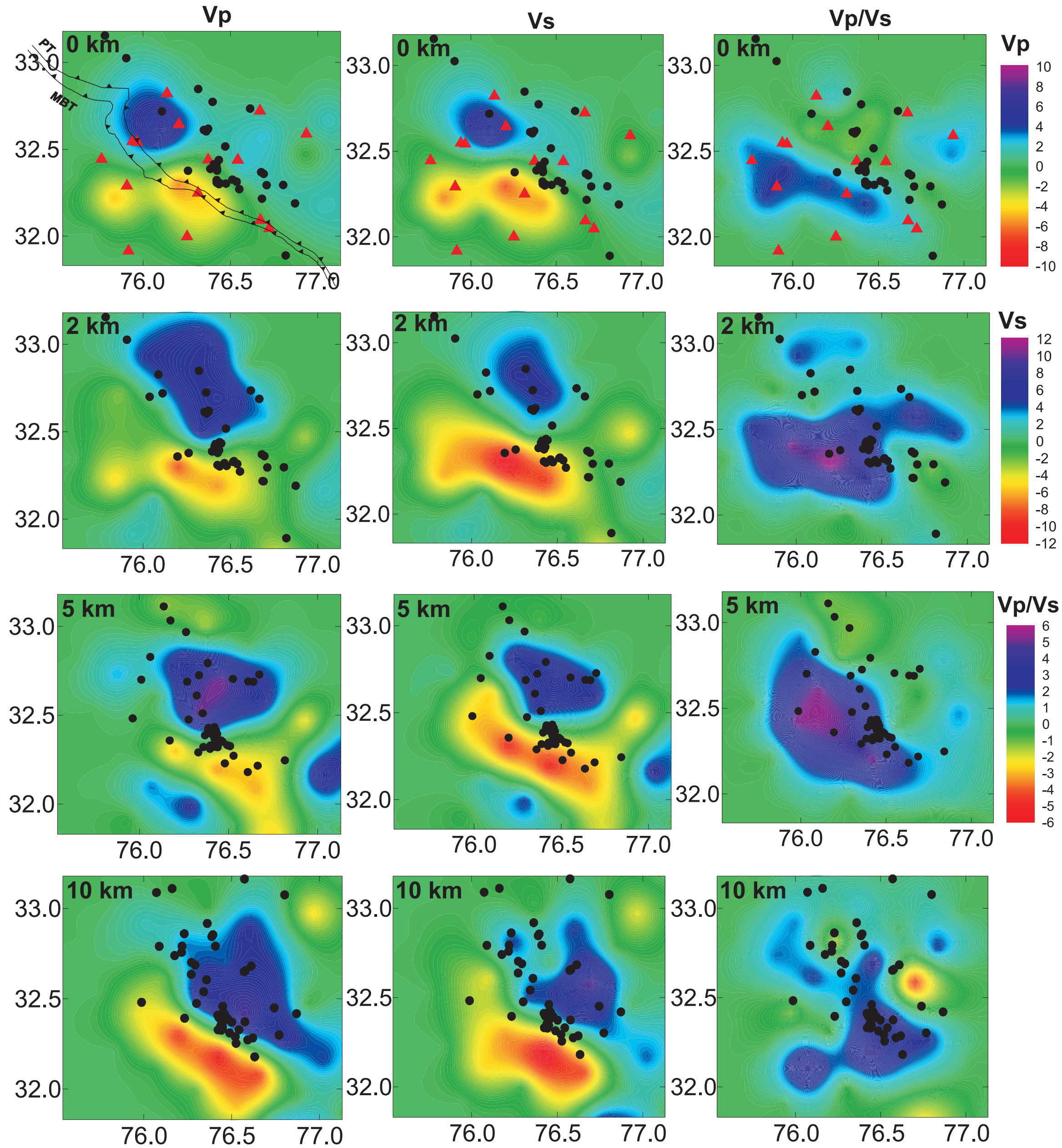


Fig. 25. Variation of Vp, Vs and Vp/Vs at different depth sections in the Kangra-Chamba region, Himachal Pradesh.

In the next phase, using the principle of local tomography, the 3-D velocity model is established for the Kangra-Chamba region. Near surface, 3D velocity perturbation in Vp and Vs (Fig. 25) shows that Siwalik formations running NW-SE are characterized by low velocity zone (LVZ), whereas the area of Chamba Nappe immediately north of the Main Boundary Thrust and the Panjal Thrusts is identified as relative high velocity zone (HVZ), although absolute velocities are typically below the characteristic velocities of the continental upper crust. In all depth range, hypocenters of earthquakes are confined to transition between LVZ and HVZ. In the depth range from 2 to 8 km, a LVZ extending NE-SW forms the most conspicuous feature of the velocity distribution in the eastern part of the Kangra region. In the depth range of 18 km, area of LVZ is marked by high velocity zone. The nodal planes of earthquakes in this depth range are oriented along N50^{o}E and their normal fault movement indicates NE-SW trending faults with SW plunge. The presence of a structural discontinuity is also evidenced by the contour map of station corrections, obtained as a by-product of the adopted inversion processes. A tectonic model is visualized where it is inferred that this steep SW dipping fault running at right angles to the main strike of the Himalaya exerts stresses on the base of NE dipping MBT and detachment. The intense interaction of stresses along the two roughly perpendicular thrust/faults may produce normal fault movements and this asperity may account for the dense cluster of seismic events NE of the source region of the 1905 Kangra earthquake.

5.7 Source Mechanism of Earthquakes by Waveform Modeling

(Ajay Paul, Naresh Kumar and D.K.Yadav)

With an objective to understand the earthquake processes responsible for earthquakes and material properties controlling the strain accumulation/release, organized studies were carried out to evaluate source parameters, fault mechanisms and stress patterns. Two different classes of investigations were undertaken. First, the source parameters were estimated for (a) M4.9 Kharsali earthquake of July 23, 2007 and its aftershocks, and second (b) for events recorded all over the Uttarakhand Himalaya by ten stations V-SAT linked network.

(a) Kharsali earthquake and aftershocks: The seismic moment of the main shock determined from the displacement spectra was 4.15 x 10^{16} Nm with source radius of 1.66 km. The seismic moment of the aftershocks varied from 1.7 x 10^{13} Nm to 8.0 x 10^{14} Nm with source radii ranging from from 0.35 km to 0.67 km. The stress drop obtained for the main event using spectral analysis of Brune's circular model was 41.5 bar, a value close to the expected value of 30 bar for the inter-plate region of Himalayan tectonics. The stress drop obtained for the aftershocks varies from 1 to 30 bar. The calculated stress drops in the region are low, which can be explained on the basis of partial stress drop model

The early aftershocks occurring at greater depth near the main shock have caused higher stress drop in comparison to the later aftershocks occurring at shallow depth, permitting inference that the formation at greater depth have more stress accumulating strength and thereby produce earthquakes of higher magnitude at relatively greater depths in the Himalaya.

(b) The source parameters have also been calculated for the 88 events recorded since the introduction of 10 stations VSAT linked network. The seismic moments for these events varied from 5.6x10e11 Nm to 7.04x10e14Nm with very low stress drops; 39 events have stress drop of less than 1 bar whereas for 26 events corresponding drop ranged between only 1 bar and 10 bars. The maximum stress drop was found to be 9.3 bars for an earthquake of magnitude 2.7. Though GPS measurements suggest that this part of Himalaya has enough amount of accumulated strain energy but the hypocentral parameters of last twenty years indicate that the upper crust is releasing energy frequently in the form of micro-earthquakes. This may be attributed to the reason that the rock mass constituting the upper crust in the region has low strength for accumulation of strain energy and the rocks undergo brittle fractures and adjustments.

In a parallel work plan, the source mechanism studies were carried out for 168 earthquake events that have occurred between 1999 and 2005 in the Kumaon Inner Lesser Himalaya. The local magnitudes of these

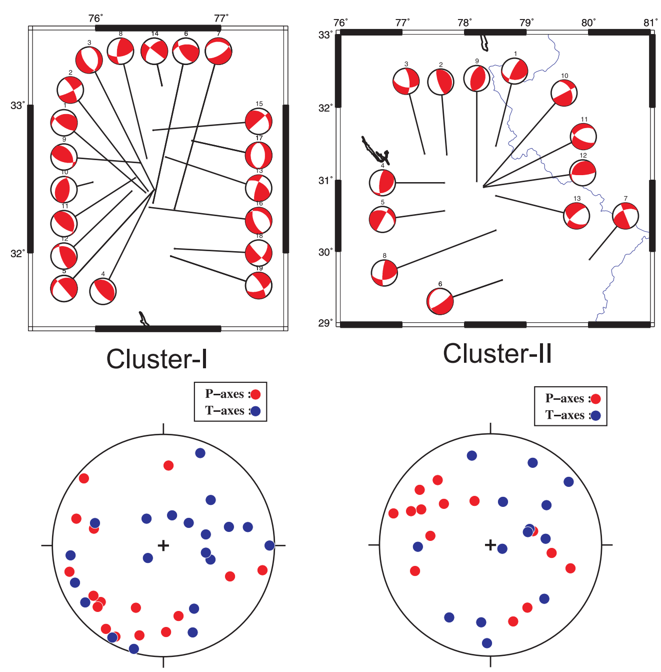


Fig. 26. Fault plane solutions of earthquakes for NW Himalayan region in two different clusters, cluster-I around Dharamsala and cluster-II around Shimla regions and their respective P-T axes projections on a focal sphere. The shaded region in the beach ball represents compressional Quadrants and the open area dilatational.

shallow-depth events lie between 0.2 and 4.2. The microseismicity pattern identifies the most recent active fault tectonics. On the basis of fault plane solution (FPS), it is clear that the direction of thrusting related to microseismicity is perpendicular to the trend of the Himalayan thrusts and the other seismically active strike-slip fault is inferred parallel to the major Himalayan thrusts. The later lies south of the Munsiari thrust.

Further, as a step to decipher the nature of stress pattern in the western part of the NW Himalaya, FPS were obtained for two well defined cluster of events; one near Dharamsala region and the other one around Shimla (Fig. 26). The FPS of 21 and 14 events from these clusters were used to calculate the compressional/ tensional (P-T) axes and then subjected to stress tensor inversion to estimate direction of maximum compressional axes. The plots of P-T axes on a focal sphere indicate dominance of thrust mechanism with a small strike slip component. The direction of maximum compressional axis is towards NW-SE in Shimla sector.

5.8 Seismic microzonation and shallow subsurface studies in NW Himalaya and adjoining areas

(A.K. Mahajan and B.R. Arora)

Earlier as part of the microzonation studies, the Institute introduced methodology of Multichannel Analysis of Surface Waves (MASW,) recorded using 24 channels of geophones with sledge hammer as a source, for characterizing the stiffness factor and thickness of near surface sediments. Some fifty sites were surveyed in an area of 65 sq km in city of Dehra Dun. The site specific shear wave velocity measurements showed significant variation in shear wave velocity, both laterally and with depth (Fig.27). Noted variations were correlated qualitatively with material type and structural loading conditions. Such structural control and correlation with lithology suggested that images of subsurface shear-wave velocity distribution could be exploited to trace evolution history of the Doon fan where tectonic and climatic pulses during the Quaternary period appears to have played key role in shaping the geomorphic development of the intermontane valley. Revisit to the subsurface variation of shear wave coupled with geological inputs, mainly along stream cuttings, allowed to divide the Doon fan deposits into four broad zones/sectors (Fig. 28a&b). The northwestern (Zone-1) Doon fan is mainly marked by the existence of palaeo-channels and cavities because of karst topography. The area also indicates that the sediment thickness in this zone is about 20m -25m. The central part (Zone-2) showing the evidences of thick sedimentation (>50m) might be the result of erosion and aggradations. The eastern (Zone-3) shows much layered sediments indicating the presence of Siwalik outlier, which hitherto, is considered part of Doon fan. The southwestern (Zone-4) lies in the distal end of the Doon fan, having thick clay deposits mostly derived from the sediments of uplifted Siwalik range. Subsurface divisions of the Doon fan indicate varying influence of tectonics and climate in multiple phases in the evolution of the Doon fan. In the northwestern part different phases of uplift are due to tectonic movements along the Main Boundary Thrust followed by phase of erosion. In the central and eastern part, climatic changes during the Quaternary period led to deposition/erosion of sediment corresponding phases of wet and dry climate. In contrast, sedimentation in the southwest part is sourced by rising Siwalik. Further investigations using dating technique are planned to mark the timing of different phases of erosion and uplift, which lead to present geomorphic evolution of Doon valley.

5.9 Site Response Studies in Major Population Centres / Cities of North Western India

(A. K. Mahajan and A.K. Mundepi)

Earthquake damage scenario in a region is determined by the local site conditions (nature and thickness of sedimentary column) as well as by the frequencies dominating the earthquake generated seismic waves vis-a vis the natural frequencies of standing structures. Given this, the site response studies in major and metro cities located in the frontal part of the Himalaya have been a priority area of research at the WIHG. The two complementary techniques, namely the Nakamura technique and Multi-channel Analysis of the Shear Wave (MASW) are being employed. After successful application of these techniques in the cities of Dehra Dun, New Delhi and Chandigarh, the studies were extended to the city of Jammu in the current year. The expanding city of Jammu is located in the rontal part of the Himalaya, near the potentially active Himalayan Frontal Thrust (HFT). Hence hazard assessment for this city is of great importance.

Nakamura Site Response Studies in Jammu City

The surface geology of Jammu city is dominated by Upper Siwaliks in the north and sediments of Indo-Ganga Plain in south. During the field survey some 136 sites were sampled

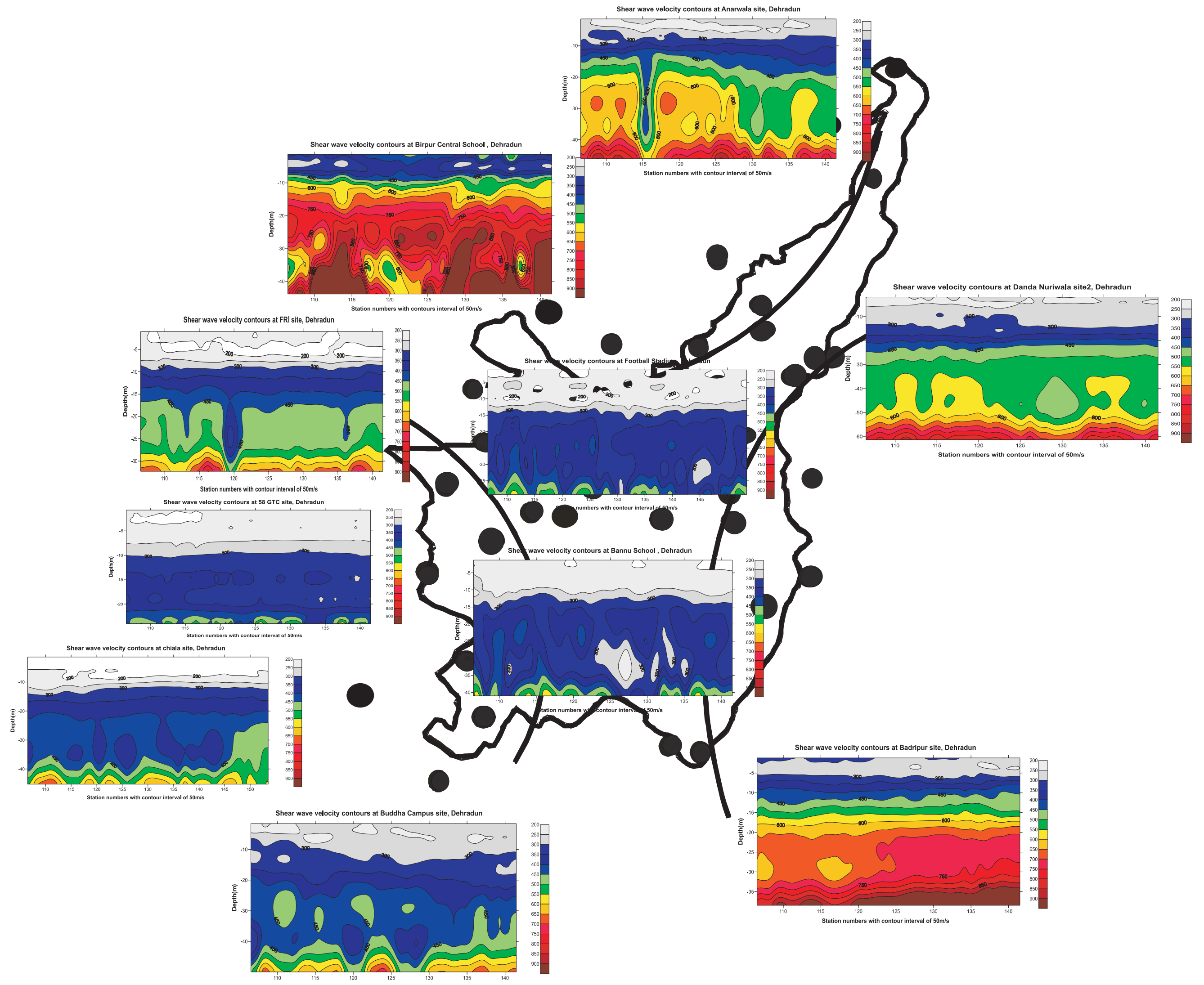


Fig. 27. Showing lateral and vertical variation in shear wave velocity at different depth levels in Dehradun city area indicating the role of climate, tectonics and incision in the development of Doon valley.

(Fig.29). The H/V ratios of ambient noise were used to determine the resonance frequency in the region. Assuming sedimentary cover as a single layer overlying the bed-rock, the estimated resonance frequency is used to provide the sediment thickness by empirical relationship:

$$H = S_{av} /4*f_{H/V}$$

Where, H: thickness of sediments; S_{av}: Average shear wave velocities; $f_{H/V}$: Resonance frequency at site. For a $V_{av,}$ we have used the shear wave velocity of 350 m/s, obtained by MASW studies. The average thickness of the sediment column so calculated was in fair agreement with the thickness obtained by MASW. The shear wave velocity profiles have been correlated with the peak amplification of sediments obtained using Nakamura technique shows good agreement (Fig. 28). Maps showing spatial distribution of soft sediment in the Jammu city coupled with resonance frequency serve as basic inputs for earthquake mitigation actions as well as a base for more detailed investigations of sedimentary sequences.

Microzonation studies of Jammu city based on MASW methology

In this approach, the near surface shear wave velocity at given site is obtained using Multichannel Analysis of Surface Waves (MASW) - a seismic reflection method. In the next

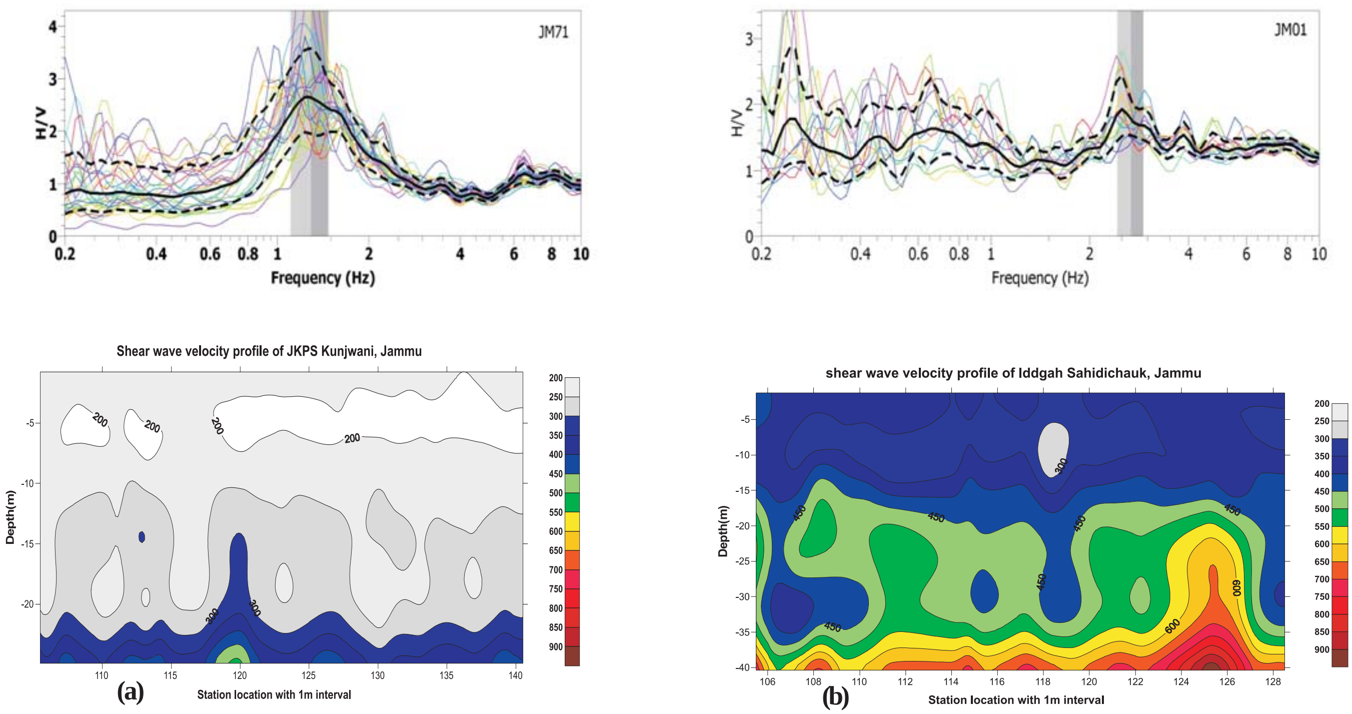


Fig. 28. Shear wave investigations using MASW (Lower) and peak Amplification using H/V (Upper) in the Jammu city help identifying zones of (**a**) high and (**b**) low seismic amplifications characterized respectively by large thickness of sediments with low resonance frequency at 1.5Hz and thickness of sediments with high resonance frequency at 2.7Hz.

phase, the deduced shear wave velocity model will be used to simulate the dominant frequencies as well as site amplification to known ground acceleration.

According to the investigations the Jammu city can be broadly classified into three categories as per NEHRP classification i.e. class 'C'(360-760m/s) in the northern part, Class 'D' (180-360m/s) in the Gandhi Nagar and Shastri Nagar and Class 'E' (<180m/s) in Talab Tillo side or in Satwari area where thickness of sediments is very high (Fig. 29). The results are in concordance with the site response analysis (Nakamura method) which indicates resonance frequency ranges from 0.432 to 3.369 Hz.

5.10 Dynamics of Crustal shortening and Lithospheric Structure of Garhwal-Kumaon Himalaya

(Rajesh, Sathyaseelan)

The Garhwal Kumaon Himalaya (GWKH) is geographically bounded by the Himachal Himalaya (HH) at its west and the Nepal-Bihar Himalaya (NBH) at its east. These two regions had the history of great earthquakes of magnitude > 8 in 1905 and in 1934, respectively. The objective of this work is to understand the mechanism of crustal shortening as a cosequence of lithospheric loading by deeper density anomaly structures. Large amount of satellite data have been collected from all the possible sources and processed. Almost eight years of data from various satellites at various collection modes have been used to get the preliminary information of the regional geoid. Processing codes have been developed and made it functional, further improvement and development are currently in progress. A theoretical formalism has been done to understand the depth degree harmonics relationship for tracing the deeper density anomaly structures. A set of new five GPS instruments were tested and successfully integrated with a few meteorological systems. In this attempt, a few hardware components were developed and subjected all instruments to perform under simulated field conditions. Preliminary results suggest that :

- In the Western Himalaya, where anomalous crustal shortening is observed in GWKH sub-region, is characterized by low density lithospheric mantle.
- Analysis of geoid anomalies over the Himalaya and its contiguous zone in the Indian plate are studied. Results suggest the existence of a strong density anomaly dipolar field in the Indian plate.
- Negative positional offsets were observed in all the three components of continuously operating GPS station in Guttu followed by the July 22, Kharsalai earthquake (Mw = 5.5), Uttarkashi.

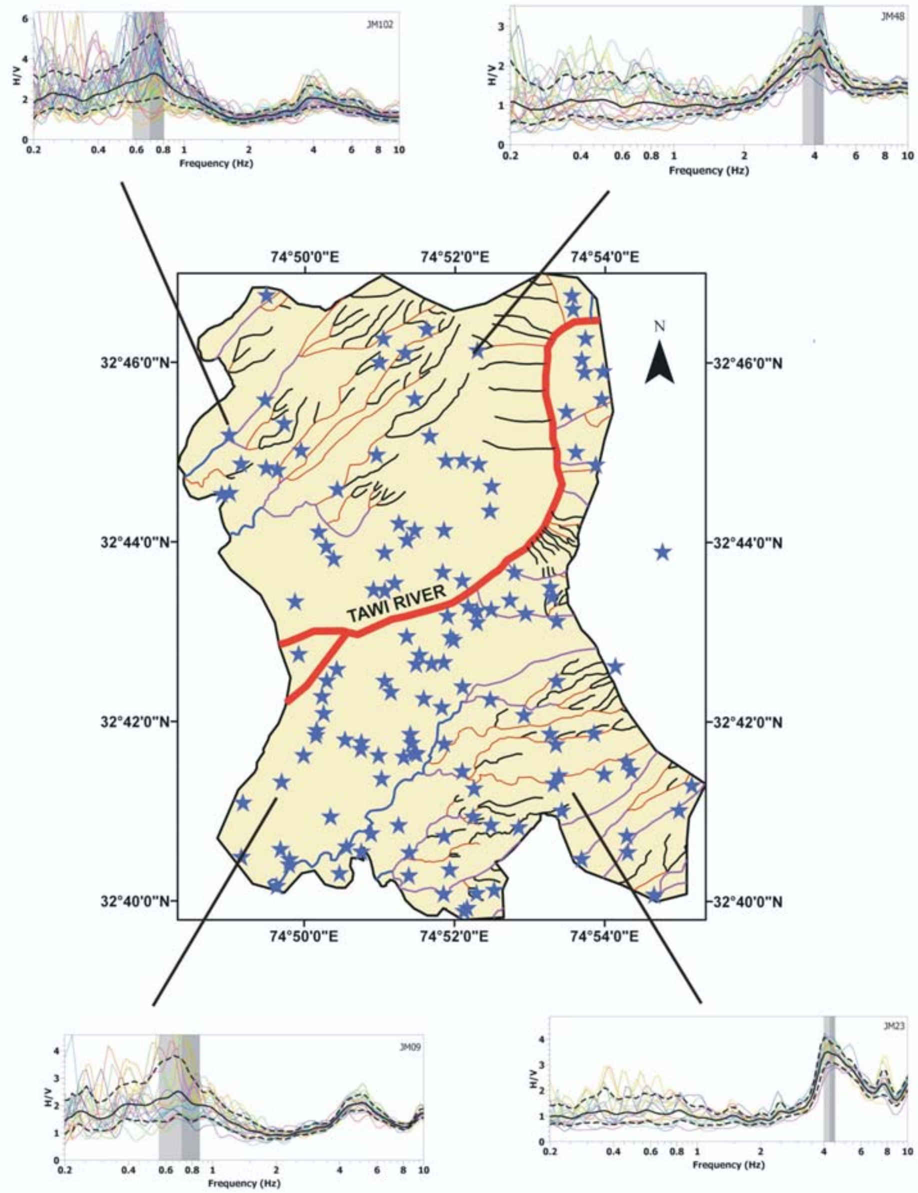


Fig. 29. Shear wave velocity profiles of different sites in Jammu city showing lateral and vertical variation in shear wave velocity. Based on NEHRP classification, city can be classified into three major zones of seismic hazards i.e., class 'C', 'D' and 'E'.

5.11 Crustal Deformation, Strain Accumulation and Geohazard study in the Himalayan Region using SAR Interferometric Techniques

(Swapnamita Choudhury)

Synthetic Aperture Radar Intereferometric Technique (InSAR) has been successfully implemented for several deformation studies in the recent past. This technique has been conceived and proposed to be applied for deformation/subsidence and strain accumulation study for reservoir induced crustal changes due to the impounding of Tehri reservoir and also existing tectonic activities in the study area. The software for microwave satellite data processing (SARscape 3.0) was successfully installed and tested with example data of Bam, Iran. Interferogram and deformation map was generated successfully and checked with already published products as part of learning the software and microwave data processing. The program envisages combining InSAR data with ongoing GPS campaign surveys around the reservoir to constrain better the uplift/subsidence associated with annual loading/unloading of the resvoir. There can be good correlation of GPS observations with the InSAR observations in the region.

To check tectonic ground truth and to have an idea of the terrain conditions of the study area a field visit was undertaken in the Bhagirathi and Bhilangana valleys. Indications of recent tectonic activities and ground changes like subsidence/landslides etc. have been noted at certain places.

5.12 Monitoring of geophysical and hydrological change due to impounding of reservoir

(B.R. Arora, V.M. Choubey, Gautam Rawat, P.K.R.Gautam)

The project is aimed at monitoring geophysical and seismic changes due to impounding of Tehri Dam reservoir. Influx of water causes variation in pressure and other physical properties in the dilatant zone. If these changes can be quantified, they serve as a controlled experiment to establish the stress-sensitivity of physical parameters which can be later used to translate earthquake precursory changes in magnetization/density, etc. to the magnitude of impending earthquake. To isolate such changes, some 14 stable bench marks are established around the Tehri reservoir to record GPS, total magnetic field intensity and radon emission. During this year, two campaign mode observations in July, 2007 and October-November, 2007 were undertaken when continuous registration of three parameters were taken from 24 hours to 96 hours in each campaign. Magnetic field at each pillar is compensated for global variations using continuous concurrent recordings at Ghuttu and Bhatwari. Also, one continuous total magnetic field station along with ULF induction coil was established at Adibadri.

The campaign mode GPS data was combined with daily solutions of Global IGS stations and twelve IGS stations (BAHR, BAN2, DGAR, HYDE, IISC, KIT3, LHAS, MALD, NTUS, POL2, THEN and WUHN) to estimate nature of crustal deformation and to find out surface displacements. The differential velocity vectors conform to subsidence/uplift with increasing/decreasing level of water in the lake (Fig. 30). However, errors associated are large and one would

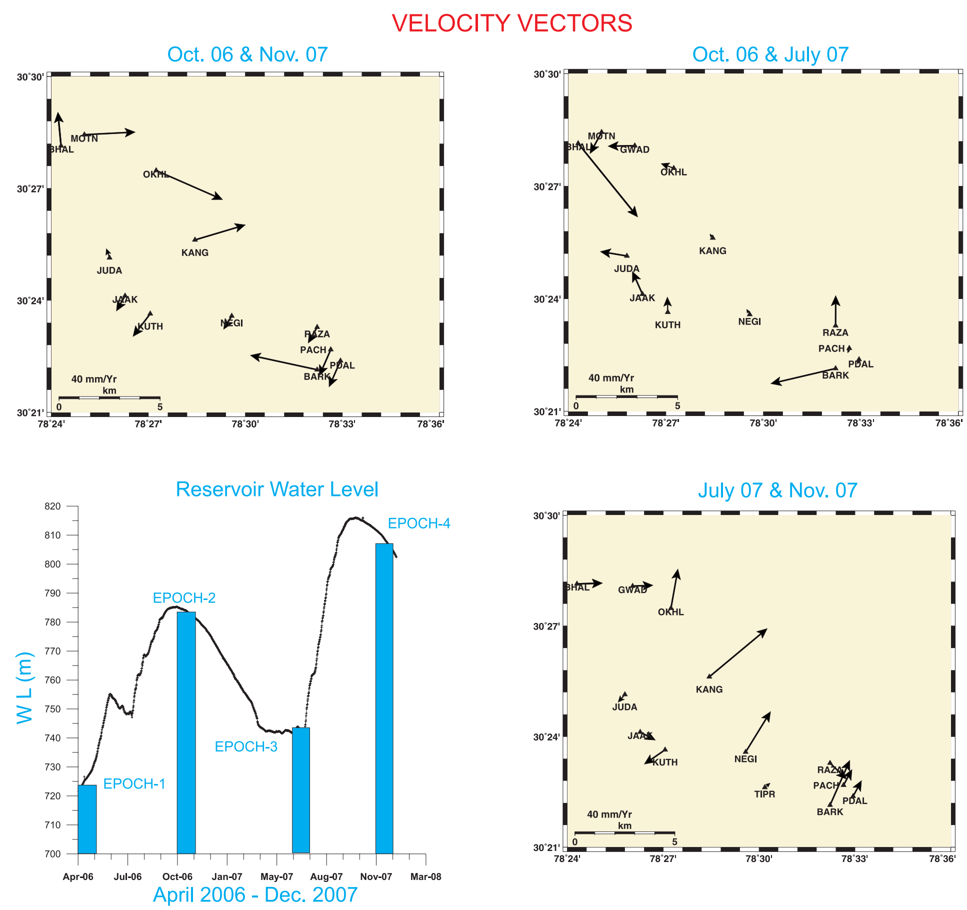


Fig. 30. Residual velocity vectors characterizing nature of crustal deformation due to loading/unloading of Tehri Dam Reservoir.

need data for relatively longer period to draw definite conclusions. Refining of the data quality and precision of the computed solution is in progress to improve the robustness of velocity vectors.

The radon data collected during the last four campaigns period were analyzed with reference to level of reservoir water, air temperature and atmospheric pressure. In general, no correlation of radon emanation has been observed with the atmospheric parameters. However weak positive relation between radon and reservoir water level was recorded during the second and fourth campaign mode. During the above two campaigns the increase in water level resulted in increase of radon concentrations at few bench marks. This is possibly because of the increase of pore-pressure and accumulated stress at tectonic discontinuities with increase of load of enhanced water column. After completing and processing the radon data of four campaign mode, it is realized that continuous radon data even at one or two sites will help us to correlate the radon signals with geodynamic changes occurring in the region particularly due to loading and unloading of the reservoir.

SPONSORED PROJECTS

PROJECT

Multi-parametric Geophysical Observatory for Earthquake precursor studies

(B.R. Arora, V.M. Choubey, Ajay Paul, Gautam Rawat, Naresh Kumar)

The Institute has established the first Indian Multi-Parameter Geophysical Observatory (MPGO) at Ghuttu, Central Himalaya to study earthquake precursory studies in an integrated manner. The MPGO became fully operational in April 2007 and is equipped with super conducting gravimeter, overhauser magnetometer, tri-axial fluxgate magnetometer, ULF band search coil magnetometer, radon data logger, water level recorders and is backed up by the dense network of Broad Band Seismometers (BBS) and GPS. The installation of strain meters and magnetotelluric units are also envisaged. The simultaneous recording of multi-disciplinary parameters is searched for characteristic space-time variation in micro-seismicity, seismic wave velocity changes, crustal deformation, small-scale changes in gravity, resistivity, magnetic field intensity, electromagnetic and radon gas emission as well as by fluctuations in hydrological parameters expected during the earthquake preparatory cycles.

Although the high precision equipments have the requisite sensitivities to record characteristic stress-induced perturbations, the isolation of weak precursory signals is still a challenge as each geophysical time series has characteristic time variability related to inter-planetary, terrestrial, hydrological and tectonic sources. During the year, the focus was on characterizing the time variability of various parameters to facilitate the isolation of weak earthquake related precursory changes.

The singular spectrum analysis jointly with regression analysis is developed to estimate time varying amplitude of tidal effects as well as atmospheric pressure influence on gravity field. Superconductivity gravimeter is calibrated by establishing the frequencies of spheroidal mode oscillations of the free Oscillations of the Earth (FOE), excited by the great Soloman Islands (M8.1) occurred on 1^{st} April, 2007. The formulation of principal component is found effective in isolating components of extra-terrestrial and seismotectonic origin in geomagnetic field intensity. The critical value analysis is performed on radon time series to identify earthquake related signals.

A moderate (M4.9) Kharsali earthquake of 23^{rd} July, 2007 with epicentral distance of 59 km from MPGO at Ghuttu provided testing ground to search pre-, post- and co-seismic changes. The SG data, corrected for tidal effects, had showed bay like decrease of few microgals about four days before the occurrence of Kharsali earthquake. The analysis of radon data shows perturbations more than 2σ confidence level in the radon values in both probes installed at 10m and 50m depths in the 68m borehole about 23 days before the earthquake. Night time differential plot of total magnetic field for pair of stations, located on either of the epicenter across the MCT (Ghuttu-Bhatwari) showed sudden drop in magnetic field intensity 10 days before the earthquake that recovered equally rapidly 4 days after the earthquake (Fig. 31). The eigen value plots resulting from the application of PCA to time varying magnetic field also show anomalous behaviour during the same interval (Fig. 32). The largest eigen value trend correspond with geomagnetic indices whereas variation of second and third eigen value depict variability associated with tectonic origin.The relatively large offset in the N-S component of GPS data between 9^{th} July (190) to 13^{th} July (194) was noticeable A off set (fall) of nearly 1cm in the N-S component was also equally noticeable from 19^{th} (200) to 27^{th} (208) July. Physical mechanism to relate such time-varying signals with the earthquake is yet to be understood. Similar observations during future earthquake will give a vital clue to develop the earthquake precursory model.

PROJECT

Electrical Conductivity Imaging of Uttaranchal Himalaya

(B.R.Arora)

As part of electrical resistivity imaging of Uttaranchal Himalaya, magnetotelluric (MT) data along two extended profiles, first along Bijnaur-Mallari and second along Pilibhit to Dharchulla have already been collected. Both profiles pass along major litho-tectonic units of the Himalaya starting from Indo-Ganga Plain, Siwalik, Lesser, Higher Himalaya to Tethys Himalaya. In all data from 18 and 12 sites were collected with occupancy of five days at each site to enhance the signal to noise ratio at long periods. Frequency dependent Transfer functions are estimated using robust processing of time series for single site and remote reference as well. Few stations electric field recordings were very noisy perhaps due to unbalanced power network of the region. This necessitated revisit to some sites to collect noise free data.

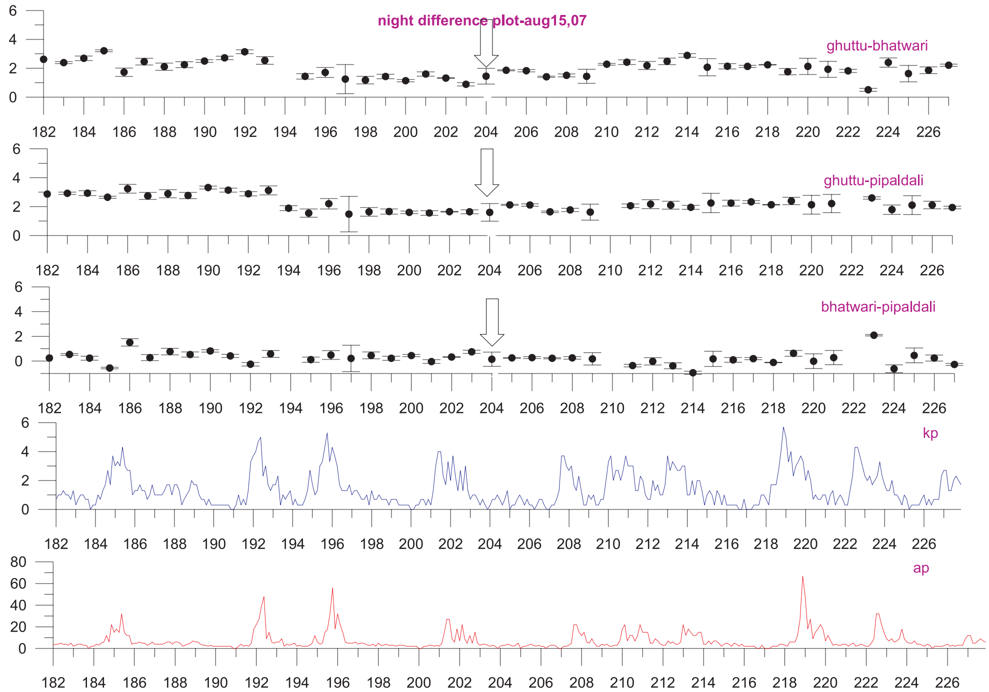


Fig.31. Difference plots of total magnetic fields between pairs of stations indicating seismotectonic anomaly in association with Kharsali earthquake of July 23, 2007.

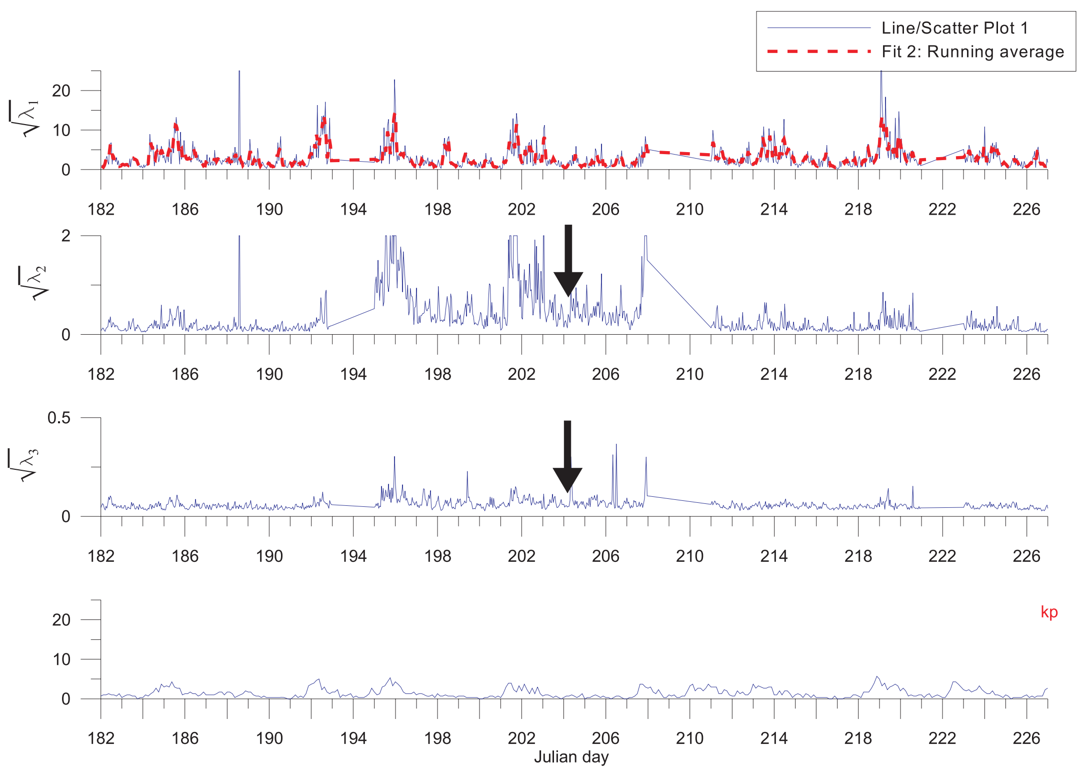


Fig. 32. Daily plots of eigen value (EV) obtain using principal component analysis on the total magnetic field data at Ghuttu, Bhatwari and Pipaldali. While large EV depict variations associated with global geomagnetic activity, smaller value component relate to seismic activity.

Skewness and other dimensionality parameters indicate the validity of 2-D regional model. Robust impedance decomposition for the period band of 10 Hz- 1000 sec. Thirteen stations on profile Bijnaur-Mallari reveal that EM strike coincides with the geologic fabric. Considering this as regional strike, EM field were decoupled in TE, TM mode and then inverted for frequency dependent conductivity distribution along the profile. The most conspicuous feature of the inverted resistivity section is the low resistivity zone at a shallow depth of 10 km beneath the Indo-Gangetic Plains that dips down at a low-angle and extends as a continuous plane right up to MBT or little north. The geometry of this layer is correlated with the basement thrust separating the top of the under thrusting Indian Plate from the over-riding sedimentary wedge of lesser Himalaya. Beneath Lesser Himalaya, this low angle dipping conductor shows strong modulation and may signify the role of duplex structure. The modeling with fresh data from revisited sites is in progress to quantify the deep crustal structure.

Processing of data from 12 sites along the Pilibhit-Dharchulla profile was also taken up. MT Transfer function has been estimated and apparent resistivity curves has been calculated. Dimensionality analysis is in progress for further modeling of resistivity data.

PROJECT

Multiple Geophysical Investigation around Eastern Himalayan Syntaxis

(DST Deep Continental Studies)

(B.R.Arora, Sriram, Gautam Rawat and D. Hazarika)

With the objective to probe deep subsurface in terms of electrical resistivity and velocity structure around Eastern Himalayan Syntax region, a multidisciplinary program with the sponsorship of DST under “Deep Continental Studies” has been started. Although limited in spatial extent, the syntaxial region provides distinctive setting to understand the various tectonic processes associated with plate collision, particularly related to the indenter corner. The Institute’s component involves passive seismic and magnetotelluric experimentations to deduce velocity structure and resisitivity imaging.

Passive Seismic Experiment

Twelve Broad Band Seismographs (BBS) installed along Teju-Wallang profile recorded 132 teleseismic events during the operation this period. Out of these102 were extracted for P to S conversion studies and 47 events for S to P conversion studies. 652 P-Receiver functions were computed using Spiking de-convolution and Water level de-convolution and the better one among them was used for stacking. 73 S - Receiver functions were computed using seismic Handler. The P-receiver functions were stacked as per the ray arrival with in a bin of 0.2° x 0.2° in one azimuth. Thus 16 distance-Azimuth bins were obtained for further analysis. Time sections for each azimuth were made for further processing and interpretation.

Magnetotelluric (MT) Surveys

MT surveys along the Lohit valley were greatly resistricted due to the rugged topography. Given this, only eleven MT sites were occupied along the profile wherever 50-70 m long length with gentle relief in N-S and E-W could be tracked. Single site robust processing of five component time series for eleven sites is completed toward the estimation of MT transfer function. Out of eleven sites, Transfer functions are estimated for eight sites. Transfer function for three remaining sites could not be estimated due to poor data quality. Figure 33 shows apparent resistivity curve for Dimway (MT site2). Resistivity variations in apparent resistivity curve indicate complex crustal structure. MT transfer functions are being analyzed for dimensionality of regional conductivity structure for selection of appropriate modeling scheme.

PROJECT

Erection of Standard Reference Sections for the Siwalik Group in India, Linkage and Migration of the Siwalik Mammalian Faunas

(A. C. Nanda, R. K. Sehgal)

Field investigations were carried out in Jammu, Nurpur and Haritalyangar (Himachal) and Chandigarh regions and data interpreted. Emphases were put on the erection of Standard Reference Sections for the Siwalik Group in India and on the linkage and migration of the faunas with the contemporary faunas of Europe, Africa, Turkey and Central Asia. To achieve the targets, faunal lists of various fossiliferous areas were prepared and nomenclature was updated in the light of recent faunal discoveries in China, Mongolia, Europe, Turkey and Africa. Several sections were examined. Lower Siwalik of Ramnagar area (Jammu) is found suitable for the reference section for the Chinji Formation of Potwar Plateau, Pakistan. Forty six taxa are known from this area. One generalized section, measuring 575 m of the Lower Siwalik Subgroup, was measured along Udhampur-Dhar road. The positions of various mammalian taxa are being

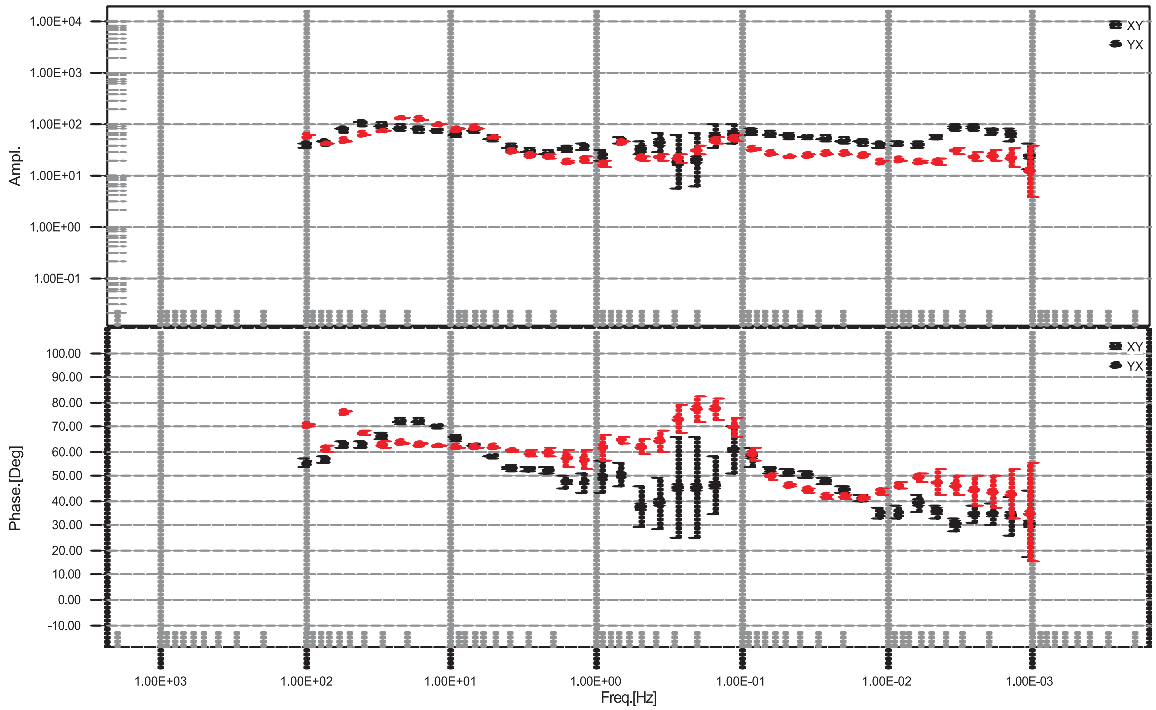


Fig. 33. Apparent resistivity curve at Dimway.

demarcated in this generalized column to know the appearance and disappearance of the various taxa. Various stratigraphic contacts of Middle and Upper Siwalik subgroups of Nurpur area were marked. In this area there are two conglomerate units; one belongs to Middle Siwalik and other to Upper Siwalik. The conglomerates belonging to the Middle Siwalik are bright and mainly contain pebbles and cobbles, where as Upper Siwalik conglomerates are dirty and comprised of cobbles and boulders. Two different mammalian faunas, belonging to Nagri and Dhok Pathan, are known from Haritalyangar area (Bilaspur, H.P.). Faunal lists were compiled and updated in the light of recent works. Rich Nagri Fauna, comprising fifty seven characteristic taxa, is recorded. Dhok Pathan Fauna is comparatively less developed and only nine characteristic taxa are encountered. This area may be referred to the Standard Reference Section for the Nagri and Dhok Pathan formations.

Several sections of the Upper Siwalik Subgroup of Chandigarh region were examined. The mammalian collection belongs to both the Tatrot and Pinjor formations. Twenty six Tatrot taxa are known from this area. Several other sections, which yielded Tatrot Fauna, were examined for the reference section for Tatrot Formation. These include Masol, Dhamala, Khetpurali and Haripur sections (lying between Ghaggar and Yamuna rivers). Several sections of Jammu regions were also examined and considered, but Tatrot Fauna is not well developed here. Only 14 Tatrot taxa are known, as compared to 26 known from Chandigarh region. Saketi area is found suitable for the Standard Reference Section for Tatrot Formation, as it is richly fossiliferous and its base is exposed (i.e. the contact of Middle and Upper Siwalik subgroups). Faunal list of the Pinjor Formation is prepared and updated. The work shows that about fifty five Pinjo taxa are known from this area. On the basis of lithology, fauna and magnetostratigraphy, the Patiali Rao may be referred to as Standard Reference Section for the Pinjor Formation. Several sections (including Ghaggar section) of the Pinjor Formation between Sutlej and Yamuna rivers were considered. In the Patiali Rao section, the contacts between the Tatrot and Pinjor, and Pinjor and Boulder Conglomerate are very well exposed. In addition the section is richly fossiliferous and magnetostratigraphic dates are available. However in Ghaggar scarp the base of the Pinjor is not exposed and the section is comparatively less fossiliferous. Several sections of Jammu regions, such as Parmandal-Utterbeni, Jammu-Nagrota and Samba-Mansar were also considered and examined in the field. However, these sections are comparatively less fossiliferous and only 14 taxa are known from this region as compared to about 55 taxa in Chandigarh region. Section along Nadah-Morni road may be considered as Standard Reference Section for the Boulder Conglomerate Formation. Excellent exposures of this formation are exposed along this road and its lower contact with Pinjor Formation can be examined. Several sections of Jammu-Udhampur regions were also examined, but sections near Chandigarh are better exposed and overlie the richly fossiliferous Pinjor Formation.

Dispersal of Eurasian mammalian faunas during the Cenozoic was affected by uplift of the Himalaya. After the collision of the Indian Plate with the Eurasian Plate, the Himalaya was not a topographic barrier to prevent the to- and fro- migration of faunas between Indian Plate and central Asia. With successive uplifts, it became a formidable barrier for movement across it and it also led to the onset of monsoon conditions in the Indian subcontinent. The continental uppermost Subathu Fauna from the foothills of the Himalaya, Oligo-Miocene fauna of Trans Himalaya Kargil Molasse, the Bugti Fauna, Murree Fauna and fauna from the basal and medial level of Manchar Group of Pakistan indicate that these faunas had links with Chinese or central Asian localities. In other words till Oligo-Miocene the main Himalayan Range was not a barrier for the migration of the fauna. Even in Oligo-Miocene, Kargil area of Trans Himalaya region provided a link between central Asian localities and Bugti area of Pakistan. It was during the deposition of Siwalik Group that Himalaya started acting as a barrier for migration across its width.

To know the relation of the faunas with respect to the uplift and monsoon conditions, the faunal lists of the various Cenozoic formations of the northern part of the Indian subcontinent were prepared and studied. For comparisons, the faunal lists of Orleanian, Astaracian, Vallesian and Turolian of Europe, Africa, central Asia and Turkey were prepared and distribution of various Siwalik genera was studied. Normally, it is considered that the Siwalik faunas are endemic. However the present work shows that it has a linkage with the faunas from Turkey, Europe and Africa. For the first time the Siwalik faunas were compared with Turkey. The Chinji Fauna of the Lower Siwalik Subgroup shows linkage with central Asia as 12 genera are common. It also shows good links with Europe and Africa as 22 and 21 genera are common respectively. However, Middle Siwalik faunas show poor linkage with central Asia, indicating that Himalaya was barrier for the to- and fro- migration of the fauna. Faunal evidence indicates that Himalaya became a barrier in Nagri time (say about 10 Ma). Monsoon conditions started at this time, but became prevalent in Dhok Pathan. However, in the duration of Nagri Formation, the fauna shows good links to Europe as18 genera are common. Ten and eight Nagri genera are found in Turkey and Africa respectively. This is for the first time that faunas are interpreted to know the uplift of Himalaya and setting of Monsoon conditions.

Pinjor fauna marks the end fauna of the Siwalik Group. The Pinjor fauna is compared with the Pleistocene-Holocene faunas (post Siwalik faunas) of Peninsular India and Indo-Gangetic plain. This work is being carried out for the first time. Post Siwalik faunas were first reported in 1830's. However, a single compiled mammalian faunal list is not available till date. For the first time, this list is compiled and published. In total 21 Pinjor genera with different species occur in the Indo- Gangetic and Peninsular fauna. It indicates that elements of the Pinjor were present. Pinjor Fauna is wide spread and is recorded from Myanmar, Nepal and Kashmir. The routes of migration were traced. It seems faunas moved to- and fro- along the foot hills of Himalaya. It migrated to Kashmir and Kathmandu valleys as Lesser Himalaya was not high enough to offer obstruction in movements. However at the time of deposition of Boulder Conglomerate, the environmental conditions were hostile and the fauna migrated to Indo-Gangetic Plain and Peninsular India. It is noticed that the route of migration was along the Yamuna River as all the post Siwalik fossil localities lay along Yamuna and from here fauna migrated to Peninsular India through a tributary of Yamuna which flowed south to north. The present available data is insufficient to demarcate the palaeotributary through which the fauna migrated to Peninsular India.

PROJECT

Himalaya School Earthquake Laboratory Programme

(A.K. Mahajan)

Under this programme 58 school seismographs have been installed all along the Himalayan region in different schools to inculcate the culture of measurements and to provide awareness among the students towards earthquakes and its damaging effects. The principal investigator has also delivered lectures of earthquake processes and earthquake awareness in different schools like Bir, Sujanpur Tira, Mandi, Nagrota Suriyan, Sulyali, in Himachal, Hillwood Academy, Delhi especially to students apart from providing training to school teachers in this aspect (Fig.34).

Under this programme a web site (himselp.net.in) has been developed for the benefit of students who can have complete coverage of earthquake processes, major earthquakes that triggered in India and historical details of all major earthquakes triggered in India especially in NW Himalaya. There is a complete coverage of historical photographs especially of Kangra earthquake which may not be available in normal circumstances. The web site has also been loaded with the earthquake measurement procedure for the students. This web site is not only good for children for upgrading their knowledge but also for

Fig. 34. Public awareness programmes carried out in various schools under HIMSELP project by Wadia Institute of Himalayan Geology, Dehradun.

preparing school projects on earthquakes and disaster management.

PROJECT

Telemetric Seismic Monitoring of Garhwal for Developing Hazard Scenario in Uttaranchal

(B.R.Arora, Ajay Paul and Naresh Kumar)

The VSAT linked Broad Band seismic network installed in June 2007 has recorded nearly three thousand five hundred events till March, 2008. These include local, regional and teleseismic events. Since the seismic data is being acquired in real time it is processed immediately to provide information on the local earthquake of the region. If a local event of Magnitude > 3.5 is recorded then its phase data is passed on to IMD for assessing the seismic activity on regional basis. The impact of this network in bringing down the detection threshold of local earthquakes, improvement in location parameter of earthquake and its implications in developing seismotectonic model etc are summarized in the progress report of the project MMP 5.6. Here we give summary of in-depth investigations made possible in source characterization of the July 23, 2008 Kharsali earthquake.

M 4.9 Kharsali Earthquake

Within a month of the network's installation, a moderate (M_L = 4.9) earthquake occurred near Kharsali on July 23, 2007 at 04:32:13.5 (IST). It was felt as far as Delhi and its meizoseismal intensity was VI (EMS scale, near Kharsali). Location parameters as estimated by the VSAT linked BBS array is summarized in Table 1a. Its location is 50 km NW from the epicenter of October 20, 1991 Uttarkashi earthquake

(M_b 6.5). Fault plane solution of the main shock indicates thrust movement on a plane aligned with the major tectonics of the collision belt. Its location within the high seismic belt and focal depth of 15 km favour its seat in the section of the down dip end of the locked portion of the Main Himalayan Thrust (detachment plane). Steep dip of fault plane solution is consistent with the ramp structure on the detachment plane, hypothesized based on the 1991-Uttarkashi and 1999-Chamoli earthquakes. The main shock was followed by a sequence of aftershocks. Due to good azimuthal coverage, source region and source parameters of as many as 36 after shocks were determined. The hypocenter plots of the aftershocks shows SE dipping plane at right angle to the fault plane of main shock. Integration of all gleaned information allows to infer that junction of two mutually perpendicular structures provides asperity for strain accumulation. The thrust movement along the MCT in response to the accumulating stress accounted for the main shock whereas this movement reactivated the structure aligned at right angles wherein aftershocks are consequence of residual release of strains adjusting to structural instability.

PROJECT

Petromineralogical and Geochemical characterization of the Ophiolite suite, Manipur, North Eastern India

(A. Krishnakanta Singh)

The primary relationships between the litho units of the Manipur Ophiolite Complex (MOC) and Indo-Myanmar Orogenic Belt are generally disturbed; however, the grade of metamorphism is generally low. The effect of the regional deformational features in the litho-units is difficult to recognize due to strongly dismembered nature and absence of well developed primary planar structures except for chert and limestone. The contact between the ophiolite and the Disang Formation is a mélange zone marked by high-angle reverse faulting as evidenced by shearing and brecciation.

Ultramafic rocks which show affinity to Abyssal peridotites are characterized by partial to complete serpentinisation, alteration of ferromagnesian minerals, such as olivine and pyroxenes. The presence of relict or partially altered grains of olivine and residual chromites, texture and

Fig.35. Types of chromitites from Manipur ophiolite complex, Indo-Myanmar Orogenic Belt, Northeast India (A) Massive chromitite (B) Nodular chromitite (C) Disseminated chromitite and (D) Granular chromitite.

field relationship among the peridotites show beyond doubt that most tectonised bodies were formed by hydrothermal metasomatism of peridotites. Chromitite of various varieties (massive, nodular, disseminated and granular) that are characteristic of podiform chromitites have been recorded in the field (Fig.35,a,b,c,d). Despite the intense penetrative deformation of the host rocks, the chromitites display typical structures of ophiolitic chromitites such as massive and nodular like textures. The distribution of chromitites is very irregular and the exact nature of the chromitite pockets with the associated host rocks could not be ascertained due to high degree of alteration. Random distribution of chromitites suggests deep mantle magmatic segregation and subsequent disruption of primary cumulate chromitite structures by deep seated mantle subsolidus deformation.

The ultramafic rocks show higher concentration of Palladium-group PGE (PPGE) (Rh=4.4-6.6 ppb; Pd=336-458 ppb; Pt=14.6-36.4 ppb; Au=38.8-116.8 ppb) and Ag (94-145 ppb) than the Iridium-Group PGE (IPGE) (Os=2.4-5.8 ppb; Ir=3.2-4.8 ppb; Ru=5.2-7 ppb). They are characterized by overall enrichment of PGE concentration (“PGE=393.6-518.2 ppb) and high ratio of (Pt+Pd)/(Os+Ir+Ru) (24.18-35.23 ppb). Cu/Pd ratios (1183-1473 ppb) in these rocks are lower than those in primitive mantles probably suggests that the rocks contain cumulus sulfides. Chromitites show lower concentration of Palladium-group PGE (PPGE) (Rh = 9-17 ppb; Pd = 4-18 ppb; Pt = 1-9 ppb) than the Iridium-group PGE (IPGE) (Os = 25-187 ppb; Ir = 11-72 ppb; Ru = 65-279 ppb). They are characterized by extensively low ratio of (Pt+Pd)/(Os+Ir+Ru) (0.03-0.16) and Au contents (6-11 ppb) and show overall enrichment of PGE concentration (“PGE = 135-551 ppb). They are extremely poor in Pt and Pd, characteristic features of the chromitites of the ophiolite complex. Based on the results of the present preliminary study, a detailed research work is warranted to understand the behavior of PGM and PGE in magmas and to access the economic potential of platinum group of elements.

PROJECT

Evolution and Radiation and Extinction of Cambrian Trilobites from the Zanskar and Spiti Himalaya: Morphometric and Statistical approach

(DST-SERC)

(S.K. Parcha, Shivani Pandey of WIHG and S. V. Sabnis, IIT, Bombay)

The fauna collected from the field was processed and scanned for various genera identification. The fauna identified mostly belongs to the Middle Cambrian age. It is only in one section some fauna which was collected indicates that it belongs to the early late Cambrian age. The detailed lithostratigraphic column of the studied section was prepared. Three distinctive lithofacies are recognized on the basis of texture and fabrics. Numerous medium scale shoaling cycles that range from storm–influenced offshore deposited to thick cross-bedded fluvial facies were marked. Many thin carbonate beds with abundant trilobite fossils directly overlie the fluvial facies, thereby representing the transgressive system; the quality of preservation is very high which increases its potential for morphometric analysis.

In the present study morphmetric method was used on 125 specimen of trilobite fossil. After checking manually, three groups of trilobite genus were identified: *Pagetia*, *Eodiscus* and *Oryctocephalus.* Among them one trilobite genus was selected for detailed morphometric/biometric analysis which is in progress.

PROJECT

Integrated Stratigraphic and Paleontologic Study of the Trilobite bearing Cambrian Tethyan Himalaya

(NSF- National Science Foundation, USA)

(Paul Myrow, Nigel Hughes, S.K. Parcha and Sanchi Peng)

Field work was carried out in Nepal to look for sections in the Kathmandu klippe south of Kathmandu, and to visit the Tethyan Himalayan rocks of the Annapurna region. We were successful in the first objective and were able to collect both Neoproterozoic and Ordovician/Silurian carbonates for analysis of calcite twinning, in order to further explore our interest in the terminal Cambrian tectonic event in the Himalaya. The late monsoon rains prevented us from accessing the Annapurna region. In order to examine rock drill core a trip to the Oil and National Gas Commission in Dehra Dun, was made to look into the sedimentary rocks of the Ganga Basin. Some of these rocks reported to be of Cambrian age, were examined for both detrital zircons, and for acritarchs in order to try and confirm or refute age estimates, as previous age interpretations of these cores have been controversial. Initial analysis of the acritarch samples has recovered specimens, we are now proceeding with their identification.

PROJECT

Active faults and neotectonic activity (with reference to seismic hazards) in parts of the Frontal Himalaya and the Piedmont zone between the Satluj and Yamuna rivers (AFNAH).

(DST Seismology Programme)

(N.S. Virdi and G. Philip)

During the report period further analysis of data collected in the earlier years was carried out for preparing the Project

Completion Report. Important new data was also collected on the behaviour of the Main Boundary Fault (MBF/Bilaspur Thrust) in the terrain between Nahan and Kalawar. The MBF marks the tectonic contact between the lower Tertiary (Subathu-Dagshai-Kasauli) and the upper Tertiary (Siwaliks) rocks. Originally described as the Main Boundary Fault by Medlicott (Memoir GSI, 1864), the thrust is now described as Bilaspur Thrust by ONGC workers. We have observed at a number of localities strike slip movement apart from southward thrusting. The strike slip has resulted into a pull-apart basin around Dhon along the upper reaches of Talon ki Nadi. The blocking of Talon ki Nadi had created a lake, about 1.5x 0.5km, filled with 5-10 m thick Quaternary sediments. The dextral slip along the fault zone is evident from the deflection of the tributaries joining on either side of the main stream, Talon ki Nadi, The eastern extension of the thrust has exercised profound control on the topography and the Jalmuse ka Khala, which flows east to west along the thrust contact for over 4 km, is joined by the two major streams before it takes a sharp southerly turn to join the main Bata Nadi. The Jalmuse ka Khala which originally flowed to join the Markanda (paleo-Sarswati) west of Katasan brought a huge fan of late Quaternary sediments (30 ka-35ka B.P.) and deposited in the wide channel of the paleo-Saraswati to create a major blockade at Uttamwala. This blockade has resulted into diversion of the Bata to the east and the Markanda to the west.

The Lower Tertiary belt is 10-15 km wide in the western part between Nahan and Sarahan. East of Baila in the Giri, Yamuna and the Tons valleys it narrows down to 0.5 to 1 km and is traceable for over 40 km up to Kalsi. Southeast of Kalsi, it crosses the Yamuna valley and extends up to Thangaon where it is overlapped by the Krol nappe along the MBT. The strike slip (dexrtral) is also well defined at Kalawar in the Tons valley where the terraces of the Tons are displaced by over 40m. Sinhval *et al.*, (1973), using geodetic survey, estimated the movement along the fault @4mm/year. The displacement of the MBF by a number of active faults was also observed in the Chibro-Khodri power tunnel. This is corroborated by the strike slip component observed on seismic profiles by the ONGC.

PROJECT

Neotctonic -Active Tectonics of 1905 Kangra Earthquake Meizoseismal Region in Kangra and Soan Dun in Himachal Pradesh, NW Himalaya.

(DST Seismology Programme)

(V.C.Thakur)

Kangra area

Quaternary geological mapping of the Kangra and adjoining areas including Dharamsala and Palampur was carried out with an emphasis to analyse the tectonogeomorphology for determining the neo-active tectonic activity in the 1905 Kangra earthquake affected region. During the mapping the fans and geomorphic surfaces have been divided into four areas: (a) immediately south of the topographic break of the Dhauladhar range, the area is made of unassorted angular blocks, boulders and clasts of different dimensionss of sandstone of Dharamsala Formation in sandy to silty matrix, (b) the noth-south trending ridges forming hill top surface with elevation reaching 800-1000 m; the ridges are principally made of post-Siwlaik sedimentaries with few exceptions where upper Siwalik conglomerate exposed at the base, (c) the broad north-south trending valleys between the ridges at lower elevation is essentially made of sand and silt with subordinate clay along with boulders of varying dimensions predominantly of granite, and (d) the alluvial fan lies close to the southern Siwalik range; it is composed of gravels with sandy to silty matrix and pebbles and boulders of quartzite, phyllite, sandstone and occasionally granite.

The provenance of alluvial fans appears to be predomantly from the south i.e. Siwalik range. There is no tectono-geomorphic evidence of active tectonic activity related to the Main Boundary Thrust (MBT). An active fault trending NW-SE is recognized ~8 km south of the MBT. An abrupt slope break in Quaternary landform and post-Siwalik sediments is characterized along the active fault. In the north-south oriented ridges, a topographic break showing 30-40 m of vertical separation of the hill surface is observed at several localities. This topographic expression occurs along the alignment of the active fault demarcated in the satellite imagery. We interpret the active fault extending for a distance of ~40 km trending northwest-southeast.

The thrust separating the upper Siwalik boulder conglomerates and the overlying Dharamsala Formation, dips NE at ~ 30^0. This thrust is equivalent of Murree Thrust in Jammu-Kashmir and Main Boundary Fault (MBF) in Simla hills. The active fault appears to correspond to the MBF in its locatoin and orientation, suggesting that the MBF may be an active fault. Although the MBF is an older fault lying between the Dharamsala and the upper Siwalik in the area, it appears to have been reactivated in late Quaternary time as evidenced in a outcrop showing upper Siwalik conglomerate overlying the late Quaternary- Holocene sediments..

There is no geomorphic or structural evidence to suggest that the MBT is active. The Jwalamukhi Thrust (JT) occurring at the base of Jwlamukhi range defines a topographic expression of abrupt rise from the southern lower level surface. The JT brings the lower Siwalik strata to override the middle Siwalik. The Baner Khad (river) flowing across the Jwalamukhi range and farther south in Kangra valley show development of both strath and valley fill terraces. There are 2-3 levels of terraces developed across the Jawalamikhi range along Baner Khad. The terraces have

SPONSORED PROJECTS

been uplifted as a result of neotectonic displacement along the JT. The terraces T_0 are the present day terrace in the process of development which predominantly comprise pebbles from Upper Siwalik boulder conglomerate with small granite boulders in fine grained sand matrix. The terraces T_1 contains dominantly granite boulders in coarse sand matrix with subordinate quartzite boulders. The terraces T_2 contains dominantly quartzite boulders with granite boulders in almost equal proportion embedded in fine-grained sand matrix. The Baner Khad has cut through basement rocks of the Siwaliks to expose strath terraces which are overlain by terraces T_1 and T_2 in different segments of the river. Using Total station instrument, we have measured the precise elevation of the strath and valley fill terraces at four locations. The OSL ages of the sandy layers in indicate bed rock uplift (incision) rate ranging 1.22 mm/yr to 2.88 mm/yr. Assuming the terraces on the hanging wall were uplifted by Jawalamukhi Thrust dipping 30^0 NE, the shortening and slip rates calculated indicate 2.11 mm/yr to 4.98 mm/yr and 2.44 mm/yr to 5.76 mm/yr respectively.

Soan Dun Area

In the Soan Dun area structural and Quaternary geological mapping has revealed the following: (a) fault scarps upto 10-20 m high in post, Siwalik sediment have been recorded along the HFT suggesting active nature of the fault, (b) post-Siwalik Quaternary sediments horizontally bedded occur in the dun as well as on the northern and southern margins of the Janauri anticline abutting against the northerly and southerly dipping limbs respectively of the Janauri anticline; late Quaternary sedimentaries, horizontal bedded and unconsolidated occur in the central part, i.e. hinge zone of the Janauri anticline, (c) Janauri anticline has grown during late Quaternary and is an active growing structure during Holocene; it was formed over the HFT as a fault-bend fold, and (d) occurrence of tectonic scarps along HFT having potentiality for paleoseismological trenching may indicate evidence for a surface rupture earthquake as reported from Garhwal Sub Himalaya (Kumar et al. 2006) and eastern Nepal (Lave and Avouac 2005)

Morphometric indices extracted from Digital Elevation Model (DEM) are: the Mountain Front Sinuosity (SM^f), Drainage Basin Asymmetry value (AF) and Valley Floor Width to Height Ratio (VF). An active fault, trending NW-SE and displacing the distal part of the alluvial fans in the Soan Dun is delineated on the DEM map. In the field south-west facing scarp, 10-20 m high is observed at several locations along the alignment of the fault marked in the map.

Samples collected from post-Siwalik Dun sediments have given OSL ages of 40 Ka to 12 Ka. Dating of these strata have constrained the age of the fold growth of the Janauri nticline and in finding uplift (growth) rate of the anticline, indicating uplift rate 3.81 mm/yr. Assuming HFT dipping 30^0 NE the shortening and slip rates calculated indicate 6.60 mm/yr and 7.56 mm/yr respectively. These determinations of shortening and slip rates indicate that the shortening is partitioned along the HFT and the Jwalamukhi Thrust of the total convergence ~ 15 mm/yr in the Kangra reentrant area.

PROJECT

Rock Properties Laboratory -A National Facility

(DST- Earth Science)

(Vikram Gupta)

The project was initiated with the aim of creating standard facility: (i) for the measurement of P and S wave velocities in the rock samples under the laboratory condition, (ii) to train students and researchers in the measurement of interpretation of rock properties, and (iii) eventually to develop a database on rock properties and make it available on a public domain.

44 samples of different granitoids collected from across the Himalaya were also analysed for the measurements of density, P- and S- wave velocities and elastic constants. On the basis of their age, these granitiods were classified into four major groups viz. Proterozoic granitiods (Ghuttu, Bhatwari, Januna and Saruna), Early Paleozoic granitiods (Mandi-Dalhousie), Cretaceous granitiods (Ladakh) and Tertiary granitiods (Gangotri). It has been observed that Ladakh granitiods, which is I-type or mantle derived possesses higher density and higher P- and S- wave velocities than the other group of granitiods which are S-type or crustal derived. Thus chemical and mineral composition of the granitoids has profound influence on the density, P- and S- wave velocities rather than the age of the granitoids bodies.

During the year, field work was carried out in the Alaknanda valley and block samples of different lithologies viz. gneiss, schist, quartzite, limestone, phyllite, and amphibolite were collected. About 350 cylindrical cores were drilled and were analysed for the measurement of density, P and S wave velocity and the attenuation characteristics. It has been observed that foliated rocks like gneiss, schist and phyllite exhibit large scattering of data for the measured parameters, whereas rocks dominantly composed of single minerals like quartzite and limestone show a very strong relation between density and the P- and S- wave velocity parameters, indicating the increase of P- and S- wave velocities with the increase in density. It has further been noted that the wave propagation is faster along foliation than across foliation by 40%–52% for P-waves and about 40% for S-waves. Further P- and S- waves get attenuated by 2.2 times and 1.6 times, respectively, when measurements are done across foliation ca along foliation. Thus anisotropic characters of the rocks are all well reflected in the seismic wave velocity and the attenuation characteristics.

RESEARCH PUBLICATIONS

Papers Published

Asthana, A.K.L. & Sah, M.P. 2007. Landslides and cloudburst in the Mandakini basin of Garhwal Himalaya. *Him. Geol.,* **28**(2), 59-67.

Azmi, R.J. & Joshi, D. 2007. Comment on paper "A Neoproterozoic geomagnetic field reversal from the Kurnool Group, India: implications for stratigraphic correlation and formation of Gondwana" by M.R. Goutham *et al*., *Jour. Geol. Soc. India*, 2006, **67**(2), 221-233. *Jour. Geol. Soc. India*, **70**(5), 876-878.

Bajpai, S., Das, D.P., Kapur, V.V. Tiwari, B.N. & Srivastava, S.S. 2007. Early Eocene rodents (Mammalia) from Vastan Lignite Mine, Gujarat, Western India. *Geol. Mag.* **22**(2), 91-95.

Banerjee, Paramesh, Pollitz, F. & Burgmann, R. 2007. Coseismic slip distribution of the 26 December 2004 Sumatra-Andaman and 28 March 2005 Nias earthquakes from GPS static offsets. *Bull. Seism. Soc. Am.*,**97**, No.1A, pp.S1-S, doi: 10.1785/ 0120050609.

Bartarya, S.K., Mazari, R.K. & Virdi, N.S. 2007. Bhimgoda slide of August 24, 1994 in the Siwalik rocks near Haridwar : a success story of landslide control measures. *In:* Varma, O.P., Mahajan, A.K. & Gupta, Vikram (eds), *Natural Hazards.* Spl. Publ. Indian Geological Congress, 155-167.

Brook, G.A., Marais, E., Srivastava, P. & Jordan, T. 2007. Timing of lake-level changes in Etosha Pan, Namibia, since the middle Holocene from OSL ages of relict shorelines in the Okondeka region. *Quaternary International*, **175**, 29-40.

Chabak, S.K. & Sharma, P.K. 2007. Numerical Simulation of coupled wave Equations. *Int. Review of Pure and Applied Mathematics*, **3**(1), 81-91.

Chakrapani, G., Mahanta, C., Routh, J., Magnus, Morth & Khanna, P.P. 2008. Coupling between seismic activity and hydrogeochemistry at the Shillong Plateau, Northeastern India. *Pure and Applied Geophysics*, **165**(1), 45-61.

Charu, C. Pant & Paul, A. 2007. Recent trends in seismicity of Uttaranchal. *Jour. Geol. Soc. India*, **70**, 619-626.

Choubey, V.M., Mukherjee, P.K., Bajwa, B.S. & Walia, V. 2007. Geological and tectonic influence on water-soil radon relationship in Mandi-Manali area, Himachal Himalaya. *Environ. Geol.*, **52**(6), 1163-1171.

Choudhury, S., Hemlata Rajpal & Saraf, A.K. 2007. Mapping and forecasting of North Indian winter fog: an application of spatial technologies. *Int. Jour. Remote Sensing*, **28**(16), 3649-3663.

Dobhal, D.P., Gergan, J.T & Thayyen, R.J. 2007. Mass balance and snout recession measurement (1991-2000) of Dokriani glacier Garhwal Himalaya India, International Hydrological Programme. *Technical Documents in Hydrology*, **80**, 53-63.

Dobhal, D.P., Gergan, J.T & Thayyen, R.J. 2008. Mass balance studies of Dokriani glacier from 1992 to 2000, Garhwal Himalaya, India. *Bull. Glaciological Res.*, **25**, 9-17.

Dubey, A.K. & Bhakuni, S.S. 2008. Neotectonic stresses and active tectonics in the Garhwal Inner Lesser Himalaya: anisotropy of magnetic susceptibility studies. *Him. Geol.*, **29**(1), 35-47.

Goel, O.P. & Bhakuni, S.S. 2007. Petrochemistry and petrogenesis of the Great Himalayan gneisses and granites from Chamoli District, Kumaun-Garhwal Himalaya. *In:* Saklani, P.S.(ed.), *Himalaya (Geological Aspect).* Satish Publishing House, New Delhi, **5**, 51-101.

Gupta, Vikram & Ahmed, Iqrar 2007. The effect of pH of water and mineralogical properties on the slake durability (degradability) of different rocks from the Lesser Himalaya, India. *Eng. Geol.*, DOI: 10.1016/ j.enggeo.2007.09.004.

Gupta, Vikram & Ahmed, Iqrar 2007. Geotechnical characteristics of Surabhi Resort landslide in Mussourie, Garhwal Himalaya, India. *Him. Geol.,* **28**(2), 21-32

Gupta, Vikram, Bist, K.S., Sharma, B. & Asthana, A.K.L. 2007. Varunavat landslide in the Bhagirathi valley, Garhwal Himalaya: its causes and risk assessment. *In: Verma, O.P., Mahajan, A.K. & Gupta, V. (eds), Natural Hazards,* Sp. Publication, Indian Geological Congress, 97-111.

Gururajan, N.S. & Choudhuri, B.K. 2007. Geochemistry of the Trans Himalayan Lohit Plutonic Complex, Eastern Arunachal Pradesh. *Jour. Geol. Soc. India.*, **70**, 17-33.

Jowhar, T.N. 2007. Significance of chemical zoning in garnets. *Indian Mineralogist,* **41**(2), 200-210.

Jowhar, T.N. 2007. Pressure-Temperature paths from zoned metamorphic garnets. *Indian Jour. Geochem.,* **22**(2), 419-429.

Jaygunadaperumal, R. & Thakur, V.C. 2008. Kinematics of secondary surface fractures on southeastern extension of rupture zone, and 8 October 2005, Muzafarabad earthquake. *Tectonophysics*, **446**, 61-76

Kamal & Mundepi, A.K. 2007. Site response studies in Dehradun city: first step towards seismic microzonation. *In: Verma, O.P., Mahajan, A.K. & Gupta, V. (eds), Natural Hazards.* Sp. Publication, Indian Geological Congress, 175-181.

Kapur, V., Bajpai S., Das, D.P. & Tiwari B.N. 2007. Early Eocene Primate (Mammalia) from Vastan Lignite Mine, District Surat (Gujarat), Western India. *Jour. Palaeontol. Soc. Ind.,* **52**(2), 231-234.

Kumar, K., Rana, R.S. & Singh, H. 2007. Fishes of the Khuiala Formation (Early Eocene) of the Jaisalmer Basin, Western Rajasthan, India. *Curr. Sci.,* **93** (4), 553-559.

Kumar, Sushil, Chander, R. & Khattri, K.N. 2007. Upper mantle velocity structure in the NW Himalaya: Hindu Kush to Garhwal region from travel time studies of deep Hindu Kush earthquakes. *Educational Research and Review*, **2**(12), 302-314.

Kumar, Senthil, Weskonsky, S.G., Rockwell, T.K., Briggs, R.W., Thakur, V.C. & Perumal, R.J. 2007. Paleoseismic evidence of great surface rupture earthquakes along the Indian Himalaya. *Jour. Geophys. Res.*, iii, B03304, 10.,1029/ 2004JB00309.

Lokho, K. & Raju, D.S.N. 2007. Langhian (early Middle Miocene) foraminiferal assemblage from Bhuban Formation, Mizoram, NE India. *Jour. Geol. Soc. India,* **70** (6), 933-938.

Lokho, K. & Kumar, K., 2008. Fossil pteropods (Thecosomata, holoplanktonic Mollusca) from the Eocene of Assam-Arakan Basin, north-eastern India. *Curr. Sci.*, **94** (5), 647-652.

Luirei, K. & Bhakuni, S.S. 2007. Soft sediment deformational structures in the lacustrine deposits of Ziro valley, Lesser Himalaya, Arunachal Pradesh. *Jour. Geol. Soc. India*, **70**(1), 73-78.

Luirei, K. & Bhakuni, S.S. 2007. Landslides along frontal part of Eastern Himalaya in East Siang and Lower Dibang districts, Arunachal Pradesh, India. *Jour. Geol. Soc. India*, **71**(3), 321-330.

Mahajan, A.K. & Ghosh, G.K. 2007. Statistical analysis of earthquake data from Northwest Himalayan region and its implication for seismic hazards. *In: Verma, O.P., Mahajan, A.K. & Gupta, V. (eds), Natural Hazards.* Sp. Publication, Indian Geological Congress, 45-56.

Mahajan, A.K., Rob J. Sporry, Champati, P.K., Ranjan, Rajiv, Siefko Slob & Cees, J. van Westen 2007. Methodology for site response studies using Multi-channel Analysis of Surface Wave (MASW) technique in Dehradun city. *Curr. Sci.,* **92**(7), 945-955. (2006).

Mahajan, A.K., Siefko Slob, Rajiv Ranjan, Rob Sporry, Champati, P.K. & Cees J. van Westen, 2007. Seismic Microzonation of Dehradun city using Geophysical and Geotechnical Characteristics in the upper 30-meters of soil column. *Jour. Seismol.,* **11**, 335-370.

Mazari, R.K. 2007. Outline geomorphology of the upper Bhagirathi basin, Garhwal Himalaya. *Him. Geol.,* **28**(2), 45-57.

Misra, D.K. 2007. Evidences of Neotectonic activity along active faults in Arunachal Himalaya, NE India. *Him. Geol.,* **28**(2), 75-78.

Misra, D.K. 2007. Geomorphic features along the active faults in the Lohit and Dibang Valleys, Eastern Arunachal Pradesh, India. *Zeitschrift fur Geomorphologie* N.F., **51**(3), 327-336.

Mondal, S.K., Sastry, R., Pachauri, A.K. & Gautam, P.K. 2008. High resolution 2D electrical resistivity tomography to characterize active Naitwar Bazar landslide, Garhwal Himalaya, India. *Curr. Sci.,* **94**(7), 871-875.

Mukherjee, P.K. Purohit, K.K. Saini, N.K. & Khanna, P.P. 2007. Geochemical landscape of Garhwal Lesser Himalaya based on active stream sediment geochemistry. *Ind. Jour. Geochem.*, **22** (1), 79-89.

Mundepi, A.K. 2007. A comparative study of site amplification by using horizontal to vertical spectral ratio (Nakamura technique) of ground ambient noise (GAN) with earthquakes at various litho-units in NW Himalaya. *Him. Geol.* **28**(2) 69-74.

Mundepi, A.K., Kamal & Paul, A. 2007. Estimation of site amplification at various lithounits in NW Himalaya using horizontal to vertical ratio. *Jour. Geol. Soc. Ind.,* **70,** 605-609.

Mundepi, A.K. 2008. Site response studies using horizontal to vertical ratio (H/V) in the city of Chandigarh, North India. *Him. Geol.*, **29** (1), 87-93.

Nanda, A.C. & Sehgal, R.K. 2007. Geology and mammalian faunas of the Siwalik Group of Northwestern Himalaya: recent investigations. *In:* Sankhyan, A.R. & Rao, V.R.(eds), *Human Origins, Genome & People of India Genomic, Palaeontological and Archaeological Perspectives*. Allied Publishers Pvt. Ltd, New Delhi, 77-90.

Narasimhon, C.L. Patil, S.K. & Arora, B.R. 2008. A Palaeomagnetic perspective on the flows and intrusives of Kachchh Rift Basin and its implication on Reunion Plume-Indian Plate interaction. *In:* Srivastava, R., Shivaji, C. & Chalapathi Rao, N.V. (eds), *Indian Dykes: Geochemistry, Geophysics and Geochronology*. Narosa Publications, New Delhi, 159-180.

Negi, P.S. 2007. Alien flora of Doon Valley, North-West Himalaya. *Curr. Sci.,* **92**(7), 968-978.

Nummela, S., Thewissen, J.G.M., Bajpai, S., Hussain, S.T. & Kumar, K. 2007. Sound transmission in archaic and modern whales: anatomical adaptations for underwater hearing. *The Anatomical Record,* **290**, 716-733.

Panda, S.K., Choudhury, S., Saraf, A.K. & Das, J.D. 2007. MODIS land surface temperature data detects thermal anomaly preceding 08 October 2005 Kashmir earthquake. *Int. Jour. Remote Sensing*, **28**(20), 4587-4596.

Pant, P.D., Kothyari, G.C. & Luirei, K. 2007. Geomorphologic and geological investigation of neotectonic activity of Saryu River Fault (SRF), a part of North Almora Thrust (NAT) in Seraghat-Basoli area in Central Kumaun, Uttaranchal. *Jour. Geol. Soc. India*, **70**, 815-823.

Parcha, S.K., Sabnis, S.V. & Saraswati, P.K. 2007. Taxonomic application of classification and regression tree (CART) and random forests (RF): a case study of Middle Cambrian Trilobites. *Jour. Geol. Soc. India,* **70**, 1033-1038.

Patil, S.K & Arora, B.R. 2008. Palaeomagnetic and rock magnetic studies on the intrusives from Raniganj Basin, Damodar Valley: linkage to Rajmahal Volcanics. In: Srivastava, R. Shivaji, C. & Chalapathi Rao, N.V. (eds), *Indian Dykes: Geochemistry, Geophysics and Geochronology*. Narosa Publications, New Delhi, 511-526.

Paul, A., Pant, C.C., Darmwal, G.S. & Pathak, V. 2007. Seismicity of Uttarakhand as recorded by Kumaun Digital Telemetered Seismic Network. *In: Verma, O.P., Mahajan, A.K. and Gupta, V. (eds), Natural Hazards, Sp. Publication, Indian Geological Congress,* 57-63.

Paulsen, Timothy, S., Christie M. Demosthenous., Myrow, P.M., Thompson, K.R., Hughes, N.C. & Parcha, S. K. 2007. Paleostrrain stratigraphic analysis of calcite twins across the Cambrian-Ordovician unconformity in the Tethyan Himalaya, Spiti and Zanskar valley regions, India. *Jour. Asian Earth Sci.*, **31**(1), 44-54

Philip, G. 2007. Remote sensing data analysis for mapping active faults in northwestern part of Kangra valley, NW Himalaya, India. *Int. Jour. Remote Sensing,* **28**(21), 4745-4761.

Pollitz, F.F., Banerjee, P., Kelly, Grijalva, Nagarajan & Burgmann, Roland 2008. Effect of 3D viscoelastic structure on postseismic relaxation from the 2004 M=9.2. Sumatra earthquake. *Geophys, Jour. Int.*, doi:10.1111/j.1365-246X.2007.03666.x

RESEARCH PUBLICATIONS

Purohit, K.K., Mukherjee, P.K., Saini, N.K., Rathi, M.S. & Khanna, P.P. 2007. Geochemical dispersion pattern of some heavy metals in upper Alaknanda catchment: application in mineral exploration and its environmental implications. *Jour. Geol. Soc. India*, **70**, 97-108

Rana, R.S., Kumar, K., Escarguel, G., Sahni, A., Rose, K.D., Smith, T., Singh, H. & Singh, L. 2008. An ailuravine rodent from the early Eocene Cambay formation at Vastan, western India, and its palaeobiogeographic implications. *Acta Palaeontologica Polonica*, **53** (1), 1-14.

Rao, D.R. & Rai, H. 2007. Permian komatiites and associated basalts from the marine sediments of Chhongtash Formation, southeast Karakoram, Ladakh, India. *Miner. Petrol.*, **91** (3-4), 171-189.

Rao, D.R. & Rai, H. 2007. Are garnet-amphibolites and eclogites from Tso-Morari region, Ladakh evolved in a rift environment. *Deep Continental Studies-DST-Newsletter*, **17**(2), 2-6.

Rathi, G., Sangode, S.J. Kumar, R. & Ghosh, S.K. 2007. Magnetic fabrics under high-energy fluvial regime of the Himalayan Foreland Basin, NW Himalaya. *Curr. Sci.,* **92***,* 933-944.

Sachan, H.K, Mukherjee, B.K. & Bodnar, R.J. 2007. Preservation of methane generated during serpentinization of upper mantle rocks: evidence from fluid inclusions in the Nidar ophiolite, Indus Suture Zone, Ladakh (India). *Earth Planet. Sci. Lett.*, **257**, 47-59.

Sachan, H.K, Mukherjee, B.K. & Ahmad, T. 2007. Brine-rich Hydrothermal fluid circulation in the upper level of Nidar Ophiolite sequence, Ladakh: evidences from fluid inclusions. *Jour. Geol. Soc. India*, **70,** 780-786.

Sangode, S.J. & Mazari, R.K. 2007. Late Quaternary environmental changes in the Trans Himalayan Spiti valley, India: results of mineral magnetic studies on Kioto paleolake. *Him. Geol.,* **28**(2), 1-9.

Saraf, A.K., Sinha, S.T., Ghosh, P. & Choudhury, S. 2007. A new technique to remove false topographic perception phenomenon and its impacts in image interpretation. *Int. Jour.Remote Sensing*, **28**, 811-821.

Saraf, A.K., Choudhury, S., Panda, S.K., Dasgupta, S. & Rawat, V. 2007. Does a major earthquake precede a thermal anomaly? *Int. Jou. of Geoinformatics*, **3**(3), 1-8.

Sinha, R., Kumar, R., Sinha, S., Tandon S.K. & Gibling, M.R. 2007. Late Cenozoic fluvial deposits of India: an overview. *Quatern. Sci. Review.*, **26**, 2801–2822.

Sinha, S., Islam, R. Ghosh, S. K., Kumar, R. & Sangode, S.J. 2007. Geochemistry of Neogene Siwalik mudstones along Punjab re-entrant, India: implications for source-area weathering, provenance and tectonic setting. *Curr. Sci.,* **92**, 1103-1113.

Singh, A.K. 2007. Chemical characteristics of alkaline basalt from the Abor volcanics of Arunachal Himalaya. *Jour. Geol. Soc. India*, **69**, 189-1194.

Singh, S.K. Rai, S.K. & Krishnaswami, S. 2008. Sr and Nd isotopes in river sediments from the Ganga Basin: Sediment provenance and spatial variability in physical erosion, *Jour. Geophys. Res.,* 113, F03006, doi: 10.1029/2007JF000909.

Singh, T. & Virdi, N.S. 2007. Tectonic activity classes along the Nahan thrust (NT) in NW sub Himalaya. *Jour. Ind. Soc. Remote Sensing,* **35**(3) 221-230.

Siva Siddaiah, N. 2008.Berthierine-rich Ooidal Ironstone from the Late Palaeocene- Middle Eocene Subathu Formation, Dogadda area, NW Himalaya and its Stratigraphic Significance. *Curr. Sci.*, **94**(1), 123-127.

Sundriyal, Y.P., Tripathi, J.K., Sati, S.P., Rawat, G.S. & Srivastava, P. 2007. Landslide dammed lakes in the Alaknanda basin (Lesser Himalaya): causes and implications. *Curr. Sci.*, **93**, 568-574.

Suresh, N., Bagati, T.N., Kumar, R. & Thakur, V.C. 2007. Evolution of Quaternary alluvial fans and terraces in the intramontane Pinjaur Dun, Sub-Himalaya, NW India: interaction between tectonics and climate change. *Sedimentology*, **54**, 809-833.

Tewari, V.C 2007. The rise and decline of the Ediacaran biota: palaeobiological and stable isotopic evidence from the NW and NE Lesser Himalaya, India. *Geological Society of London , Special Publication*, **286**, 77- 101.

Tewari, V.C , Stenni Barbara, Pugliese Nevio, Drobne Katica, Riccamboni Rodolfo & Dolence Tadej. 2007. Peritidal sedimentary depositional facies and carbon isotopic variation across K/T boundary carbonates from NW Adriatic platform. *Palaeogeogr. Palaeoclim. Palaeoecol.,* **255**, 77- 86.

Thewissen, J.G.M. Cooper, L.N. Clementz, M.T. Bajpai, S. & Tiwari, B.N. 2007. Whales originated from aquatic artiodactyls in the Eocene epoch of India. *Nature*, **450**(7173), 1190-1194. doi:10.1038/ nature06343

Tiwari, M. 2008. Additional Neoproterozoic sponge spicules from Gangolihat Dolomite, Kumaun Lesser Himalaya, India. *Him. Geol.,* **29** (1), 49-55.

Virdi, N.S. & Gupta, V., 2008. Hydel projects in the Yamuna and Tons valleys, Dehradun. *Excursion Guide, Publ. CAS in Geology*, Panjab University, Chandigarh, 20p.

Yeats, R.S. & Thakur, V.C. 2008. Active faulting south of the Himalayan front: establishing a new plate boundary. *Tectonophysics*, **453**, 63-73

Papers In-Press/ Communicated

Ahmad T., Tanaka T., Sachan, H.K, Asahara Y., Islam R. & Khanna P.P. Geochemical and isotopic constraints on the age and origin of the Nidar Ophiolitic Complex, Indus Suture Zone, Ladakh, India. *Tectonophysics* (in press).

Asthana, A.K.L. & Sharma, B.P. Geomorphological study in Alaknanda valley, Garhwal Himalaya. *In:* Rawat M.M.S. (ed.) Management and Strategies in the Himalaya (in press).

Azmi, R.J. Joshi, D. Tiwari, B.N. Joshi, M.N. & Srivastava, S.S. Some observations on recent radiometric dates from the Vindhyan Supergroup of Central India, and a synthesis of latest bio- and geo-chronological results. *Himalayan Geology* (comm).

Bartarya, S.K., Sharma, A. & Khanna, P.P. Hydrochemistry of water from Indus Suture Zone in Ladakh Himalaya: effects of bedrock geology and tectonics on chemical weathering. *Chem. Geol.* (comm.).

Bhambari, R. & Chaujar, R.K. Recession of Gangotri glacier (1962-2006) measured through remote sensing data. *Proceedings of National Seminar on Management Strategies for the Indian Himalaya: Development and Conservation* (in press).

Bhambri, R & Chaujar, R.K. Changes/shrinkage in the Chorabari glacier, Garhwal Himalaya, as measured from the ground and space. *Curr. Sci.* (comm.).

Bhandari, A., Mohabey, D.M, Bajpai, S, Tiwari,. B.N. & Pickford, M. Early Miocene mammals from central Kutch (Gujarat) western India: implications for geochronology, biogeography, eustacy and intercontinental dispersals. *N Jb. Geol. Pal. Abh.* (comm.).

Brook, G.A., Srivastava, P., Haberyan, K., Brook, F.Z., Robbins, L.H., Campbell, A.C., Murphy, M.M. & Shepherd, M. Late Pleistocene-Holocene sedimentation history of Lake Ngami, Botswana, at the Kunyere-Nchabe river inlet: a response to climatic fluctuations (comm.).

Chaujar, R.K. & Dobhal, D.P. Glacial landforms and history of advance and retreat of Dokriani glacier, Garhwal Himalaya, India. *In:* Geomorphology in India, Indian Institute of Geomorphology, Allahabad (comm.).

Devrani, U. & Dubey, A.K. Anisotropy of magnetic susceptibility and petrofabric studies in the Garhwal Synform, Outer Lesser Himalaya: evidence of pop-up klippen. *Island Arc* (in press).

Dobhal, D.P. Spatial distribution and morphometric analysis of Glaciers in Bhagirathi river basin, Garhwal Himalaya, India. *Curr. Sci.* (comm.).

Dobhal, D.P. Chaujar, R.K. & Gergan, J.T. Glacial geomorphology of Dokriani glacier, Bhagirathi river basin, Garhwal Himalaya,). *Proceedings of National Seminar on Maagement Strategies for the Indian Himalaya: Development and Conservation* (comm.).

Dubey, A. K. The leading edge of the Greater Himalayan Crystalline Complex revealed in the NW Indian Himalaya: implications for the evolution of the Himalayan region: comment. *Geology* (in press).

Gitis, V. Yurkov, E. Arora, B. R. Chabak, S. Kumar, N & Baidya, P. Analysis of seismicity in North India. *Russian Jour. Earth Sci.* (comm.).

Gupta, V. Evaluation of landslides in the Satluj valley, Northwestern Higher Himalaya, India, *Buletin*

RESEARCH PUBLICATIONS

Indian Geological Congress, Roorkee (in press).

Gupta, V & Sah, M.P. The relationship between Main Central Thrust (MCT) and the spatial distribution of mass movement in the Satluj valley, Northwestern Higher Himalaya, India, *Zeitscrift fur Geomorphologie* (in press).

Gupta, V & Sah, M.P. Impact of the Trans-Himalayan landslide lake outburst flood (LLOF) in the Satluj catchment, Himachal Pradesh, India. *Natural Hazards*, (in press).

Gupta, V & Sah, M.P Spatial variability of mass movements in the Satluj valley, Himachal Pradesh during 1990-2006, *Jour. Mountain Sci.* (in press).

Gupta, V., Mazari. R.K. & Rautela, P. Engineering geological characterization of a landslide on the slope of Mansa Devi hill near, Haridwar, Uttarakhand. *Him. Geol.* (comm.).

Khanna, P.P., Saini, N.K., Mukherjee, P.K. & Purohit, K.K. An appraisal of ICPMS technique for REEs determination: long term QC assessment of silicate rock analysis. *Him. Geol.*(comm.).

Kothyari, G.C., Bhakuni, S.S. & Pant, P. D. Neotectonic activity along North Almora Thrust Zone, Kumaun Lesser Himalaya: field and digital elevation modeling (DEM) studies. *Geomorphology* (comm.).

Kothyari, G.C, Pant, P. D, Bhakuni, S.S. & Chauhan, Ritu. Deformation of fluvio-lacustrine deposit in North Almora Thrust Zone: Kumaun Lesser Himalaya, Uttarakhand. *Curr. Sci.* (comm.).

Kothyari, G.C., Bhakuni, S.S. & Pant, P. D. Status of neotectonics near NW of proposed Pancheshwar dam site on Kali river, Kumaun Lesser Himalaya, Uttarakhand. *Curr. Sci.* (comm.).

Kumar, Naresh, Sharma, Jyoti,. Arora, B.R and Mukhopadhyay, S. Seismotectonic model of Kangra-Chamba sector of NW Himalaya: constrained by joint hypocenter determination and fault plane solutions. *Bull. Seis. Soc. Amer.* (comm.).

Kumar, Naresh, Sharma, Jyoti,. Arora, B.R & Mukhopadhyay, S. 3D local tomography model of Kangra-Chamba region of NW Himalaya and its implications for seismic zoning. *Geophys. Res. Lett.* (comm.).

Luirei, Khayingshing & Bhakuni, S.S. Geomorphic imprints of neotectonic activity along the frontal part of Eastern Himalaya, Pasighat, East Siang District, Arunachal Pradesh. *Jour. Geol. Soc. India.* (in press).

Luirei, Khayingshing & Bhakuni, S.S. Ground tilting in Likhabali area along the frontal part of Arunachal Himalaya: evidence of neotectonics. *Jour. Geol. Soc. India* (in press).

Lyubushin A.A., Arora, B.R. Kumar, Naresh, Chabak, S.K. & Baidya, P.R. Investigation of seismic regime in Western Himalaya. *Jour. of Seismol.* (comm.).

Mahajan, A.K.. Thakur, V.C Sharma, M. L. & Chauhan, M. Probabilistic seismic hazard map of NW Himalaya and its adjoining area, India. *Natural Hazards* (comm.).

Mahajan, A.K, NEHRP soil classification and estimation of 1-D site effect of Dehradun fan deposits using shear wave velocity. *Engineering Geology (comm.*).

Malik, J.N, Nakata, T, Philip, G. Suresh, N. &. Virdi. N.S. Evidence of a large magnitude earthquake along Chandigarh Fault in the Frontal Himalayan zone, NW India. *Himalayan Geology* (in press).

Mathur, N.S., Juyal, K.P. & Kumar, K. 2008. Biotic response to Cretaceous-Eocene tectonic events at the northern margin of the Indian Plate and the Indus Suture Zone, Ladakh Himalaya, India. *Jour. Pal. Soc. India* (in press).

Mazari, R.K. Glaciation, tectonics and glacier wandering in Spiti-Chandra watershed region, Himachal Himalaya, India. *Jour. of Quarter. Sci.*(in press).

Misra, D.K. Geology and tectonic features of the Kameng-Subansiri sector of Western Arunachal Pradesh. *Jour. Geol. Soc. India* (comm.).

Misra, D.K. Geological setting and deformational features along the Lohit and Dibang Valleys, Eastern Arunachal Pradesh. *Jour. Geol. Soc. India* (comm.).

Misra, D.K. River response to continuing movements along the active faults in the Siang valley, Eastern

Arunachal Pradesh, India. *Zeitschrift für Geomorphologie* (comm.).

Mukherjee B.K., & Sachan, H.K, Characterization of fluids in coesite bearing rock of Tso Morari region, NW Himalaya: evidence of entrapment during peak metamorphism. *Geol. Mag.* (comm.).

Mukherjee, P.K. & Gupta, P.K. A simplified minimum norm approach for estimation of volume strain and geochemical mass transfer in metasomatic alterations. *Chem. Geol. (*comm.).

Mukherjee, P.K. & Gupta, P.K Arbitrary scaling in ISOCON method of geochemical mass balance: an evaluation of the graphical approach. *Geochem. Jour.* (in press).

Nanda, A.C. Comments on the Pinjor mammalian fauna of the Siwalik Group in relation to the Post-Siwalik faunas of Peninsular India and Indo-Gangetic Plain. *Quater. Int.* (in press).

Negi P.S. Biotic stress on Himalayan progenitors and their significance for conservation of genetic resource - A case study of Doon valley and adjacent area. *Jour. Environ. Management* (comm.).

Pant, P.D., Kothyari, G.C. Khayingshing Luirei & Joshi, S. Neotectonic rejuvenation along a part of South Almora Thrust (SAT) in Kakright-Bamsyu area, Kumaun Himalaya, Uttaranchal. *Jour. Earth Sys. Sci.* (comm.).

Patnnaik, R. & Nanda, A.C. Early Pleistocene mammalian faunas of India and evidence of connections with other parts of the world. Stony Brook Volume (in press).

Parcha, S.K. Himalayan trilobite fauna: present status with respect to the Cambrian Biostratigraphy (in press).

Paul M., Nigel C. Myrow, Hughes, Searle, Peng, S.C. & Parcha, S.K. Stratigraphic correlation of Cambrian-Ordovician deposits along the Himalaya: implications for the age and nature of rocks in the Mt. Everest region (comm.).

Parcha, S.K & Singh, B.P. Cambrian ichnofossils from the Zanskar Himalaya and their paleoenvironmental and palaeoecological implications (comm.).

Paul, A. Evaluation and implications of seismic events in Garhwal-Kumaun region of Himalaya (comm.).

Paul, A. & Bhakuni, S.S. Microseismicity in central part of Kumaun Inner Lesser Himalaya: implication to active tectonics (comm.).

Paul S.K., Diachronous India-Asia collision: evidence from Indus Suture Zone, eastern Ladakh, NW Himalaya. *Ofioliti* (comm.).

Phadtare, N.R., Extreme dry climate events in Central Himalaya during the past two millennia and their links to Indian summer monsoon (comm.).

Raju, D.S.N. Ramesh, P., Shankar, R., Kumar, P., Prabhakaran, S., Kapesa Lokho & Singh, B.P. Stratigraphic mega charts for the Indian subcontinent. Placed in the website by International Commission on Stratigraphy. *Spl. Publication ONGC Bulletin* (in press).

Rai, H. & Rao, D.R. 2007. Granite magmatism along southern margin of eastern Karakoram, Ladakh, India. *In:* Santosh Kumar (ed.), Proceeding *of National Seminar on Magmatism, Tectonism and Mineralization* (MTM-2007), Nainital (comm.).

Ramola, R.C Prasad, Y. Prasad, G Kumar, Sushil & Choubey. V.M. Soil-gas radon as seismotectonic indicator in Garhwal Himalaya, *The Int. Jour. Applied Radiation Isotopes* (in press).

Schopf, J.W., Tewari, V.C. & Kudryavtsev, A. Discovery of a new chert perminer alised microbiota in the Proterozoic Buxa Formation of the Ranjit Window, Sikkim, NE India, and its astrobiological implications. *Int. Jour. Astrobiology* (in press).

Sharma R. Sulphide mineralization in uprising lithotectonic belt of Lesser Himalaya. *In:* Santosh Kumar (ed.), Proceeding *of National Seminar on Magmatism, Tectonism and Mineralization* (MTM-2007), Nainital (comm.).

Sharma R. & Rao, D.R. Fluid inclusion studies of granitoid rocks from the central part of Askot Crystallines, Kumaun Himalaya. *Him. Geol.* (in press).

Sharma R. & Rao, D.R Stannoidite and cubanite from Askot Polymetallic Sulphides, Kumaun Lesser Himalaya, India. *Curr. Sci.*(comm.).

Sharma R, Prabha, J. & Pant, P.D. Fluid Related to the formation of talc deposits of Rema area, Kumaun Lesser Himalaya, India. *Jour. Geol. Soc. Ind.* (comm.).

Singh, A.K., Devala Devi, L. & N. Ibotombi N.S. Platinum group of elements (PGE) and gold in the ultramafic rocks of Manipur Ophiolitic Complex, North East India: a preliminary report. *Jour. Geol. Soc. Ind.* (in press).

Singh, A.K. Geology and geochemistry of the Manipur Ophiolitic Complex (MOC), Indo-Myanmar Orogenic Belt, Northeast India. *Special Issue of Journal of the Geological Society of India on "Orthomagmatic ore deposits related to mafic-ultramafic rocks with special emphasis (comm.).*

Singh, A.K. Report of platinum group of element (PGE) concentration in podiform chromites of Manipur Ophiolite Complex, Indo-Myanmar Orogenic belt, Northeast India. *Curr. Sci.* (comm.).

Singh, A.K, Ibotombi, N.S., Devala Devi, L. & Singh Bikramaditya, R.K. Pillow basalts from the Manipur Ophiolitic Complex (MOC), Indo-Myanmar Range, Northeast India. *Jour. Geol. Soc. Ind.*(in press).

Singh, A.K. Geochemistry and platinum group of elements (PGE) of ultramafic rocks and chromites of Manipur Ophiolitic Complex, Northeast India. *In:* Santosh Kumar (ed.), Proceeding *of National Seminar on Magmatism, Tectonism and Mineralization* (MTM-2007), Nainital (in press).

Singh, A.K & Vallinayagam, G. Distribution of radioelement and rare-metal mineralization in A-type acid plutonic-volcanic rocks from the Neoproterozoic Malani Igneous Suite, Western Peninsular India. *Jour. Petrol. Miner.* (comm.).

Singh, K. The reactivation in the hangingwall of Main Central Thrust: an example of break-back thrust along the Kishtwar Window, northwest Himalaya, India. *Jour. Asian Earth Sci.* (comm.).

Singh, K. Can opposite vergent folds form in a single deformational phase? structural evidences from Chamba Thrust Sheet, Chamba-Lahaul region (northwest Himalaya), India. *Geol. Jour.* (comm.).

Singh, Bikramaditya R.K., Gururajan, N.S & Singh, A.K. Petrology and geochemistry of amphibolites of the Bomdila Group, Western Arunachal Himalaya. *Jour.l of Applied Geochemistry* (in press).

Sinha S., Sen, K., Sangode, S. J., Kumar, R. & Ghosh S. K. Sedimentology and AMS studies along a part of the Siwalik Foreland Basin: implications for tectono-sedimentary expression, Nurpur Salient, NW Himalaya, India. *Curr. Sci.* (in press).

Sinha S., Mukherjee, P.K., Kumar, R., Ghosh, S.K. & Sanyal, P. Sedimentologic and stable isotope evidences for a strong aridity at 9.1 Ma from the Himalayan Foreland Basin sediments, NW Himalaya, India. *Gondwana Res.* (comm.)

Sinha S., Ghosh, S.K., Kumar, R., Islam, R., Sanyal, P. & Sangode, S.J. Role of tectono climatic factors in the Neogene Himalayan Foreland Sediments: petrology and geochemical approach, Kangra Sub-Basin. *Jour. Geol. Soc. Ind.* (in press).

Srivastava, P., Bhakuni, S.S., Luirei, K. & Misra, D.K. Fluvial records from the Brahmaputra river exit, NE Himalaya: climate-tectonic interplay during Late Pleistocene-Holocene. *Jour. Quater. Sci.* (in press).

Srivastava, P. Tripathi, J.K., Islam, R & Jaiswal, M.K. Fashion and phases of Late Pleistocene aggradation and incision in Alaknanda River, western Himalaya, India. *Quater. Res.* (in press).

Srivastava, P. & Misra, D.K. Morpho-sedimentary records of active tectonics at the Kameng river exit, NE Himalaya. *Geomorphology* (in press).

Siddaiah, Siva N. Geochemistry and genesis of ooidal ironstone from Late Paleocene-Middle Eocene Kakara-Subathu formations, NW Himalaya. *Chem. Geol.* (comm.).

Siddaiah, Siva N. & Kumar, K. Reply to ash beds from the Himalayan Foreland Basin: their nature and significance. *Curr. Sci.* (comm.).

Tewari, V.C Proterozoic unicellular and multicellular fossils from the NE Lesser Himalaya , India and their astrobiological implications. *In*: Seckbach, J. (ed.), *From Fossils to Astrobiology,* Springer Verlag (in press).

Thakur V.C. Active tectonics of the Himalaya. Golden Jubilee Volume. *Jour. Geol. Soc. Ind.* (in press).

Tiwari, M. & Pant, Indu. Microfossils from the Neoproterozoic Gangolihat Formation, Kumaun

Lesser Himalaya; their stratigraphic and evolutionary significance. *Jour. Asian Earth Sci.* (comm.).

Popular Article

Dobhal, D.P. 2007. Garmiyon me bhari himpat: ek mausmi vibinnta. *Ashmika*, **13**, 12-15

Negi, P.S. 2007. Himalaya me javtakneeki dwara bhooskhalan wale chetron ki pahichan. *Ashmika*, **13**, 6-9.

Rawat, R.S.2007, Khuli arth vyastha evm vigyan: Uttarakhand ke pariprakhya main. In: Special Issue of Sainya Sandesh on Uttarakhand *on the Occasion of Diamond Jubillee Celerbation of Indian Union's Independance by the All India Purv Sainik Sewa Parishad*, Dehradun, 4th Issue, August 2007, 3-16.

Rawat, R.S.,2007, Uttarakhand ki prakritik khanij sampadyan evm unka dohan. *In*: *A Special Issue of Sainya Sandesh on Uttarakhand on the* Occasion of *Diamond Jubillee Celebration of Indian Union's Independence by the All India Purv Sainik Sewa Parishad*, 4th Issue August 2007, 26-27.

Technical Reports

Bist, K.S. 2007. Field excursion guide on 'Lithotectonic sequence of Outer and Lesser Himalaya from Dehradun to Mussoorie and Rishikesh to Deoprayag in Dehradun and Tehri districts, Garhwal Himalaya, Uttarakhand', 1-18.

Bist, K.S. & Asthana, A.K.L. 2008. Feasibility report on the geological investigation of Basan road through Basan slip zone near Kalsi, Yamuna valley, Uttarakhand. 1-11.

Gupta, V. & Bhakuni, S.S. 2007. Stabilization of cut slope at 132 kv Sub-Station, Satpuli (Pauri Garhwal), submitted to Executive Engineer, Uttarakhand Power Transmission Corporation, Dehra Dun, 5 pages with 3 figs and 4 maps.

Mazari, R.K., Sah, M.P. & Gupta, V. 2007. Report on the relative slope stability in Mussoorie Muncipal Area, District Dehra Dun, submitted to Mussoorie Dehra Dun Development Authority (MDDA) Dehra Dun, 14 pages and 6 figures.

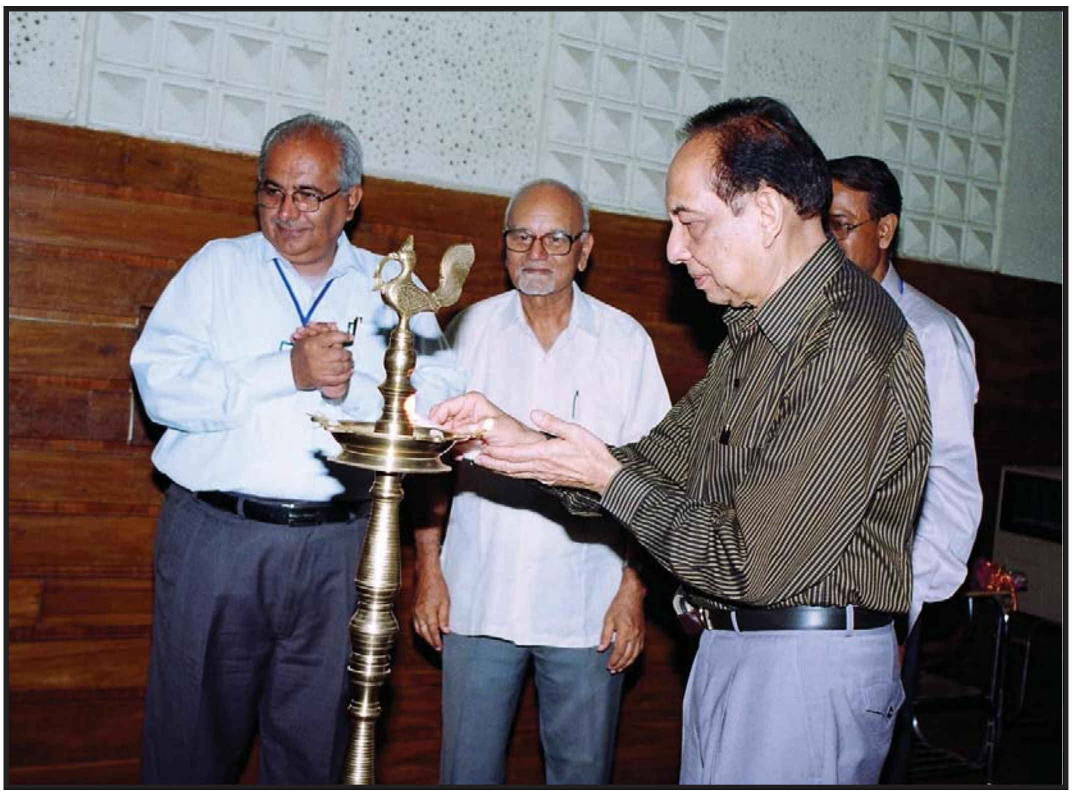
Sah, M.P. & Gupta, V. 2007. Geological feasibility of a site for the proposed residential house at Radha Bhawan Estate, New Circular Road, Mussoorie.

SEMINAR/SYMPOSIA/WORKSHOP ORGANIZED

Workshop on 'Collision Zone Geodynamics'

Institute organized a workshop on 'Collision Zone Geodynamics' at its premise during September 20-21, 2007, to commemorate the golden jubilee year of the Geological Society of India. Director, on behalf of the Wadia Institute and geoscience community, felicitated the Geological Society of India on this occasion and appreciated its role in disseminating the geoscientific knowledge. Special tributes were paid to Dr. B.P. Radhakrishna for steering the Society from its inception to its glorious golden jubilee year. Dr. Harsh Gupta, Present President, Geological Society of India and Dr. K.R. Gupta, Convener, Northern Chapter of the Geological Society of India graced the occasion.

Chief Guest, Dr. Harsh Gupta in his inaugural address stressed on the possibility that triggered earthquakes in Koyana reservoir area can be predicted since earthquakes occur in a small area of 30 X 15 km and there are no other seismically active tectonic elements in the vicinity. Special invitees were Dr. Djordje Grujic, Department of Earth Sciences, Dalhousie University, Canada; and Prof. L. Vinnik, Institute of Physics of the Earth, Russian Academy of Sciences, Moscow, who delivered talks on "Channel Flow Model" and "Upper Mantle Beneath the Foot Hills of Western Himalaya - Subducted Lithospheric slab or a keel of the Indian Shield". The other prominent speakers were Prof. T. Ahmad, Dr. B.R. Arora, Dr. T.R.K. Chetty, Dr. A.K. Dubey, Prof. B. Prakash, Dr. Mita Rajaram, Dr. Y.J. Bhaskar Rao, Prof. R.S. Sharma, Dr. S. Sinha Roy, Prof. D.C. Srivastava, Dr. V.C. Thakur, etc.



Chief Guest Dr. H.K. Gupta along with Dr. B.R. Arora and Shri D.P. Dhondiyal lighting the lamp during the inaugural function of workshop on 'Collision Zone Geodynamics'.

About eighty participants from various organizations participated in this event. The deliberations were arranged in six technical sessions starting with one/two invited talks. Technical proceedings of first day included first session devoted on "Collision Tectonics", second session on the "Crustal Deformation" followed by a session on "Climate and Tectonics". On 21st September three technical sessions were organized which included "Geophysical Imaging", "Magmatism", and third on the "Dynamic Evolution". Highlight of the workshop was Poster session primarily for young researchers from various participating institutions. Three selected posters were given cash prizes with citation for their best overall presentation.

A parallel program was organized in the morning of 21st September, 2007 to launch the Institute's program for the International Year of Planet Earth. Dr. P.S. Goel, Secretary, Ministry of Earth Sciences, Government of India, was the Chief Guest. In the inaugural address, he pointed that the time has come for integrated and interdisciplinary research in the field of Earth Sciences. Outreach program to disseminate knowledge of earth system sciences for the healthier and wealthier society should be the central theme of the Wadia Institute program for the international Year of Planet Earth.

In the valedictory session, it was recommended that integrate geological, geophysical, geochronological and geochemical studies along selected geotransect across the Himalayan orogen coupled with GPS and seismic monitoring network will shed new insight into the evolution model of the Himalayan orogen and provide better understanding of the geological processes controlling seismic hazards. A special focus would be on real time geodynamic processes allowing sustainable management of natural resources and providing clues to cope up with natural hazards.

Chief Guest Dr. P.S. Goel, Secretary, Ministry of Earth Sciences (Govt. of India) along with Dr. B.R. Arora, and Dr. N.C. Mehrotra sharing the Dias during the inaugural function of International Year of Planet Earth.

VISITS ABROAD

- Dr. V.C. Tewari visited the Centre for the Study of Evolution and the Origin of Life (CSEOL), University of California, Los Angeles, USA as Research Scientist on May 7-27, 2007.
- Dr. R.K. Mazari visited International Centre for Integrated Mountain Development (ICIMOD), Kathmandu, Nepal to attend Regional Workshop on Social Inclusion in Disaster Risk Reduction in the Himalayan Region: Sharing Knowledge and Bridging Gaps on May 9-11, 2007.
- Dr. P.S. Negi visited Bejing, China to attend International Seminar on Global Eco-Summit Ecological Complexity and Sustainability: Challenge and Opportunities for 21st Century's Ecology on May 22 –24, 2007.
- Dr. R.J. Azmi attended 22nd Himalayan Karakoram Tibet Workshop at the University of Hong Kong, SAR China on May 22-25, 2007.
- Dr. B.R. Arora visited Peruvia Italy to attend IUGG General Assembly on July 2-13, 2007.
- Dr.V.M. Choubey visited Taipei (Taiwan) to attend International Conference on Gas Geochemistry on October 1-8 2007.
- Dr. V.C. Tewari visited International Centre for Theoretical Physics , Trieste , Italy as Senior Associate from 1 October to 22 December 2007.
- Dr. P. Banerjee visited Phuket, Thailand to attend International Symposium on Restoration Programs from Great Earthquakes and Tsunamis on January 22-24, 2008.

MEMBERSHIP OF NATIONAL/INTERNATIONAL COMMITTEES

Name of the Scientist	Status	Prestigious Committee/s outside WIHG
B.R.Arora	Member	Editorial Board Current Science.
	Member	Advisory Committee to *review SAP Program of UGC, ISM, Dhanbad.*
	Member	Sectional Committee for Earth and Planetary Sciences for the year 2008, Indian Academy of Sciences, Bangalore.
	Member	Governing Council of Frontier Basins, Oil & Natural Gas Corporation.
	Member	Expert Committee on " Integrated Program on the Dynamics of Glaciers in the Himalaya, Department of Science and Technology, Govt. of India
	Member	Study Group on Himalayan Glaciers, Department of Science and Technology, Govt. of India
	Member	Group Monitoring Committee on Seismicity Programme, Ministry of Earth Sciences, Govt of India
	Member	Executive Council of the Geological Society of India.
	Member	Editorial Board of the Indian Society of Applied Geochemists, Hyderabad.
	Member	Advisory Committee of SAP-CAS, Panjab University, Chandigarh.
G. Philip	Chairman	*Indian Society of Remote Sensing- Dehradun Chapter*
R. Sharma	Member	Scientific Committee - II Asian Current Research on Fluid inclusions (International Body), 2008, IIT Kharagpur.
	Advisor	South Asian Association of Economic Geologists.
	Member	Editorial Board- Iranian Journal of Earth Sciences, Iran
T.N.Jowhar	Member	Indian Science Congress, Calcutta.
	Executive Member	Computer Society of India, Dehra Dun Chapter.
D.R. Rao	Member	Working Group of IGCP-510 : 'A-type granite'
S,K.Bartarya	Member	Himalayan Society for Landslides and Environment, Nepal.
Vikram Gupta	Member	National Disaster Management Authority (NDMA), New Delhi
	Member	Uttarakhand State Disaster Management Authority.
Santosh K. Rai	Member	Geochemical Society, America.

AWARDS AND HONOURS

- Dr. D.P Dobhal was recognized as "Heroes of the Environment" by the prestigious Times magazine.
- Dr. Pradeep Srivastava received G.K. Gilbert Award for Excellence in Geomorphological Research from American Association of Geographers, United States (2007).
- Dr. Pradeep Srivastava received Most Cited Paper Award (2004-2007) from the scientific journal Palaeogeography, Paleoecology and Paleoclimatology of Elsevier (2007).
- Shri Santosh K. Rai received DST Young Scientist Prize (second) at the 3rd Meeting of the PAC-ES at VIT University, Vellore (Tamil Nadu) on 17th-19th January 2008.

Ph.D. THESES

Name	Supervisor	Title of the Theses	University	Awarded/ Submitted
Yogesh Prasad	Dr. R.C. Ramola Dr. V.M.Choubey	Occurrence of radon in soil and water in relation to lithology and seismic activity.	HNB Garhwal University, Srinagar, Garhwal	Awarded
Dirghayu Prasad	Dr. B.L. Dhar Dr. R.K.Mazari	Landform-soil-forest relationship in the Kiarda Dun, District Sirmour, H.P.	FRI University Dehra Dun	Awarded
Ms Jyoti Shah	Prof.D.C. Srivastava .P.K. Mukherjee	New Methods of strain Analysis and deformational Style of Kumaun Lesser Himalaya	IIT, Roorkee	Submitted
V. Kumaravel	Dr N. Siva Siddaiah Dr. S. J. Sangode	Rock magnetic and Geochemical Character- -ization of Plio-Pleistocene Paleosols from the Siwalik group of the Himalayan Foreland Basin, NW Himalaya	HNB Garhwal University, Srinagar, Garhwal	Submitted

PARTICIPATION IN SEMINARS/SYMPOSIA/ WORKSHOPS/ TRAINING COURSES

- Third Meeting of the Steering Committee on Snow & Glaciers and Coastal Zone Projects (sponsored by MoEF) at SAC, Ahmedabad, April 13, 2007.
  Participant: R.K. Mazari

- International Conference on Geoenvironments: A Challenge Ahead, Centenary of the establishment Department of Geology, Jammu University, Jammu, April 23-25, 2007.
  Participants: B.R. Arora and A.K. Mahajan

- 3rd Group Monitoring Workshop cum 5th Meeting of DST on Fast Track Proposals for Young Scientists in Earth & Atmospheric Sciences at IICT, Hyderabad, April 27– 28, 2007.
  Participant: A. Krishnakanta Singh

- Regional Workshop on Social Inclusion in Disaster Risk Reduction in the Himalayan Region: Sharing Knowledge and Bridging Gaps, organised by ICIMOD, Kathmandu, Nepal, May 9-11, 2007.
  Participant: R.K. Mazari

- International Seminar on Global Eco-Summit 2007. Ecological Complexity and Sustainability: Challenge and Opportunities for 21st Century's Ecology, organized by International Ecological Association at Bejing, China, May 22-24, 2007.
  Participant: P.S. Negi

- 22nd Himalaya-Karakoram-Tibet Workshop, Hong Kong, May 22-25, 2007.
  Participant: R.J. Azmi

- International Symposium on Ecological Restoration: Dialogues Between Scientists, Government and Enterprises, organized by Ministry of Science and Technology, People's Republic of China, Men-Tou-Gou. Bejing, China, May 25- 27, 2007
  Participant: P.S. Negi

- National Workshop on Environmental Geo-Hazards (Earthquakes, Landslides, Floods, etc.): Management and Mitigation Strategy for Himachal Pradesh at District Headquarter Mandi, June 4-5, 2007.
  Participant: Vikram Gupta

- Colloquium on Neotectonics and its Seismic Implications in Frontal Himalaya and Adjoining Plains, Department of Geology, Panjab University Chandigarh, 7-8 June, 2007.
  Participant: G. Philip

- Humboldt Workshop-2007, Nainital, June 8-10, 2007.
  Participant: R.J. Azmi

- Preventive Maintenance Training and Advanced Operational Training of SX-100 EPMA at NGRI, Hyderabad. June 18-29, 2007.
  Participants: D.R. Rao and H.K. Sachan

- National Symposium on SSNTD and their Application at H.N.B. Garhwal University Tehri Campus, June 21-23, 2007.
  Participant: S.K. Bartarya

- IUGG XXIV General Assembly Perugia Italy, July 2-13, 2007
  Participant: B.R. Arora

- DST Sponsored Field Workshop on Crustal Dynamics in Godavari Triple Junction, July 9-8, 2007.
  Participant: Narendra K. Meena

- 5th Course on Microwave Remote Sensing and Applications at IIRS, Dehra Dun, July 9-12, 2007.
  Participant: Swapnamita Choudhury

- Brain Storming Session on Study of Himalayan Glaciers, organized by Wadia Institute of Himalayan Geology and DST at Dehra Dun, August 12, 2007.
  Participants: R.K. Mazari, M.P. Sah, S.K. Bartarya, D.P. Dobhal and P.S Negi

- Geological Expedition to Ladakh and Karakoram Mountains as invited faculty member, IIT Roorkee, August 11-22, 2007.
  Participant: P.K. Mukherjee

- Workshop on National Building Code of India 2005, organized jointly by Bureau of Indian Standards (BIS) and The Institution of Engineers (IE) (India), Dehra Dun, September 1-2, 2007.
  Participant: Vikram Gupta

- Intensive Training Course (Prabodh), Central Hindi Training Institute, New Delhi, September 5-10, 2007.
  Participant : Kapesa Lokho

- Conference on Asian Monsoon Variability held at Nainital, September11-14, 2007.
  Participant: Pradeep Srivastava

- VIth Training Course in Glaciology, organized by GSI Training Institute, August 26 to September 20, 2007.
  Participant: Swapnamita Choudhury

- Brain Storming Session on Receding of Himalayan Glaciers at Vigyan Bhavan, New Delhi convened by Principal Scientific Advisor to Government of India, September, 9, 2007.
  Participants: B.R.Arora, R.K. Mazari and D.P.Dobhal

- Workshop on Collision Zone Geodynamics "Geocollision-2007", WIHG, Dehra Dun, September 20-21, 2007.
  Participants: B.R. Arora, R.J. Azmi, P.P. Khanna, S.K. Ghosh, K. Kumar, N.S. Siddaiah, R.S. Rawat, B.N. Tiwari, R. Sharma, P. Banerjee, N.K. Sachan, Rajesh S. and Gautam Rawat.

- Workshop on Uttarakhand, organised by the All India Ex-Servicemen Association-Diamond Jubilee Celebration, September 2007.
  Participant: R S Rawat

- 15th Convention of Indian Geological Congress and National Seminar on Geoexploration and Metal Mining: Vision 2025,t Dharwad, September 27, 2007.
  Participant: B.R.Arora

- 9th International Conference on Gas Geochemistry, held in Taipie, Taiwan , October 1-8, 2007.
  Participant: V.M. Choubey

- Workshop on Indian Contribution to the International Science Years at INSA, New Delhi October 3, 2007.
  Participant: B.R.Arora

- Workshop on Accelerator Mass Spectrometry at Inter-University Accelerator Center, New Delhi, October 5, 2007.
  Participant: Pradeep Srivastava

- Physics of the Living State Seminar, International Centre for Theoretical Physics, Trieste, Italy, October 25, 2007.
  Participant: V.C.Tewari

- National Seminar on Management Strategies for the Indian Himalayan Development and Conservation, organized by HNB Garhwal University, Srinagar Garhwal, October 29-31, 2007.
  Participants: R.S. Rawat and D.P. Dobhal

- National Seminar on Magmatism, Tectonism and Mineralization and Tenth Convention of the South Asian Association of Economic Geologists, Kumaun University, Nainital. October 29-31, 2007.
  Participants: R. Sharma and Barun K. Mukherjee

- National Field Workshop on Neogene Successions of Mizoram in the Context of India-Asia Collision, Mizoram University, Aizawl, November 1-3, 2007.
  Participants: Kishor Kumar and Kapesa Lokho

- National workshop on Global Warming and Consequences, organized by Institute of Instrumental Research and Development (IIRD), Dehra Dun, November 15-16, 2007.
  Participants: D.P. Dobhal and P.S.Negi

- 2nd Uttarakhand Science Congress at Administrative Training Institute (ATI), Nainital, organized by Kumaun University, Nainital, November 15-17, 2007.
  Participants: Kishor Kumar and Vikram Gupta

- XXI Indian Colloquium on Micropaleontology & Stratigraphy, organized by Birbal Sahni Institute of Paleobotany, Lucknow, November 16-17, 2007.
  Participants: K. Kumar, B. N. Tiwari and S.K.Parcha

- Workshop on Laser Raman Micro Probe held at USIC, Delhi University, November 18, 2007.
  Participant: R. Sharma

- Central Command Seminar on Natural Disasters, organised by Army, Dehra Dun, November 19-20, 2007.
  Participant: R.K. Mazari

- h Annual Convention of Indian Geophysical Union on Science of Shallow Subsurface, held at Kurkshetra University, Kurukshetra, November 21-23, 2007.
  Participants: B.R. Arora , A.K. Mahajan and Pradeep Srivastava

- National Seminar on Biodiversity Importance in Present Context, organized by National Botanical Research Institute Lucknow, November 22-23, 2007.
  Participant: P.S. Negi

- Brain Storming Session on National /Central Facility for Remote Reference Magnetotelluric (RRMT) Network in India, N. Bose National Center for Basic Sciences, Salt Lake, Kolkata, November 26, 2007.
  Participant: Gautam Rawat

- Using Ambient Vibration Array Techniques for Site Characterization, C-MMACS, Bangalore, 26 November-December 1, 2007.
  Participant: A.K. Mundepi

- International Tropical Ecological Congress, organized by H.N.B. Garhwal University, Srinagar at Forest Research Institute, Dehra Dun, December 2-5, 2007.
  Participants: S.K. Bartarya and P.S. Negi

- International Conference on Precambrian Sedimentation and Tectonics and Second GPSS Meeting, IIT Bombay, December 10-12, 2007.
  Participant: R.J. Azmi

- Training Programme on Comprehensive Landslide Risk Management at National Institute of Disaster Management (NIDM), New Delhi, December 17-20, 2007.
  Participant: Vikram Gupta

- National Conference on Integrated National Security, organized by Forum for National Integrated Security (FINS), December 22-23, 2007.
  Participant: R S Rawat

- 95th Proceedings of the Indian Science Congress held at Andhra University, Visakhapatnam, January 3-7, 2008
  Participant: B.R. Arora and T.N. Jowhar

- International Symposium on Snow, Ice, Glacier and Avalanche, jointly organized by IIT Bombay and SASE Chandigarh, IIT Bombay, Mumbai, January 7-9, 2008.
  Participant: D.P. Dobhal

- Workshop on Landslide Inventory, Hazard and Risk Management under Asian Programme for Regional Capacity Enhancement for Landslide Impact Mitigation (RECLAIM-II), IIRS, Dehra Dun, January 10-11, 2008.
  Participants: B.R. Arora, K.S. Bist, A.K. Mahajan and A.K.L. Asthana

- DST Young Scientists' Meet (PAC-ES) held at VIT University, Vellore (Tamil Nadu), January 17-19, 2008.
  Participants: Santosh Rai, and A. Krishnakanta Singh

- National Seminar-cum-Workshop on Recent Trends and Application in Geo-Tech Engineering at Panjab University, Chandigarh, January 17-19, 2008.
  Participant: Vikram Gupta

- International Workshop on Active Fault Studies in Kutch at Kutch, Bhuj, January18-19, 2008.
  Participant: G. Philip.

- International Symposium on Restoration Programs from Great Earthquakes and Tsunamis, Phuket, Thailand, January 22-24, 2008.
  Participant: Paramesh Banerjee

- International Seminar on Terrestrial Planets: Evolution through Time, organized by PRL, Ahmedabad, January 22-25, 2008.
  Participants: Pradeep Srivastava and Santosh Rai

- National Conference on Application and Trends in Data Warehousing, Data Mining and Data Modeling (DWDM 2008), Forest Research Institute, Dehra Dun, February 9-10, 2008.
  Participant: T.N. Jowhar

- Diamond Jubilee Conference on Landslide Management: Present Scenario and Future Directions at CBRI, Roorkee, February 10-12, 2008.
  Participant: Vikram Gupta

- International Conference on Geology and Hydrocarbon Potential of the Neoproterozoic– Cambrian Basins in India, Pakistan and the Middle East at Jammu University, February 20-21, 2008,
  Participants: V.C. Tewari and S.K. Parcha

- Seminar on Tectonics of the Indian Sub-continent, IIT, Bombay, March 3-6, 2008.
  Participants: A. K. Dubey, V.C. Tewari, Rohtash Kumar, S.K. Ghosh, and H. K. Sachan

- XXIV convention of Indian Association of Sedimentologists (IAS-2008), AMU, Aligarh, March 4-6, 2008.
  Participants: R.J. Azmi, S.K. Ghosh and R. Islam

- Consultative Meet on Dynamics of Glaciers in the Himalaya at JNU, New Delhi, March 8, 2008.
  Participants: B.R. Arora and R.K. Mazari

- National Conference on Showcasing Cutting Edge Science and Technology by Women, organized by Task Force for Women in Science, DST and Confederation of Indian Industry, Vigyan Bhawan, New Delhi, March 8-9,2008.
  Participant: Swapnamita Choudhury

- National Seminar on Glacial Geomorphology and Palaeoglaciers in Himalaya, organized by University of Lucknow, Lucknow, March 13-14, 2008.
  Participants: Pradeep Srivastava and D.P. Dobhal

- 1st Indo-German Workshop on Electromagnetic Induction Studies for Complex Geological Problems, Lonavala, Maharashtra., March 14-18, 2008.
  Participants: B.R. Arora and Gautam Rawat

- Hindi Workshop on Scientific and Technical Terminology, its Construction and use: a discussion, ONGC Dehra Dun, March 17-18, 2008.
  Participants: K.S. Bist

- Workshop on October 8, 2005 Kashmir Earthquake and After, University of Jammu, Jammu, March 22-23, 2008.
  Participants: B.R. Arora, A.K. Mahajan and A.K. Mundepi

LECTURES BY VISITING SCIENTISTS

Name and address	Date	Topic
Prof. Mathew K. John University of South Colorado USA	14.3.07	From monazite to mountain P-T history of the Central Nepal Himalaya.
Dr. M. Rao Emeritus Scientist, NGRI, Hyderabad	22.3.07	Current use of acousting methods in the laboratory study of rock fracture.
Prof. M. Gokhberg Institute of Physics of the Earth Moscow		1. Geochemical problems for California a cluster. 2. New approach of the monitoring of porosity, permeability, shear and bulk viscocity of the modulus and dynamic pore fluid in vicinity of seismoactive fault zone. 3. Tsunami detection by bottom electro-magnetic station.
Shri Jokhan Ram E.D.-Chief, KDMIPE, Oil & Natural Gas Corporation Dehra Dun	11.5.07	New technologies and risk mitigation in hydrocarbon exploration.
Prof. S.P. Singh, F.N.A. Vice Chancellor, Garhwal University, Srinagar, Uttarakhand	29.06.07	Ecosystem services: an overview.
Dr. Navin Juyal PRL, Ahmadabad	13.8-07	Chronology of late Quaternary climate change in Higher Central Himalaya.
Dr. N. Porat Israel Geological Survey Israel	Nov. 2007	Paleosismological investigations in OSL applications.
Prof. Albrecht W. Hofmann Research Scientist Lamont-Doherty Earth Institute Columbia University New York, USA	11.9.07	Recycling oceanic and continental Crust through mantle.
Dr. A. K. Singhvi PRL, Ahmedabad	23.10.07	The societal dimensions of geosciences.
Shri Ravi Shanker Director General (Retd.) Geological Survey of India	28.2.08	Earth sciences relevance to society.

LECTURES BY INSTITUTE SCIENTISTS

Name of Scientist	Venue	Date	Topic
Swapnamita Choudhury	Centaur Hotel, New Delhi	3.4.07	Remote sensing in earthquake thermal precursory studies.
A. K. Dubey	NGRI, Hyderabad	30.4.07	Simultaneous development of folds and faults.
A. K. Dubey	Geological Survey of India, Dehra Dun	23.5.07	Development of non-cylindrical folds.
A. K. Dubey	Geological Survey of India, Dehra Dun	23.5.07	Development of thrust faults: examples from the Himalaya.
A.K. Mahajan	ITBP Academy, Mussoorie	30.5.07	Earthquake and its management.
Vikram Gupta	Institution of Engineers, Dehra Dun	10.6.07	Developmental activities in the Himalayan terrain vis-a-vis natural disasters.
A.K. Mahajan	Academy of Uttaranchal Administration, Nainital	30.6.07	Importance of preparedness for disaster management and protection scheme.
S.K.Bartarya	Amity University, Noida	4.8.07	Characterization, Control and Conservation of Himalayan Springs in context of Uttaranchal
Vikram Gupta	Lal Bahadur Sashtri National Acadeny of Administration, Mussoorie	10.8.07	Natural disasters with special reference to landslides and their management in the Himalayan terrain.
A.K. Mahajan	ITBP Academy, Mussoorie	22.8.07	Earthquake and its management.
Vikram Gupta	Administrative Training Institute, Nainital	22.9.07	Application of remote sensing and GIS.
B.R. Arora	Department of Geology, Lucknow University, Lucknow	6.10.07	Prof S.N. Singh Memorial Lecture, "Understanding the Himalayan Seismicity: An ultimate Geodynamic Challenge"
Rajesh Sharma	Geology Department Kumaon University, Nainital	9.10.07	a. Magmatic Records in fluid inclusions. b. Hydrothermal fluids of magmatic origin.
B.R. Arora	KDM Institute of Petroleum Exploration, ONGC, Dehra Dun	6.10.07	Dr A. M. N.GHOSH Memorial Lecture, "Himalayan Seismicity: Window to collision Geodynamics"

Name of Scientist	Venue	Date	Topic
D.P. Dobhal	IRDE, Dehra Dun	15.11.07	Global warming and retreat of glaciers: a climatic scenario.
P.S.Negi	IRDE, Dehra Dun	15.11.07	Adverse effects of global warming.
P.K. Mukherjee	Indira Gandhi National Forest Academy, Dehra Dun	10.12.07	a. Introduction to geology and b. Important rock types and their weathering pattern.
D.P. Dobhal	Doon Rotary Club, Dehra Dun	12.12.07	The face of Himalayan glaciers.
Vikram Gupta	Indira Gandhi National Forest Academy, Dehra Dun	12.12.07	Parent material and rock types.
S.K.Bartarya	Indira Gandhi National Forest Academy, Dehra Dun	17.12.07	Introduction to hydrogeology, and Himalayan springs and their conservation.
G. Philip	Indira Gandhi National Forest Academy, Dehra Dun	19.12.07	Tectonic geomorphology and active faults.
Vikram Gupta	National Institute of Disaster Management, New Delhi.	19.12.07	Landslide hazards in the Satluj valley.
P.K. Mukherjee	Indira Gandhi National Forest Academy, Dehra Dun	20.12.07	The dynamic earth.
B. N. Tiwari	WIHG, Dehra Dun	4.01.08	A new hypothesis for the origin of whales: a tribute to modern mammalian.
D.P. Dobhal	WIHG, Dehra Dun	4.01.08	Himalayan glaciers: resources and social environment appraisal.
S.S. Bhakuni	WIHG, Dehra Dun	22.02.08	Neotectonics along frontal part of northeast Himalaya, Arunachal Pradesh: field-evidences.
B.R. Arora	Survey of India Dehra Dun	28.02.08	Earthquake Precursors : Knowledge, Research and Applications
S.K.Bartarya	IIRS, Dehra Dun	7.03.08	Hydrogeology of mountainous terrain with special reference to Himalaya
S.K.Bartarya	IIRS, Dehra Dun	14.03.08	Role of geological structures on Groundwater Occurrence and movement and Groundwater targeting in Hilly and Mountainous terrain
G.Philip	WIHG, Dehra Dun	14.03.08	How active the active faults are? Myths and truths.
P.S. Negi	Oil and Natural Gas Corporation, Dehra Dun	17.03.08	Slope instability and bioengineering in Himalaya: an innovative approach.

TECHNICAL SERVICES

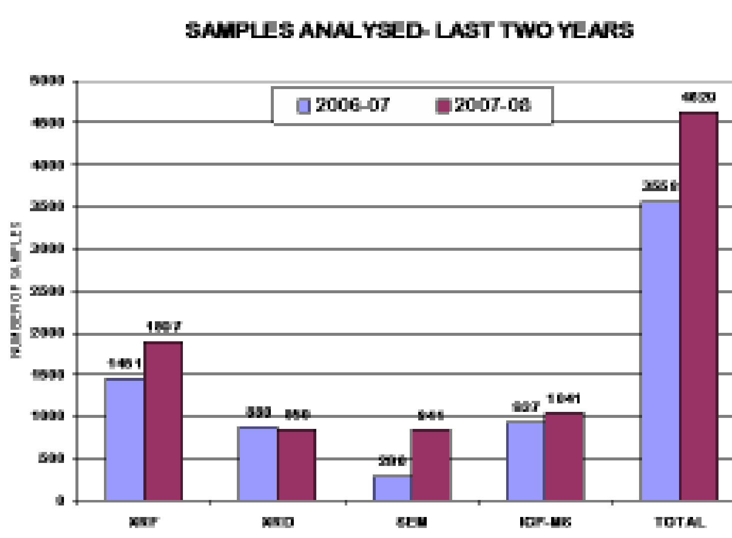
Analytical Services

Central Facility Laboratories

During the year a total number of 4629 samples were analyzed for different elements by XRF, XRD, SEM and ICPMS/AAS laboratories. All equipments were maintained and remained functional through out the year. The number of samples analysed this year is approximately 30% higher than last year. The new SEM-EDX facility attracted more users from the Institute who took the advantage of performing microanalysis on the samples along with enhanced quality of SE and BSE images.

Samples Analysed from April, 07 to March, 08

LABORATORY	WIHG USERS	OUTSIDE USERS	TOTAL
XRF	1283	614	1897
XRD	554	196	850
SEM	629	212	841
ICP-MS/AAS	504	537	1041
EPMA	90	42	132
TOTAL SAMPLES ANALYSED			4761



Several users and students from nearby institutions were given practical training on analytical instruments and techniques used. Six post graduate students from Gurukul Kangri University, Haridwar, and Vanasthali Vidyapeeth, Rajsthan were supervised for their dissertation work.

Photography Section

The Photography Section now has a total of 25 digital cameras. This has drastically improved the results as can be gauged by the quality of pictures appearing in publications and at the same time has brought down considerably expenditure on photography related consumables.

During the reporting year around 1550 snaps were clicked using digital cameras, and 10 colour films were exposed to cover the various functions, including Foundation Day, Founder's Day, National Science Day, National Technology Day, New Year Day, Seminars/Symposia, superannuation farewells, etc. organized in the Institute. Portraits of Institute staff for use in the new identity cards were clicked. Apart from this around 1000 snaps were clicked for rock and fossil specimens. The developing and processing of around 10 films was arranged with a total of about 1000 prints (digital and regular) of assorted sizes.

Drawing Section

The Drawing Section catered to the cartographic needs of the scientists of the Institute including the sponsored projects. During the year the Section has provided 74 geological/geo-morphological maps to the scientists of the Institute. The staff of the Drawing Section has also prepared posters /charts 1; identity cards - 44; addition and alteration in maps/diagrams – 3, geological cross sections – 25, spectral diagrams, litho-logs, geochemical graphs, etc.

Sample Processing Lab.

The Sample Processing Lab provided thin/polished sections to the requirements of the Institute scientists. During the year the laboratory provided 1995 thin and polished sections to various users for carrying out microscopic, fluid inclusion and EPMA studies. 1407 rock samples were powdered for carrying out mineral identification, major, trace and REE analysis by XRD, XRF and ICPMS.

S.P. NAUTIYAL MUSEUM

Museum is the key affiliation of education and continues to generate an axis of awareness to the students and general public not only from the local areas and distant corners of India but also from abroad. Museum as usual remained the main centre of attraction for the national and international visitors. Students from different schools, universities, colleges and from other institutions visited the museum and guided tours were provided to them.

The activities of the museum are according to the needs and the interests of the students. A large number of students continue to visit the museum for their respective school projects. During the year the visitors from U.K, U.S.A., France, Turkey, Italy, Nepal, England, Switzerland, Canada, Australia and Germany also visited the Museum.

The museum observed four open days on National Technology Day (11 May 2007). Foundation Day (29 June 2007), Founder's Day (23 October 2007) and National Science Day (28 February 2008). Similar to preceding years a large number of students and general public visited the museum on these open days. The print media gave wide coverage on these days. Science quiz and essay competition were organized on the eve of Science Day Week celebrations. Various schools of the Doon valley and of the surrounding areas participated in the quiz competition and the prizes were distributed to the outstanding students who stood first, second and third in order of merit in the quiz and essay competitions. Consolation prizes were also given for Hindi essay competitions and for science quiz.

LIBRARY

The Library of the Wadia Institute of Himalayan Geology is a medium size specialized library consisting of books, monographs, journals and seminar/conference proceedings on earth sciences with special reference to Himalayan geology. A large number of national and international scientific journals in the field of earth sciences are subscribed in the Library which are not available in any other Library in the northern region of the country. The Library serves to the scientific, technical and administrative staff of the Institute as well as to the scientists, academicians and researchers of sister organizations situated at Dehra Dun and various universities.

The Library subscribed to 79 foreign and 44 Indian Journals in Print format. The main thrust was given to provide full text online access of journals to the users on Intranet. Presently library has full text online access to more than 250 titles pertaining to various disciplines of thrust areas of the Institute. The Library has access to two collections of Elsevier's Science publishers through science direct platform. These are Earth & Planetary Collection (subscribed) consisting of 110 title and Earth & Environmental Science Collection (gratis) consisting of 105 titles. In addition to these the Nature and Science were subscribed online only with 4 years and 10 years back files respectively. Two new titles from Elsevier were added to print subscription by replace existing titles.

The enhanced access with 10 years back files with Print subscription of Blackwell Journals (9 titles) Springer (6 titles), John-Wiley and Sage (1 titles from each) was acquired. The online access was subscribed for the current year for the AGU (3 titles) and Geological Society of America (2 titles). The 23 titles which are subscribed in print only by the Library are having free full text online access with varying access period from current year to full archive.

During the period of this report the Library acquired a total number of 258 books. Out of these 127 books/ reference books were purchased while 24 books were received as gratis. In addition, 107 books in Hindi were purchased for Hindi collection. The Library has a good collection of Hindi books to promote the usage of Hindi language in the staff of the Institute.

The Library incorporates a reprographic cell which serves as a central facility for photocopying. During the period of this report the Library provided a large number of photocopies of articles from journals, books and monographs to the scientists of the Institute and projects. The photocopying facility was also provided to the administrative and technical sections of the Institute.

PUBLICATION & DOCUMENTATION

The Publication and Documentation Section is involved in bringing out the regular journal of Himalayan Geology and publishing Hindi magazine Ashmika, Annual Report, Abstract volumes, Brochures etc. During the year, the Section published Himalayan Geology vols. 28(2) 2007 and 29(1) 2008, Hindi magazine 'Ashmika' volume 13 and Annual Report of the Institute for the year 2006-07 both in Hindi and English. Abstract volume 28(3) 2007 for the Workshop on 'Collision Zone Geodynamics' was also brought out by the Section. Apart from this, various jobs such as printing of the S.P. Nautiyal Memorial Lecture, Circular for the above-mentioned workshop, invitation cards for seminars/ workshops, certificates for celebration of Foundation Day and National Science Day were also brought out by the Section. Additionally, services for scanning and color printing of maps, diagrams and figures as requisitioned by the Institute scientists were provided by the Section.

FOUNDATION DAY CELEBRATIONS

The Foundation Day of the Institute was celebrated on 29 June 2007. Prof. S.P. Singh FNA, Vice Chancellor of HNB Garhwal University, Srinagar, Garhwal, was the Chief Guest. He delivered the Foundation Day Lecture on "Ecosystem services: An overview". Padamshri Prof. A.N. Purohit was the Guest of Honour. On this occasion, Himalayan Geology Volume 28(2) and Hindi Magazine 'Ashmika' Volume 13 were also released by the Chief Guest. On this day, distribution of awards for best research papers published and scientific achievements made by the Scientists in various fields were also given by the Chief Guest. First prize for Best Research Paper was given to Dr Hakim Rai and Dr D.R. Rao for their paper entitled *"Signatures of rift environment in the production of garnet-amphibolites and eclogites from Tso-Morari region, Ladakh, India: a geochemical study"* published in *Gondwana Research* and second prize was given to Dr N.R. Phadtare and Dr S.J. Sangode for their paper entitled *"Accelerated melting of Himalayan snow and ice triggers pronounced changes in a valley peat land from northern India"* published in *Geophys. Research Letter.* Dr. D.P. Dobhal was given award for the best Hindi article published in Ashmika magazine, 2007, while Dr. V.M. Choubey and Dr A.K. Mahajan received Director's Special Award for Interdisciplinary and Inter-institutional Research and Adoption of Scientific Methodology for Benefits of Society respectively. Best worker awards were given to Shri Chander Shekhar, JTO, Shri T.K. Ahuja, Technical Assistant, Shri Kulwant Manral, LDC, Shri Rahul Sharma, LDC, Shri Dinesh Prasad Saklani, Cook-cum-Guest House Attendant and Shri Vijay Ram Bhatt, Bearer for good work carried out by them during the year 2006-2007.

Chief Guest Prof. S.P. Singh, FNA, Vice-Chancellor, H.N.B. Garhwal University along with Dr. B.R. Arora, Prof. A.N. Purohit and Dr. A.K. Dubey releasing Himalayan Geology volume 28 (2) 2007 on the eve of Foundation Day Celebration.

NATIONAL TECHNOLOGY DAY CELEBRATIONS

The eighth National Technology Day was observed on 11 May 2007. On this day museum and other laboratories were kept open for the general public and for the school and college students. A large number of students and the people visited the Institute museum and other laboratories. On this occasion Sh. Jokhan Ram, E.D.-Chief, KDMIPE Oil & Natural Gas Corporation, Dehra Dun delivered Technology Day lecture on New Technologies and Risk Mitigation in Hydrocarbon Exploration. The lecture was attended by students and general public and by the Institute staff.

FOUNDER'S DAY

The Institute celebrated its Founder's Day on 23 October 2007 in honour of Prof. D.N. Wadia. Generally a lecture by some eminent person is organized. On this occasion, the Chief Guest, Dr. A.K. Singhvi, Physical Research Laboratory, Ahmedabad, delivered the D.N. Wadia Honour Lecture on *"The Societal Dimensions of Geosciences"*. The lecture was well attended by scientists from different organizations from the Doon valley.

Chief Guest Dr. A.K. Singhvi, PRL, Ahmedabad along with Dr. B.R. Arora and Dr. A.K. Dubey sharing Dias during Founder's Day Celebration.

NATIONAL SCIENCE DAY CELEBRATION

The National Science Day-2008 was organized in the Institute by a week long activities beginning with a Science Quiz Competition. The various educational institutions of Dehra Dun were invited for participation in the Science Quiz and Hindi Essay Competition. Inspite of Annual Board Exams in Schools, a total of 34 educational institutions participated in the quiz competition. On this day all the laboratories were kept open to students and general public. In total nearly 43 educational institutions with more than 2,500 school children and a large number of general public visited the Institute Museum and various laboratories. Various exhibits depicting Himalayan glaciers, Earthquakes, Landslides, Origin of Life, Volcanoes, Rocks Minerals, etc. were displayed and guided tours were provided. The scientists along with technical staff and research scholars explained to the students and general public, the functioning of the various scientific instruments and their use. This year a special exhibit in the form of a artistic pictorial mode was prepared, which became a point of attraction to the students and general public.

In the evening an invited special science lecture was delivered on *"Earth Science: Relevance to Society"* by a distinguished scientist Shri Ravi Shanker, Director General (Retd.), Geological Survey of India. This was attendant by scientists of the Institute and by a large number of general public and the students of different schools

DISTINGUISHED VISITORS TO THE INSTITUTE

- ❖ Dr. P.S. Goel , Secretary Ministry of Earth Sciences, Government of India
- ❖ Prof. S.P. Singh FNA, Vice Chancellor of HNB Garhwal University, Srinagar Garhwal,
- ❖ Padamshri Dr Harsh K. Gupta, National Geophysical Research Institute
- ❖ Padamshri Prof. A.N. Purohit
- ❖ Shri Ravi Shanker, Director General (Retd.), Geological Survey of India
- ❖ Sh. V.K. Singh, Commndant, ITBP
- ❖ Dr. Rajiv Sharan, Scientist, DST
- ❖ Dr. S. Stang, Germany
- ❖ Denis Sahangs , Germany
- ❖ Dimhaid William, Germany
- ❖ Renater Pip, Germay

Dr. T. Ramasami, Secretary, Dept. of Science & Technology (Govt. of India) with four generations of Directors of the Institute during one of his visit. Left to right : Dr. N.S. Virdi, Dr. B.R. Arora, Dr. T. Ramasami, Dr. S.C.D. Sah and Dr. V.C. Thakur.

STATUS OF IMPLEMENTATION OF HINDI

During the year under report, efforts for progressive use of Hindi were continued. The scientists and staff of the Institute were time and again apprised with the various orders and constitutional provisions of official Language Act to increase awareness for progressive use of Hindi in day-to-day work. Various incentive schemes for encouraging progressive use of Hindi were implemented. General orders, circulars and notices were issued in Hindi as well as in English.

On the occasion of the Foundation Day of the Institute on 29 June 2007, the Hindi magazine 'Ashmika' volume 13 was released.

Hindi fortnight was celebrated from 14 to 30 September 2007 during which various competitions like poetry, essay and debate were organized. To inspire the staff for progressive use of Hindi in their work Rajbhasha lecture was also arranged.

The Annual Report of the Institute for the year 2006-2007 was translated in Hindi and published in bilingual form. On the occasion of the National Science Day week, a Hindi essay competition was organized for the students of various schools of Dehra Dun. The title of the Hindi essay was 'Vigyan aur Aastha'.

Chief Guest Prof. S.P. Singh, FNA, Vice-Chancellor, H.N.B. Garhwal University along with Prof. A.N. Purohit, releasing Hindi Magazaine "Ashmika" during Foundation Day Celebration.

MISCELLANEOUS ITEMS

1. Reservation/Concessions for SC/ST employees

Government's orders on reservations for SC/ST/OBCs are followed in recruitment to posts in various categories.

2. Monitoring of personnel matters

Monitoring of personnel matters relating to employees of the Institute are done through various committees appointed by the Director/Governing Body from time to time.

3. Mechanism for redressal of employees grievances

There is a Grievance Committee consisting of four Senior Scientists/Officers for redressal of employee's grievances. No request regarding grievance of any of the employee was received during the year by the Grievance Committee.

4. Welfare measures

The Institute has various welfare measures for the benefit of its employees. Various advances like House Building Advance, Conveyance Advance, Festival Advance, etc. are given to the employees. There is a salary Earner's Cooperative Society run by the Institute employees which provides loans to its members as and when required. The Institute also runs a canteen for the welfare of the employees. As a welfare measure, the Institute is providing recreational facilities to its employees.

5. Mechanism for redressal of complaints of sexual harassment of women employees at work places.

To inquire into the complaints of sexual harassment of women employees at work places in the Institute, a separate Committee has been constituted. The Committee consists of six members. The Chairman and two other members of the Committee are female officers, which includes a female officer from the Geological Survey of India. No complaint of sexual harassment of women employees at work places was received by the Committee during the year 2007-2008.

6. Status of Vigilance Cases

No vigilance case was either pending or was contemplated against any of the employee of the Institute during the year, 2007-2008.

7. Information on the RTI cases

No applications for seeking information or appeals thereof under the Right to Information Act, 2005 were carried forward from the previous year 2006-2007.

The details of information on the RTI cases during the year 2007-2008 are as under:-

Details	Opening balance as on 01.04.07	Received during the year 2007-08	Number of cases transferred to other public authorities	Decisions where requests/ appeals were rejected	Decisions where requests/ appeal accepted
1	2	3	4	5	6
Requests for information	Nil	4	Nil	Nil	4
First appeals	Nil	2	Nil	2	Nil
2nd Appeals to the Central Information Commission	Nil	2	Nil	1	1 was accepted for providing partially the disclosable information under the RTI Act, 2005.

No application or appeal under the Right to Information Act, 2005 was carried forward to the next financial year 2008-2009.

8. Sanctioned Staff strength(categorywise)

Group/ Category	Scientific	Technical	Admin-istrative	Ancillary	Total
A	63	-	2	-	65
B	-	2	6	-	8
C	-	37	30	14	81
D	-	28	-	26	54
				Total	208

9. Sanctioned budget grant for the year 2007-2008

(including Rs.50.00 lakhs under Plan sanctioned during 2006-2007 but received during 2007-2008)

Plan : Rs. 1350.00 lakhs
Non-Plan : Rs. 111.00 lakhs
Total : Rs. 1350.00+111.00 = 1461 lakhs

10. XIth Plan approved outlay

The details of XIth Plan approved outlay are yet to be received.

STAFF OF THE INSTITUTE

(A) Scientific Staff

1.	Prof. B.R. Arora	Director
2.	Dr. A.K. Dubey	Scientist 'G'
3.	Dr. R.K. Mazari	Scientist 'G'
4.	Dr. Trilochan Singh	Scientist 'F' (vol retired on 29.02.2008)
5.	Dr. R.J. Azmi	Scientist 'F'
6.	Dr. J.T. Gergan	Scientist 'F' (retired on 30.06.2007)
7.	Dr. N.S. Gururajan	Scientist 'F' (retired on 31.12.2007)
8.	Dr. V.C. Tiwari	Scientist 'F'
9.	Dr. B.K. Choudhuri	Scientist 'F'
10.	Dr. V.M. Choubey	Scientist 'F'
11.	Dr. P.P. Khanna	Scientist 'F'
12.	Dr. Rohtash Kumar	Scientist 'F'
13.	Dr.(Mrs.)Meera Tiwari	Scientist 'F'
14.	Dr. S.K. Ghosh	Scientist 'F'
15.	Dr. N.R. Phadtare	Scientist 'F'
16.	Dr. N.K. Saini	Scientist 'F'
17.	Dr. K.K. Purohit	Scientist 'F'
18.	Dr. Kishor Kumar	Scientist 'F'
19.	Dr. N.Siva Siddaiah	Scientist 'F'
20.	Dr. R.S. Rawat	Scientist 'E'
21.	Dr. K.S. Bist	Scientist 'E'
22.	Dr. D.K. Misra	Scientist 'E'
23.	Dr. R.K. Chaujar	Scientist 'E'
24.	Dr. Keser Singh	Scientist 'E'
25.	Dr. M.P. Sah	Scientist 'E'
26.	Dr. S.K. Paul	Scientist 'E'
27.	Dr. T.N. Jowhar	Scientist 'E'
28.	Dr. Rajesh Sharma	Scientist 'E'
29.	Dr. G. Philip	Scientist 'E'
30.	Dr. Rafikul Islam	Scientist 'E'
31.	Dr. D.Rameshwar Rao	Scientist 'E'
32.	Dr. B.N. Tiwari	Scientist 'E'
33.	Dr. S.K. Bartarya	Scientist 'E'
34.	Dr. P.K. Mukharjee	Scientist 'E'
35.	Dr. P. Banerjee	Scientist 'E'
36.	Dr. S.K. Parcha	Scientist 'E'
37.	Dr. H.K. Sachan	Scientist 'E'
38.	Dr. S.J. Sangode	Scientist 'D' (on lien)
39.	Dr. Sushil Kumar	Scientist 'D
40.	Dr. A.K. Mahajan	Scientist 'D
41.	Shri B.S. Rawat	Scientist 'C' (on deputation)
42.	Dr. D.P. Dobhal	Scientist 'C'
43.	Dr. Vikram Gupta	Scientist 'C'
44.	Dr. S.S. Bhakuni	Scientist 'C'
45.	Dr. Suresh N.	Scientist 'C'
46.	Dr. Pradeep Srivastava	Scientist 'C'
47.	Dr. Ajay Paul	Scientist 'C'
48.	Dr. A.K. Mundepi	Scientist 'C'
49.	Shri V. Sriram	Scientist 'C'
50.	Dr. P.S. Negi	Scientist 'C'
51.	Dr. A.K.L Asthana	Scientist 'C'
52.	Dr. B.P. Sharma	Scientist 'B'
53.	Dr. (Ms) Kapesa Lokho	Scientist 'B'
54.	Dr. A.K.Singh	Scientist 'B'
55.	Dr. R. Jayangondaperumal	Scientist 'B' (on lien)
56.	Dr. Khaying Shing Luirei	Scientist 'B'
57.	Dr. Rajesh S.	Scientist ' B'
58.	Shri Gautam Rawat	Scientist ' B'
59.	Dr. B.K. Mukherjee	Scientist 'B'
60.	Shri Naresh Kumar	Scientist 'B'
61.	Shri Narendra Kumar Meena	Scientist 'B'
62.	Dr. Dilip Kumar Yadav	Scientist 'B' (lien vacancy)
63.	Dr.(Miss)Swapnamita Choudhury	Scientist 'B'
64.	Shri P.K. Rao Gautam	Scientist 'B' (lien vacancy) Joined on 30.4.2007
65.	Dr. Devajit Hazarika	Scientist 'B' (joined on 27.8.2007)
66.	Shri Santosh Kumar Rai	Scientist 'B' (joined on 28.9.2007)
67.	Dr. Satyajeet Singh Thakur	Scientist 'B' (lien vacancy) joined on 3.1.2008
68.	Dr. Kaushik Sen	Scientist 'B' (lien vacancy) joined on 3.1.2008

(B) Technical Staff

1.	Shri V.P. Singh	Sr. Pub. & Doc. Officer Gr.III (5)
2.	Shri Saeed Ahmad	Sr.Librarian Gr.III (5)
3.	Shri J.J. Sharma	Sr.Technical Officer Gr.III (5)
4.	Shri M.M.S. Rawat	Sr.Tech.Officer Gr.III (4)
5.	Shri B.B. Sharma	Sr.Tech.Officer Gr.III (4)
6.	Shri A.K.Pandit	Artist cum Modellor Gr.III (4)
7.	Shri Sanjeev Dabral	Junior Tech.Officer Gr.III (3)
8.	Dr. R.K.Sehgal	Technical Officer Gr.III (4)
9.	Shri Chandra Shekhar	Tech.Officer Gr.III (4)
10.	Shri V.P. Gupta	Tech.Officer Gr.III (4)
11.	Shri Samay Singh	Tech.Officer Gr.III (4)
12.	Shri Rakesh Kumar	Jr.Tech.Officer, .Gr.III(3)
13.	Shri Ravindra Singh	Jr. Technical Officer, Gr. III(3)
14.	Shri H.C. Pandey	Jr. Technical Officer, Gr. III(3)
15.	Shri Vishnu Shrestha	Sr Lab.Asstt.Gr.II (5)
16.	Shri S.C. Kothiyal	Sr Lab.Asstt.Gr.II (5)
17.	Shri N.K. Juyal	Sr. Tech, Asstt.Gr.III (2)
18.	Shri T.K. Ahuja	Sr. Technical Assistant Gr. III (2)
19.	Shri C.B. Sharma	Junior Engineer Gr. III (2)
20.	Shri S.S. Bhandari	Technical Assistant Gr. III (1)
21.	Shri Rambir Kaushik	Technical Assistant Gr. III (1)
22.	Dr. Jitendra Bhatt	Technical Assistant(EDP)Gr.III (1)
23.	Shri Bharat Singh Rana	Technical Assistant Gr. III (1)
24.	Shri Pankaj Chauhan	Technical Assistant Gr. III (1)
25.	Shri V.K.Kala	Draftsman Gr.II (5)
26.	Shri G.S. Khattri	Draftsman Gr.II (5)
27.	Shri Navneet Kumar	Draftsman Gr.II (5)
28.	Shri B.B.Saran	Draftsman Gr.II (3)
29.	Shri Chandra Pal	Section Cutter Gr.II (5)
30.	Shri Shekhranandan	Section Cutter Gr.II(5)
31.	Shri Pushkar Singh	Section Cutter Gr.II (5)
32.	Shri Satya Prakash	Section Cutter Gr.II (5)
33.	Shri Santu Das	Section Cutter Gr.II (3)
34.	Shri Nand Ram	Elect.cum-Pump.Optr.Gr. II(5)
35.	Shri Lokeshwar Vashistha	S.L.T.
36.	Dr. S.K. Chabak	S.L.T.
37.	Shri R.M. Sharma	S.L.T.
38.	Shri C.P. Dabral	S.L.T.
39.	Shri Satish Pd.Bahuguna	Lab. Assistant Gr. II (3)
40.	Shri S.K. Thapliyal	Lab. Assistant Gr.II (3)
41.	Shri Shiv Pd. Bahuguna	Lab. Assistant Gr.II (3)

42.	Shri Sashidhar Pd.Balodi	Lab. Assistant Gr.II (3)
43.	Shri Rajendra Prakash	Lab. Assistant Gr.II (3)
44.	Shri A.K. Gupta	Lab. Assistant Gr.II (3)
45.	Shri Tirath Raj	Lab.Assist.(Photography) Gr.II(3)
46.	Shri Balram Singh	Elect.cum Pump Opt.Gr.II (3)
47.	Shri Anoop Singh	F.C.L.A.Gr. I (4)
48.	Shri Pratap Singh	F.C.L.A.Gr. I (4)
49.	Shri Ram Kishor	F.C.L.A.Gr. I (3)
50.	Shri Ansuya Prasad	F.C.L.A.Gr. I (3)
51.	Shri Puran Singh	F.C.L.A.Gr. I (3)
52.	Shri Ram Khilawan	F.C.L.A.Gr. I (3)
53.	Shri Madhu Sudan	F.C.L.A.Gr. I (3)
54.	Shri Hari Singh	F.C.L.A.Gr. I (3)
55.	Shri Ravi Lal	F.C.L.A.Gr. I (3)
56.	Shri Preetam Singh	F.C.L.A.Gr. I (2)
57.	Shri Vivekanand Khanduri	F.C.L.A.Gr.I (1)
58.	Shri Subodh Kumar Barthwal	Lab.Assistant
59.	Shri Nain Das	Lab.Assistant
60.	Mrs.Rama Pant	Field Attendant
61.	Shri R.S.Negi	Field Attendant
62.	Shri Ramesh Chandra	Field Attendant
63.	Shri Khusi Ram	Field Attendant
64.	Shri Tikam Singh	Field Attendant
65.	Shri Bharosa Nand	Field Attendant
66.	Shri B.B.Panthri	Field Attendant
67.	Shri M.S.Rawat	Field Attendant

(C) Administrative Staff

1.	Shri Dinesh Chandra	Registrar
2.	Shri Harish Chandra	Fin. & Accounts Officer
3.	Shri R.K. Matah	Admin Officer (Retried on 31.01.2008)
3.	Shri G.S. Negi	Asstt. Fin. & Accounts Officer
4.	Shri Manas Kumar Biswas	Store and Purchase Officer
5.	Shri Tapan Banerjee	Sr. Personal Assistant
6.	Shri U.S. Tikkha	Accountant
7.	Mrs. Manju Pant	Office Superintendent
8.	Mrs. Shamlata Kaushik	Assistant (Hindi)
9.	Mrs. Nirmal Rattan	Assistant
10.	Shri O.P. Anand	Assistant
11.	Shri N.B. Tewari	Assistant
12.	Shri B.K. Juyal	Assistant
13.	Shri Hukam Singh	Assistant
14.	Shri D.P. Chaudary	Stenographer Grade - II
15.	Shri P.P. Dhasmana	Stenographer Grade - II
16.	Smt. Rajvinder Kaur Nagpal	Stenographer Grade - III
17.	Shri D.S. Rawat	U.D.C
18.	Shri S.S. Bisht	U.D.C.
19.	Mrs. Sarojini Rai	U.D.C (Retired on 29.02.2008)
20.	Mrs. Sharda Sehgal	U.D.C.
21.	Shri M.M. Barthwal	U.D.C.
22.	Shri M.C. Sharma	U.D.C.
23.	Shri A.S. Negi	U.D.C.
24.	Shri S.K. Chettri	U.D.C.
25.	Shri Vinod Singh Rawat	U.D.C.
26.	Shri S.K. Srivastava	U.D.C
27.	Mrs. Prabha Kharbanda	U.D.C.
28.	Shri R.C. Arya	U.D.C.
29.	Mrs. Kalpana Chandel	L.D.C.
30.	Mrs. Anita Chaudhary	L.D.C.
31.	Shri Shiv Singh Negi	L.D.C.
32.	Mrs. Neelam Chabak	L.D.C.
33.	Mrs. Seema Juyal	L.D.C.
34.	Mrs. Suman Nanda	L.D.C.
35.	Shri Rahul Sharma	L.D.C.
36.	Shri Kulwant Singh Manral	L.D.C.

(D) Ancillary Staff

1.	Shri Puran Singh	Driver (Retried on 30.06.2007)
2.	Shri Dewan Singh	Driver
3.	Shri Sohan Singh	Driver
4.	Shri Ganga Ram	Driver
5	Shri Chander Pal	Driver
6.	Shri Naresh Kumar	Driver
7.	Shri Shyam Singh	Driver
8.	Shri M.K. Tamang	Driver
9.	Shri R.S. Yadav	Driver
10.	Shri Surjan Singh	Driver
11.	Shri Girish Chander Singh	Guest House Attendant cum Cook
12.	Sh. Dinesh Parsad Saklani	Guest House Attendant cum Cook
13.	Shri Bhagat Singh	Bearer
14.	Mrs. Kamla Devi	Bearer
15.	Mrs. Deveshawari Rawat	Bearer
16.	Shri Shyam Lal	Bearer
17.	Shri S.K. Gupta	Bearer
18.	Shri Chait Ram	Bearer
19.	Mrs. Omwati	Bearer
20.	Shri Jeevan Lal	Bearer
21.	Shri Surendra Singh	Bearer
22.	Shri Vijai Ram Bhatt	Bearer
23.	Shri Lal Bahadur	Chowkidar
24.	Shri Har Prasad	Chowkidar
25.	Shri Mahendra Singh	Chowkidar
26.	Shri Rohlu Ram	Chowkidar
27.	Shri H.S. Manral	Chowkidar
28.	Shri G.D. Sharma	Chowkidar
29.	Shri Swaroop Singh	Mali
30.	Shri Ashok Kumar	Mali
31.	Shri Satya Narayan	Mali
32.	Smt. Dukhni Devi	Mali
33.	Shri Ramesh	Safaiwala
34.	Shri Hari Kishan	Safaiwala

(E) Security Staff (on contract)

1.	Shri Manhora Lal Uniyal	Security Guard (Retired on 31.07.2007)
2.	Shri Ratan Singh Panwar	Security Guard (Retired on 31.10.2007)
3.	Shri Om Prakash Thapa	Security Guard
4.	Shri Mohan Singh Rawat	Security Guard
5.	Shri Kirti Dutt	Security Guard

GOVERNING BODY/RESEARCH ADVISORY COMMITTEE/FINANCE COMMITTEE/BUILDING COMMITTEE MEMBERS

Governing Body
(w.e.f. 1.12.2006)

Sl. No.	Name	Address	Status
1.	Dr. T. Ramasami	Secretary, Dept. of Science & Technology Technology Bhavan, New Mehrauli Road, New Delhi 110016	Chairman
2.	Shri K.P. Pandian	Joint Secretary & Financial Adviser, Dept. of Science & Technology, Technology Bhavan, New Mehrauli Road, New Delhi 110016	Member
3.	Dr. N.C. Mehrotra	Director, Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007	Member
4.	Dr. V.P. Dimri	Director, National Geophysical Research Institute, Uppal Road, Hyderabad 500 007	Member
5.	Dr. S. Krishnaswami	Emeritus Scientist, Physical Research Laboratory, Navrangpura, Ahmedabad 380 009	Member
6.	Prof. M.P. Singh	Dean, Faculty of Science and Head, Geology Department, Lucknow University, Lucknow 226 007	Member
7.	Prof. G.S. Roonwal	C-520, SFS, Sheikh Sarai I, New Delhi 110 017	Member
8.	Shri M. Ramakrishnan	Flat No.8, Mani Pallavam 29, Balakrishna Road Valmiki Nagar, Thiruvanmiyur, Chennai 600 041	Member
9.	Dr. B.R. Arora	Director, Wadia Institute of Himalayan Geology, Dehra Dun 248 001	Member Secretary

10.	Shri Dinesh Chandra	Registrar, Wadia Institute of Himalayan Geology, Dehra Dun 248 001	Non-Member Asstt. Secretary

Research Advisory Committee (w.e.f. 1.12.2006)

Sl. No.	Name	Address	Status
1.	Shri M. Ramakrishnan	Flat No.8, Mani Pallavam, 29, Balakrishna Road, Valmiki Nagar, Thiruvanmiyur, Chennai 600 041	Chairman
2.	Prof. L.S. Chamyal	Geology Department, M.S. University, Baroda	Member
3.	Prof. Abhijit Bhattacharya	Department of Earth Sciences, Indian Institute of Technology, Kharagpur 721 302	Member
4.	Dr. S. Sinha Roy	(Ex-Sr. Deputy D.G., GSI), Birla Institute of Scientific Research, Statue Circle, Jaipur 302 001	Member
5.	Prof. G.V. R. Prasad	Geology Department, Jammu University, Jammu 180 004	Member
6.	Dr. Rasik Ravindra	Director, Antarctic Research Institute, Goa - 403 804	Member
7.	Shri V.K. Raina	(Ex- Deputy, D.G., GSI), 258, Sector 17, Panchkula 134 109 (Haryana)	Member
8.	Dr. R.K. Chadha	Scientist 'F', National Geophysical Research Institute, Uppal Road, Hyderabad 500 007	Member
9.	Dr. M. Prithviraj	Scientist 'F'/Director, Earth System Science Division, Dept. of Science & Technology, Technology Bhavan, New Mehrauli Road, New Delhi 110016	Member

10.	Dr. B.R. Arora	Director, Wadia Institute of Himalayan Geology, Dehra Dun 248 001	Member
11.	Dr. A.K. Dubey	Scientist 'G', Wadia Institute of Himalayan Geology, Dehra Dun 248 001	Member Secretary

Finance Committee w.e.f. 01.12.2006)

Sl. No.	Name	Address	Status
1.	Prof. M.P. Singh	Dean, Faculty of Science & Head Geology Department, Lucknow Univesity, Lucknow 226 007	Chairman
2.	Joint Secretary & Financial Adviser or his authorized nominee	Department of Science & Technology, Technology Bhavan, New Mehrauli Road, New Delhi 110016	Member
3.	Dr. B.R. Arora	Director, Wadia Institute of Himalayan Geology, Dehra Dun 248 001	Member
4.	Shri Dinesh Chandra	Registrar, Wadia Institute of Himalayan Geology, Dehra Dun 248 001	Member
5.	Shri Harish Chandra	Finance & Accounts Officer, Wadia Institute of Himalayan Geology, Dehra Dun 248 001	Member Secretary

Building Committee (w.e.f. 1.12.2006)

Sl. No.	Name	Address	Status
1.	Dr. B.R. Arora	Director, Wadia Institute of Himalayan Geology, Dehra Dun 248 001	Chairman
2.	Joint Secretary & Financial Adviser or his outhorized representative	Dept. of Science & Technology, Technology Bhavan, New Mehrauli Road, New Delhi 110016	Member
3.	Dr. A.K. Dubey	Scientist 'G', Wadia Institute of Himalayan Geology, Dehra Dun 248 001	Member

4.	Shri Rajesh Agarwal	Chief Engineer (Civil), Dept. of Civil Engineering, Oil and Natural Gas Corporation, Shed No. 32, Dehra Dun 248 001	Member
5.	Shri C.S. Srivastava	Executive Engineer, Indian Institute of Petroleum, Mokhampur, Dehra Dun 248 001	Member
6.	Shri Shashi Kant Tyagi	Supdt. Engineer', Dehradun Central Cirecle, CPWD Nirman Bhavan, 20 Subhash Road, Dehra Dun 248 001	Member
7.	Shri Dinesh Chandra	Registrar, Wadia Institute of Himalayan Geology, Dehra Dun 248 001	Member Secretary

STATEMENT OF ACCOUNTS

CHANDRA BHAN GOEL & CO.
CHARTERED ACCOUNTANTS

21/2, Pleasant Valley
Rajpur Road, Rajpur P.O. Dehradun-248009
Phone: (0135) 2724622, 2735974
E-mail:chandrabhangoel@yahoo.co.in

AUDITORS REPORT

We have examined the attached Balance Sheet of **Wadia Institute of Himalayan Geology, Dehradun,** as at 31st March 2008 and the annexed Income & Expenditure Account and Receipt and Payment Account for the year ended on that date. These Financial statements are the responsibility of the Institute's management. Our responsibility is to express an opinion on these financial statements based on our audit.

We have conducted our audit in accordance with the accounting standards generally accepted in India. Those standards requuire that we plan and perform the audit to obtain reasonable assurance about whether the financial statements are free of material misstatements. An audit includes examining on test basis, evidence supporting the amounts and disclosures in the financial statements. An audit also includes assessing the accounting principles and significant estimates made by the managements, as well as evaluating the overall financial statement presentation. We believe that our audit provides a reasonable basis of our opinion.

In our opinion and to the best of our information and according to the explanations given to us the said accounts give a true and fair view:

1) In the case of the Balance Sheet of the state of affairs as at 31st March 2008
2) In the case of Income & Expenditure Account of the deficit for the year ended on 31st March 2008.
3) In the case of Receipt & Payment Account of the receipts and payments for the year ended on 31st March 2008.

For **CHANDRA BHAN GOEL & CO.**
CHARTERED ACCOUNTANTS

Sd/
(CHANDRA BHAN GOEL)
FCA

DATED: 30.06.08
PLACE: DEHRA DUN

CHANDRA BHAN GOEL & CO.
CHARTERED ACCOUNTANTS

21/2, Pleasant Valley
Rajpur Road, Rajpur P.O. Dehradun-248009
Phone: (0135) 2724622, 2735974
E-mail:chandrabhangoel@yahoo.co.in

SIGNIFICANT ACCOUNTING POLICIES AND NOTES TO ACCOUNTS FOR THE YEAR ENDNG 31.03.2008

SIGNIFACANT ACCOUNTING POLICIES

A. ACCOUNTING CONVENTION :

The accounts have been prepared on cash basis with income recognized and expenses accounted for on actual receipt/payment basis except the following:

1) Expenses Payable

B. FIXED ASSETS :

1) Fixed Assets are stated at cost of acquisition or cost of construction plus the related expenditure. As per the decision of management from the current year depreciation has been charged on the Fixed Assets at the rates specified in the Income Tax Act.

2) Full depreciation has been charged on the additions to all Fixed Assets made during the year.

3) Vehicle purchases prior to 01.04.98 have been debited to Equipment account.

C. CLASSIFICATION :

The previous year figures have been regrouped and rearranged wherever found necessary in order to confirm to this year classification. Further, the current years figures have been rounded off to the nearest Rupess.

CHANDRA BHAN GOEL & CO.
CHARTERED ACCOUNTANTS

21/2, Pleasant Valley
Rajpur Road, Rajpur P.O. Dehradun-248009
Phone: (0135) 2724622, 2735974
E-mail:chandrabhangoel@yahoo.co.in

NOTES TO ACCOUNTS

A. MAIN ACCOUNT OF WIHG :

i) Schedule '1' to '11' forms part of the Balance Sheet, '12' to '36' forms part of the Income & Expenditure and Receipts & Payments Account as on 31.03.08.

ii) Balance of Debtors and Creditors as on 31.03.08 subject to confirmation.

iii) Separate Balance Sheet have been prepared for :

- Contributory Provident Fund/General Provident Fund and New Pension Scheme.
- Pension Fund.
- Projects.

iv) In Schedule 11 : Current Assets. Loans & Advances an amount of Rs. 4800000.00 (Rupees Forty Eight Lakhs only) has been shown under the head Income Tax Paid represent the demand paid to the Income Tax Department during the year but as the appeal is pending so it is shown as a Current Asset.

For **CHANDRA BHAN GOEL & CO.**
CHARTERED ACCOUNTANTS

Sd/-
(CHANDRA BHAN GOEL)
FCA

DATED: 30.06.08
PLACE: DEHRA DUN

WADIA INSTITUTE OF HIMALAYAN GEOLOGY, DEHRA DUN
BALANCE SHEET
(AS AT 31ST MARCH 2008)

(Amount in Rupees)

PARTICULARS	CURRENT YEAR	PREVIOUS YEAR
LIABILITIES		
Corpus/ Capital Fund	319,874,792	301,859,409
Reserves and Surplus	-	-
Earmaked/ Endowment Fund	937,466	567,048
Secured Loans & Borrowings	-	-
Unsecured Loans & Borrowings	-	-
Deferred Credit Liabilities	-	-
Current Liabilities & Provisions	918,937	658,070
TOTAL	**321,731195**	**303,084,527**
ASSETS		
Fixed Assets	272,231,634	254,490,224
Investments from Earmaked/ Ensowment Funds	22,935	21,177
Investment-others	-	-
Current Assets, Loans & Advances	49,476,626	48,573,126
Miscellaneous Expenditure		
TOTAL	**321,731,195**	**303,084,527**

AUDITOR'S REPORT

"As per our separate report of even date"

For **CHANDRA BHAN GOEL & CO.**
CHARTERED ACCOUNTANTS

Sd/-
(CHANDRA BHAN GOEL)
FCA

Sd/-	Sd/-	Sd/-
(HARISH CHANDRA)	**(DINESH CHANDRA)**	**(B. R. ARORA)**
FINANCE & ACCOUNTS OFFICER	REGISTRAR	DIRECTOR

DATED: 30.06.08
PLACE: DEHRA DUN

WADIA INSTITUTE OF HIMALAYAN GEOLOGY, DEHRA DUN
INCOME & EXPENDITURE A/C
(FOR THE PERIOD ENDED 31ST MARCH 2008)

(Amount in Rupees)

S.N.	PARTICULARS	CURRENT YEAR	PREVIOUS YEAR
A	**INCOME**		
	Income from sales/services		
	Grants/Subsidies	-	-
	Fees/Subscription	105,840,000	65,400,000
	Income from Investments	14,000	63,254
	(Income on Invest from Earnmarked/	207,156	208,000
	Endowment - Fund)	-	-
	Income from Royalty, Publication etc.	49,025	52,797
	Interest earned	3,444,143	1,810,036
	Other Income	1,794,645	1,822,090
	TOTAL (A)	**111,348,969**	**69,356,177**
B	**EXPENDITURE**		
	Establishment Expenses	68,036,728	56,740,222
	Other Research & Administrative Expenses	23,636,184	19,635,989
	Expenditure on Grant/Subsidies etc.	-	-
	Interest/Bank Charges	13,894	19,570
	Depreciation Account	43,051,055	42,033,471
	Increase/Decrease in stock of		
	Finished goods. WIP & Stock of Publication	38,117	45,602
	TOTAL (B)	**134,775,978**	**118,444,854**
	Surplus (Deficit) being excess of Income		
	over Expenditure (A - B)	(23,427,099)	(49,088,677)
	Transfer to Special Reserve (Specify each)	-	-
	Transfer to/from General Reserve	-	-
	BALANCE BEING SURPLUS (DEFICIT)	**(23,427,009)**	**(49,088,677)**

AUDITOR'S REPORT

"As per our separate report of even date"

For **CHANDRA BHAN GOEL & CO.**
CHARTERED ACCOUNTANTS

Sd/-
(CHANDRA BHAN GOEL)
FCA

Sd/-	Sd/-	Sd/-
(HARISH CHANDRA)	**(DINESH CHANDRA)**	**(B. R. ARORA)**
FINANCE & ACCOUNTS OFFICER	REGISTRAR	DIRECTOR

DATED: 30.06.08
PLACE: DEHRA DUN

AUDITORS REPORT

WADIA INSTITUTE OF HIMALAYAN GEOLOGY, DEHRA DUN
RECEIPTS & PAYMENTS ACCOUNT
(FOR THE PERIOD ENDED 31ST MARCH 2008)

(Amount in Rupees)

PARTICULARS	CURRENT YEAR	PREVIOUS YEAR
RECEIPTS		
Opening Balance	13,528,050	12,062,252
Grants - in - Aids	146,100,000	116,400,000
Grants - in - Aids (Ear Marked)	839,820	1,880,531
Loan & Advances	37,967,129	24,855,065
Loan & Advances (Ear Marked)	60,000	782,451
Fees Subscription	14,000	63,254
Income from Investments	207,156	208,000
Income from Royalty, Publication etc.	49,025	52,797
Interest earned on Loan to Staff	3,444,143	1,810,035
Other Income	1,794,645	1,607,929
Investment (L/C Margin Money)	19,350,000	38,100,000
	223,353,968	**197,822,314**
PAYMENTS		
Establishment Expenses	68,036,728	56,740,222
Other Administrative Expenses	23,636,184	19,635,989
Interest/Bank Charges	13,894	19,570
Loans & Advances	37,187,677	33,954,329
Loans & Advances (Ear Marked)	61,842	775,424
Investment (L/C Margin Money)	27,500,000	19,350,000
Fixed Assets	59,610,073	50,743,058
Ear Marked Fund Expenses	399,952	2,956,752
Grant - in - Aid (Ear Marked) Refund	69,366	118,920
Closing Balance	6,838,252	13,528,050
	223,353,968	**197,822,314**

AUDITOR'S REPORT

"As per our separate report of even date"

For **CHANDRA BHAN GOEL & CO.**
CHARTERED ACCOUNTANTS

Sd/-
(CHANDRA BHAN GOEL)
FCA

Sd/-	Sd/-	Sd/-
(HARISH CHANDRA)	**(DINESH CHANDRA)**	**(B. R. ARORA)**
FINANCE & ACCOUNTS OFFICER	REGISTRAR	DIRECTOR

DATED: 30.06.08
PLACE: DEHRA DUN