ANNUAL REPORT

2010-2011

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WIHG

WADIA INSTITUTE OF HIMALAYAN GEOLOGY

DEHRA DUN

(An Autonomous Institute under Department of Science & Technology, Government of India)

ANNUAL REPORT 2010-2011

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RESEARCH ACTIVITIES

RESEARCH GROUPS

- Structure & Tectonics
- Igneous Petrology & Geochemistry
- Sedimentology
- Biostratigraphy
- Geophysics
- Geomorphology& Environmental Geology

MISSION PROJECTS

- Himtransects
- Climate-Tectonic Interaction
- Biostratigraphy & Biodiversity-Environmental Linkage
- Sustainable Natural Resources
- Real Time Geology for Society: Coping with Natural Hazards

UNITS ANCILLARY TO RESEARCH

- Research Planning & Co-ordination Cell
- Publication & Documentation
- Library
- Museum
- Drawing Section
- Photography Section
- Instrument Maintenance
- Sample Preparation Section

ADMINISTRATION

- Registrar's Office
- Finance & Accounts
- Establishment
- Stores & Purchase
- Works, Building & Maintenance
- Transport
- Guest House

A GLIMPSE

Wadia Institute of Himalayan Geology is a unique Institution of its type devoted to unravel the geological facts related to the orogeny of mountain belts. The Institute is engaged to study various aspects of structures & tectonics, petrology & geochemistry, geochronology, sedimentology, geomorphology, palaeontology, glaciology, hydrology and geophysical studies to unravel the geological truths related to mountain building–for manifold applications in understanding geodynamic processes, impact on climate, natural resources, evolution of life, and assessment and mitigation of natural hazards. 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. The scientific activities during the Year are centered on the following Mission Mode Projects:

- Himtransects
- Climate-Tectonics Interaction
- Biostratigraphy & Biodiversity-Environment Linkage
- Sustainable Natural Resources
- Real Time Geology for Society : Coping with Natural Hazards

Following are some of the research problems taken up by the scientists during the year 2010-2011, the results of which are communicated to National and International journals for publication.

Himtransects

The receiver function analysis of teleseismic waveform data recorded during 2010-2011 at 14 stations along a profile from Nahan to Ladakh shows northward deepening of the Moho from ~45 km beneath Nahan (NHN) station located north of the Himalayan Frontal Thrust to ~80 km beneath Ladakh ranges. The intra crustal low velocity layer (IC-LVL) is a significant feature in all stations along the profile. This observation also supports magnetotelluric (MT) and seismic tomography studies carried out in the region. A pronounced IC-LVL with the depth range of ~10 to ~35km is observed in all the seismic station of Ladakh region. The IC-LVL shows good spatial correspondence with observation of low resistivity from MT studies along a parallel profile. The HK-stack analysis of receiver function indicates high poison's ratio within the range 0.27 – 0.31 beneath Ladakh region.

The Karakoram fault system is the most important active transpressional zone on the Earth. In its northern strand, the Pangong range consists of exotic package of high grade metamorphic rocks, and show the dominance of carbonic-aqueous environment. The south of the Pangong range, the Karakoram terrane includes the deformed granodiorite with manifestations of youngest magmatism at ~35 Ma in the core of the batholith. The coherent leucogranite block bounded between Tangste and Pangong strand is considered to be associated with the development of the Karakoram fault zone, display deformation under amphibolite to greenschist facies and rapid exhumation and cooling through 10 Ma.

The palaeotectonic understanding of Lesser Himalaya visualizes the amalgamation of the supercontinent around 2.4 Ga. After initial assembly, the North Indian craton experienced intracontinental extension and mafic magmatism at 2 Ga to 1.8 Ga that led to the opening of rift related basins like Lesser Himalayan basin, Bijawar and Gwalior basin in Bundelkhand Block, Aravalli basin in Aravalli Block. The transition from rift related setting to passive margin/intracratonic setting is evidenced from sedimentological data of Lesser Himalaya which indicate deposition in a shallow shelf.

Principal Component analysis and Cluster Technique was employed for classification and discrimination of samples from Bhaironghati granite, Gangotri granite and Higher Himalayan crystallines. The studies carried out suggest that large volumes of felsic liquids can be generated by low degrees of partial melting of felsic crust which may form large batholiths of anatectic leucogranites. The Gangotri granite (23Ma) has been formed by process of fractional crystallization, and their derivation in syn-collisional environment.

Analysis of the geometry and folding pattern within the Chamba Thrust Sheet reveals that regional folds were developed during the southward translation of the Chamba Thrust Sheet. The structural mapping of the area between the Chamba and Tandi synclines further reveals that these synclines are ultimately connected with each other by the two anticlines and with a very open undulating syncline in between. The structures described fit well into asymmetric box fold geometry.

Climate-Tectonics Interaction

Two generation of alluvial fans, younger (23 to 10ka) in the northwest and older (36 to 29ka) in the southeast have been identified in the Soan Dun which record the coupling of climate and tectonic. The uplifted Late Quaternary deposit, similar in age as the top of the older fan sequence, in the hanging wall of the Soan Thrust indicates tectonic activity north of the Himalayan Frontal Thrust (HFT), and suggests out-of sequence thrusting during Late Pleistocene.

The Mio-Pliocene Middle Siwalik Subgroup of the Ranital-Kangra section of Kangra sub- basin is sandstone dominated succession. It has been observed that at around 100 to 125 ka, it is interceded with floodplain sequence of 1 to 3 m thick mudstone, which at places has also an abnormal thickness of >30 m. At basin scale this cyclic pattern is controlled by extrinsic process, however, development of abnormally thick floodplain deposits is controlled by intrinsic process due to basin tilting along basin bound transverse fault.

Speleothems from the Chulerisma and Patalbhubaneshwar caves of Uttarakhand were studied for paleoclimate interpretation as they are least altered deposits and are very reliable indicators of Monsoon pattern in past. Negative oxygen isotope values have been recorded for speleothems from both the Chulerisma cave and Patalbhubaneshwar caves, and are consistent with the data available from other caves, indicating higher monsoon rainfall. The long term rainfall and precipitation variability over the Himalaya is not well established.

Multi-parameter paleoclimate records of lacustrine sediments underlying the Chandra Peat deposit in Lahul and Spiti area have been precisely documented for the first time, as the Younger Dryas (YD) cold event in NW Himalaya. Pollen data and mineral magnetic record indicating significant wet and warm conditions before 12880 cal yr BP, point towards the Ållerød interstadial climate. This cold/dry climate further intensified until 11640 cal yr BP and terminated with gradual reappearance of local as well as regional flora. Floristic signatures and mineral magnetic record indicate that in NW Himalaya, the YD cold reversal was probably gradual compared with its abrupt change in northern high latitudes.

The trace elements like Ti have been used to study the intensity of Monsoon variations. From a small pond in rain shadow Trans-Himalaya (Chandra Tal) high Ti contents are observed which indicates intensification of the summer monsoon during Holocene optimum. Further, abrupt decrease in Ti content during mid-Holocene infers a moderate summer monsoon phase that gradually decreases in late-Holocene with lower Ti content.

Biostratigraphy & Biodiversity-Environment Linkage

The ichnofossil assemblage from Spiti valley is dominated by a high behavioral diversity ranging from suspension to deposit feeders. Majority of the ichnofauna from the Lower Cambrian succession of Parahio section appears to be produced by trilobite or arthropods, whereas some of them might have been the trails of crustacean, priapulid worm, polychaetes and polyphyletic vermiforms. The present assemblage of ichnofossil can be correlated with other contemporaneous horizons of Tethyan as well as Lesser Himalayan regions.

The oxygen isotope composition ($\delta^{18}O$) of fossil bone such as teeth and bones of shark, other fish and some terrestrial mammals from the Himalayan foreland and western Peninsular Indian successions show strong correspondence with respective animal habitats. The freshwater $\delta^{18}O$ values seem to suggest that monsoon like precipitation may have been active even during the Eocene-Oligocene period.

Molecular study of fossil resin from the Late Cretaceous Mahadeo Formation of Meghalaya indicates that, the major pyrolysis products and methyl-esterified thermochemolysis products found in the resin are abietane and labdane type diterpenoids, with minor amount of sesquiterpenoids. The exclusive presence of both labdane and abietane diterpenoids and the lack of phenolic terpenoids seems to suggest that, the Cretaceous resin was derived from Pinaceae (pine family) conifers.

The black shales with coal macerals in the early Eocene part of the Subathu Formation, in northwest Himalaya records an interval of interest in a relatively carbonate dominant sequence which is rich in organic matter and poor in carbonates as well as in fauna. They are lithologic expressions of hyperthemal event. An inverse relation between $CaCO_3$ and TOC contents is observed in the black shales. These changes are likely in response to variations in sea-water temperature, dissolved oxygen and/or pH.

Sustainable Natural Resources

Geochemical and petrogenetic studies of mafic rocks of Lesser Himalayan sequence, in Siang and Subansiri of Arunachal Himalaya suggest that a continental rift tectonic magmatism in the Eastern Himalaya probably provided the appropriate conditions for the origin of the voluminous mafic volcanics at the early stage of magmatism. The felsic volcanics generated at the final stage of magmatism, is comparable with similar evolutionary mechanism observed in the well known continental flood basalt provinces worldwide.

The graphite studies from Almora Group showed $\delta^{13}C$ values ranging from -23.2 to -31.7 ‰, with a mean of -29.08 ‰. No appreciable differences of $\delta^{13}C$ values are observed from the central and eastern parts of Almora Group. The observed $\delta^{13}C$ values suggest that the Lesser Himalayan graphite has crystallized from the biogenic carbon during the metamorphism of the host sediments.

Hydrochemistry of waters of Haridwar district indicate that carbonate weathering is main process controlling the major ion chemistry of the waters in the area. The presence of total coliform and E.Coli and NO_3 at few places in surface Ganga water and groundwater show perceptible signs of anthropogenic activities.

The observed geochemistry of Pinjaur Dun sediment samples probably reflects both the mechanical dispersion/erosion of catchment's host rocks and the hydromorphic (aqueous phase) transport and transfer of REE from the aqueous phase to the stream sediments. The high $(La/Yb)_N$ ratios along with the major and trace element chemistry in the samples suggest dominantly of a felsic provenance and deposition in an environment dominated by a particulate terrigenous source.

Treeline is one of the natural and important climate markers in the high altitude mountain ecosystems. Investigations carried out in Chorabari Dokriani glacier suggest that the treeline has shifted towards higher altitudes at the rate of 10.21m/year in Chorabari and 1.70m/year in Dokriani glacier valleys with in a period of 47 years. Treeline shift is attributed to the climate change response, while sharp difference of 8.51 m in the treeline rise rate of both glacier valleys under similar climatic domain is strongly suggestive of dominance of local site conditions, i.e., natural as well as anthropogenic traits, rather than regional and global climate pattern.

Real Time Geology for Society : Coping with Natural Hazards

Trench excavation survey carried out along the Himalayan Frontal Thrust near Kala Amb in Himachal Pradesh shows repeated reactivation of the HFT in this segment resulting into large magnitude paleo-earthquakes. Two distinct earthquake faults have been identified in the trench where Middle Siwalik rocks have thrusted over the Quaternary alluvium. In addition to this, the presence of large sized sand injection features and their disposition pattern observed in the trench suggests occurrence of another discrete large magnitude earthquake preceding the penultimate event.

The Seismological investigation carried out in Garhwal Himalaya through a VSAT linked seismic network recorded nearly six thousand events till March 2011. The seismicity pattern shows that the region south of MCT trending NNE-SSW along thrusts and faults is seismotectonically active. From the time series computed for the 22nd July 2007 M 4.9 Kharsali earthquake, it can be understood that the seismogenesis is influenced by strong or weak structural barriers in the region.

In order to understand the stiffness parameters of any site with depth, the shallow subsurface studies of different cities were carried out using engineering seismograph 1-D shear wave velocity model. The study provided thickness of sediments in Doon valley (frontal part of Himalaya) and in Ganga basin which may help the geomorphologist and climatologist to trace the variation in tectono-climatic condition and shifting of provenance during the fan/basin building processes.

A novel method has been developed to understand the dynamics of pore space fluids presented in the Doon alluvium through the application of periodic and a-periodic forces. Initial results suggest the existence of two distinct characteristic gravitational energy decay response of the Doon alluvium. At shorter periods of a-periodic excitation the alluvium response is mainly controlled by the dynamicity of fluids, especially water present in the pore spaces.

New/up-gradation of the facilities

The Institute launched major initiatives to upgrade its in-house analytical facilities. To be at par with International Labs, this year, a Stable Isotope Mass Spectrometer and a new Luminescence Reader with single Grain attachment are installed to the existing analytical facilities of the Institute.

Academic Pursuits

Under the on-going research programs pursued during the year, the Institute has published 94 research papers both in international and national journals and about 69 research papers are in press/communicated. In addition to this 36 papers were presented in national and international seminar/symposia/workshop by the Institute scientists. Four research scholars were awarded Ph.D degree, while three theses have been submitted for the award. Further the Institute continued to provide laboratory facilities to sister organizations, academic institutions, particularly the students.

The Institute continued the publication of Himalayan Geology, and brought out the volumes 31(2) 2010 and 32(1) 2011 during the year and also brought out volume 16 of Hindi magazine Ashmika.

Significant contribution has been made in the fields of Indian monsoon variability and Quaternary Geology that has led to the award of Third World Academy of Science (TWAS) Prize and S.S. Merh Award.

The Institute also organized one day workshop on "Earthquake Risk Reduction in Himalaya with special reference to Dehra Dun" on 14th December, 2010.

Other Highlight

General orders, circular, notices etc were issued in bilingual form to promote use of Hindi in routine work as well as in scientific research. The Annual Report of the Institute for the year 2009-2010 was translated in Hindi and published in bilingual form. Hindi fortnight was celebrated from 14 to 28 September 2010 during which various competitions like essay and debate were organized. The staff of the Institute has been time and again inspired for progressive use of Hindi in their work.

Anil K. Gupta
Director

PROGRESS IN MISSION MODE PROJECTS

MMP -1 : HIMTRANSECTS

Component 1.1 :

Multiple Geophysical studies for imaging deep Lithospheric structure Investigation beneath Himalaya

(Gautam Rawat, Naresh Kumar, V. Sriram, Dilip Kumar and Devajit Hazarika)

Under the program of Magnetotelluric (MT) investigations in Garhwal-Kumaun Himalaya, for deducing subsurface geoelectrical structure, six MT stations are covered along Pilibhit- Malpa Profile and four MT stations around MCT along Bijnaur Mallari profile. Four Long period magnetotelluric (LMT) observations in the profile and all MT stations along Bijnaur-Mallari profile are robustly processed with remote reference technique. At 21 stations, statistically reliable estimates of period dependent MT transfer functions are obtained. At other places, where electric field signals are affected by near source effect or low due to low solar cycle activity, time series of magnetic field variations are processed for Geomagnetic Depth Sounding (GDS) transfer function using Welch overlapped section averaging and robust approach based on Huber regression M-estimation. This state of art algorithm yielded GDS transfer function at 17 sites, including 4 stations monitored for GDS only with the help of lemi 417 fluxgate magnetometer. This approach of time series processing yielded total 38 points (21 MT/LMT and 17 GDS) along Bijnaur-Mallari profile (Fig. 1), covering each lithotectonic units across the profile, thus making data set ideal for joint inversion of MT and tipper. Swift skew and Bahr's phase sensitive skew variation along Bijnaur-Mallari profile is shown in figures 2 and 3. Station numbering starts from Indo-Gangetic Plane. Swift skew variations along the profile is segmented and indicate complexity of geo-electrical structure as we move northward in Himalaya. Since the swift skew is dependent upon diagonal and off-diagonal amplitudes therefore it can be enlarged by either galvanic distortion of the 3-D structure or induction in 3-D. At the same time, Bahr's phase sensitive skew variation indicate that regional geoelectric structure is not 3-D except for some periods at few stations. Beside this development, phase tensor analysis of MT transfer functions is also completed. Phase tensor elements are ratio of imaginary and real part of impedance tensor elements and thus free from distortion effects caused by shallow surface small scale inhomogeneities. Parameters obtained from phase tensor indicate that regional geoelectrical structure is following regional tectonic trend and geoelectric strike is N45W. Joint inversion of TM and tipper in the regional co-ordinate frame (N45W) is in progress. Earlier TM mode inversion indicates a conductor at a depth of 5 km beneath Indo-Gangetic plain which dips down as we move northward. Depth and geometry of this conductor coincide with detachment plane which is considered top of Indian plate in Himalayan orogen. Joint inversion of TM and tipper is in progress and it is expected that this joint inversion model will provide better constrain on geoelectrical structure of subsurface along the profile, which can be correlated with geological features in the area.

Seismology

Two significant Normal Events in Tehri Reservoir region

In the year 2010 two felt earthquakes occurred around tehri reservoir region. First occured on 27th January 2010 and the second on 3rd May 2010. The January event lies on the northeastern part of Tehri reservoir, and the May event lies on the Northwestern part. The source parameters of these two events are as follows:

The P-wave first motion fault plane solutions for these events are of Normal faulting type. The nodal

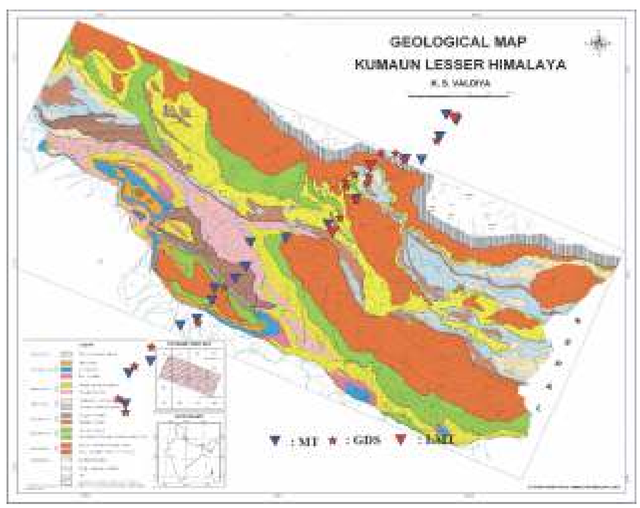

Fig. 1: Location Map of MT/GDS points along Bijnaur Mallari Profile (Filled triangle denote MT Observations wheras filled star indicate GDS point).

PROGRESS IN MISSION MODE PROJECTS

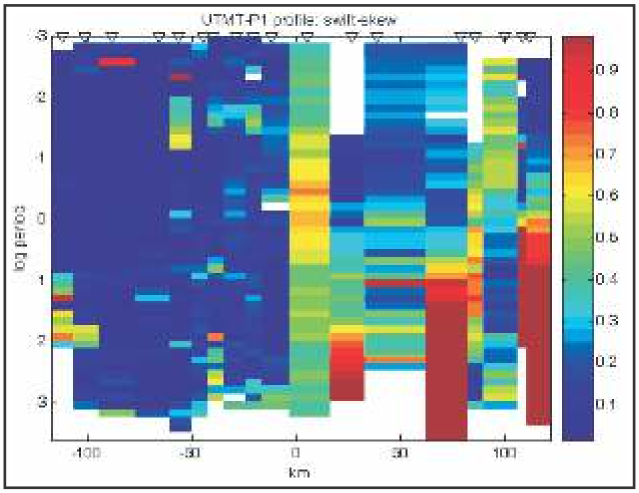

Fig. 2(a): Swit skew variation along the profile.

Date: 27-01-2010	Date: 03-05-2010
Time: 12h:10m:10.20s	Time: 17h:15m:08.20s
(UTC)	(UTC)
Lat: 30.352	Lat.: 30.360
Long: 78.601	Long:78.386
Magnitude: 3.3 Ml	Magnitude: 3.8 Ml
Focal depth:10km	Focal depth:17km

planes of both the earthquake events are trending in NW-SE directions. The 27th January event have higher dip for NE-plunging nodal plane and the SE plunging nodal plane have lower dip with small component of strike-slip movement. On May 3rd event the NE-dipping nodal plane have higher degree of dip incomparison to SE dipping nodal plane. The T-axis Orientation of January event is in NNE-direction and the T axis direction for May event is SSW (Fig. 1). The significant difference of the above two Normal faulting events are their plunge angles.

The broad band seismic data of Garhwal seismic network is used to estimate the source parameters of M4.9 Kharsali earthquake of 2007. The time series of ground motion were computed through waveform modelling technique for the mainshock. The source parameters were computed for different time series after integrating the far-field contributions of Green's function for a number of distributed point source. The resultant shows that the Kharsali earthquake occurred due to a northerly dipping low angle thrust fault at a depth of 14 km taking strike N 279°E, dip 14° and rake 117° which is agreeable finding with respect of the result obtained using P-wave first polarity motion using the data of whole WIHG network.

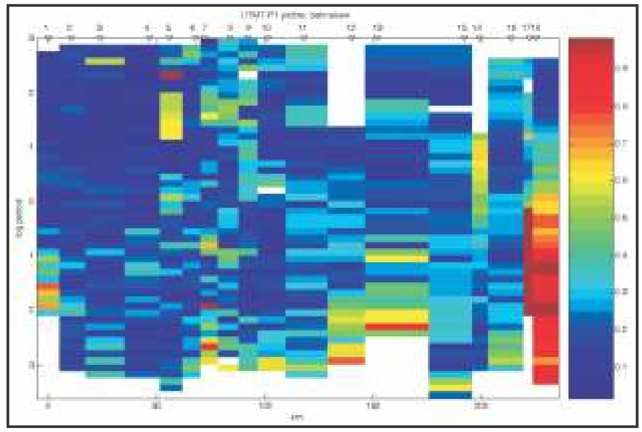

Fig. 2 (b): Bahr's skew variation along the prifile.

There are two regions on the fault surface which have larger slip amplitudes and treated as two different asperities. Around these two asperities, the rupture has been considered as circular in nature initiated from the asperity at a greater depth and then shifting gradually upwards.

Along with this the earthquake source parameters were also obtained for the main shock and aftershock activities using Brune's circular model. Through this method the displacement spectra of

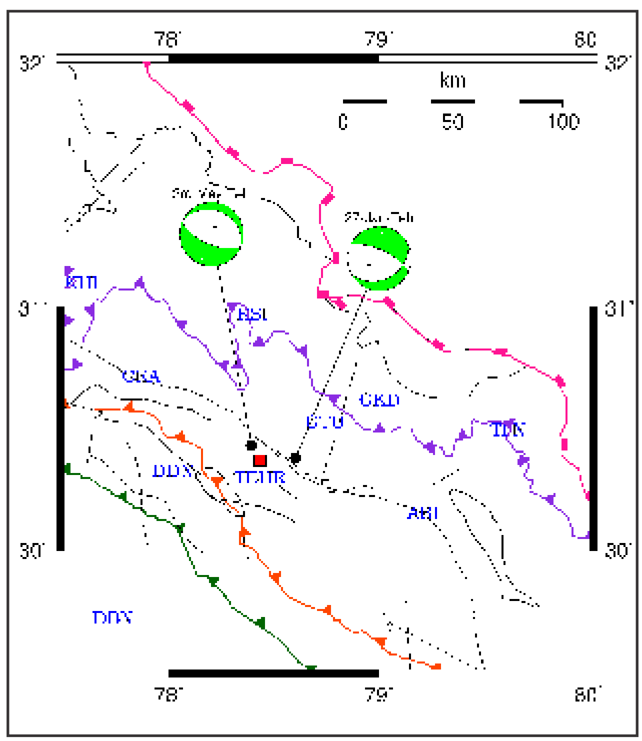

Fig. 3: Two earthquakes felt around Tehri reservoir Garhwal Himalaya, both events are of normal faulting types. The dark quadrants (green) are compression and the white parts in the FPS are dilatational quadrants.

digital data at different stations were inverted to obtain the source radius, stress drop and moment magnitudes using maximum amplitude with little variation in lower frequency band less than corner frequency . The analysis shows that the stress drops with the depth, and control the source characterization of the earthquake. In addition, we have also done the analysis of seismic wave attenuation for the Garhwal-Kumaun region separating the intrinsic and scattering attenuation.

Teleseismic Receiver Function analysis for investigation of deep subsurface structure of NW Himalaya

To investigate the deep subsurface structure beneath the Northwest part of Himalaya, an integrated analysis of teleseismic body wave recordings from 45 seismological stations operated by Wadia Institute of Himalayan Geology, Dehra Dun is being carried out (Fig. 4). The present study is focused on the Receiver Function (RF) Analysis of teleseismic earthquake data recorded on a ~450 km long profile of 14 broadband seismographs traversing the region from Himalayan Frontal Thrust (HFT) to Ladakh ranges (Fig. 4). This study is a part of a long term objective to obtain detailed 3D geometry of lithospheric structure beneath NW Himalaya. The results obtained from this profile would be integrated with the observations from rest of the stations.

About 250 Teleseismic earthquakes (M≥5.5; epicentral distance 30°-90° are analyzed to obtain the crustal shear-wave velocity structure, the average Vp/Vs of the crust, and the Moho depth beneath the linear profile. The Moho *Ps* conversion and crustal multiples in the radial RFs are used to estimate the average Vp/Vs ratio of the crust using the H-K stacking method of Zhu & Kanamori 2000 (JGR, Vol:105, pp.2969-2980). The time section plot of stacked RF as well as estimated average crustal thickness show a progressive northward deepening of the Moho from ~45 km beneath NHN station located north of the Himalayan Frontal Thrust to ~80 km beneath Ladakh ranges. The NHN station shows strong surface low velocity layer (S-LVL) indicating the presence of sedimentation and intra-crustal low velocity layer (IC-LVZ) at ~30km. The NHN and KHI stations show similar crustal thickness, however there is a dipping of mid crustal layer from 2.6s at NHN to 3.5s at KHI. The seismic station Sarahan (SARA) and Kaza (KAZA) shows 50 km and 60 km crustal thickness with average Vp/Vs ratio of 1.75.

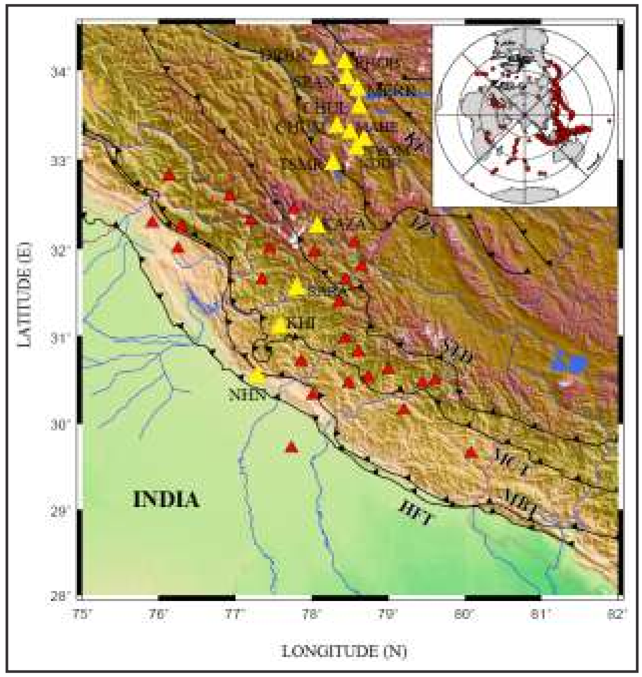

Fig. 4: Topographic map of NW Himalayan region showing the major tectonic features e.g. Himalayan Frontal Thrust (HFT), Main Boundary Thrust (MBT), Main Central Thrust (MCT), South Tibet Detachment (STD), Indus Zangbo Suture (IZS), Karakoram Fault (KF) and Bangong Suture (BNS) with locations of broad band seismic stations (triangles) operated by WIHG, Dehra Dun (Triangles). The yellow triangles indicate the stations used in this study and the inset shows distribution of earthquakes used in this study.

The inversion of RF data from seismic stations in Ladakh shows crustal thickness varying from 73 km (TSMR station) to 80km (e.g. MERK, SPAN). A pronounced IC-LVL with the depth range of ~10 to ~35km is observed in all the seismic station of Ladakh region. The minimum S-wave velocities in IC-LVL ranges from 2.7 to 3.1km/s. The minimum velocity observed in each station show a S-wave velocity (*Vs*) reduction of ~18%. The IC-LVL shows good spatial correspondence with previous observation of low resistivity from magnetotelluric studies along a parallel profile. The possible explanation for low velocity and low resistivity in mid-crust is the presence of melts or aqueous fluids which is also supported by the elevated heat flow observed in NW Himalaya. The HK-stack analysis of receiver function indicates high poison's ratio within the range 0.27 0.31 beneath Ladakh region.

Component 1.2 :

Comparison and crustal evolution of Gneissic domes in relationship with Indus and Shyok Suture zone

(H.K. Sachan, Barun K Mukherjee, S.K. Paul and Koushik Sen)

Rapid uplift of Karakoram Fault Zone Mylonites

Metamorphism and fluid evolution path show that the deformation at amphibolite facies condition prevailed till ~10.3 Ma. Moreover, we found no prolonged hiatus between two events of deformation and the change of amphibolite to greenschist facies of deformation seems more like a transitional one. Earlier obtained deformation age of 9.7±0.1 Ma of biotite is from the quartzo-feldspathic migmatite of Pangong strand. By comparing this with our data, it can be inferred that both Tangtse and Pangong strands experienced cooling through ~350°C at the same time (~9.7-9.8 Ma) and there was no partitioning of deformation between these two strands till ~9.7 Ma. The study of Rutter et al. (2007) suggests active tectonics in the Pangong strand of the KFZ till ~3 Ma. Hence it can be inferred that the evidences of rapid exhumation from 8- 10 Km depth yields average uplift rate of 1 mm a^{-1} for the KFZ rocks.

The KFZ is kinematically related along strike with the N-S Yaden Gurla Graben which has accommodated E-W extension of upper crust in southern Tibet, reveals a part of south Tibetan crust was uplifted between 12.5 to 8 Ma. The Yaden-Gurla graben is the largest graben in the southern Tibet and cooling took place during 8 Ma. The development of this structure in southern Tibet coincides with the transpression-related rapid isothermal exhumation of the Karakoram fault zone rocks that started around ~10.4 Ma and continued till 6 Ma. Consequently in this time, the southern Tibetan plateau had reached sufficient elevation level. Hence, our study arrests the phase of deformation in the KFZ that facilitated the uplift of Tibetan plateau during 11-8 Ma prior to its E-W extension. Earlier presumed slow cooling in KFZ rocks is estimated through blocking temperature of Ar data. Nonetheless, the argon is a highly incompatible element in the micawater system and will partition strongly into the fluid phase. Thus, the amounts of excess ^{40}Ar introduced into the mineral by interaction with meteoric fluids are presumably small compared with the overall (radiogenic) ^{40}Ar contribution. Mica can grow under a variety of metamorphic conditions and over variable time scales and this may represent compositionally and isotopically heterogeneous systems. This is even more critical in mylonitic rocks deformed under brittle or viscous conditions because parameters controlling isotopic exchange such as recrystallization rate, cooling rate and interaction with syntectonic fluids can vary considerably during the evolution of mylonite zones.

Activity of Fluids in Pangong Tso Area

The detailed fluid inclusion study on high grade metamorphic rocks from Pangong-tso area in trans-Himalaya region which is eastern part of Karakoram metamorphic complex reveals that these rocks underwent high-pressure metamorphism during the Cretaceous period. Fluid inclusions trapped in high grade metamorphic rocks provide important information on the fluid phases present during high-pressure metamorphism. Fluid inclusions of texturally primary occur in, staurolite,garnet and quartz, whereas secondary fluid inclusions occur mainly in the quartz in these rocks. All the trapped fluids in primary inclusions show melting temperatures in the range of −56.9 to−56.6°C, suggesting a dominantly pure CO_2 composition. The secondary fluids are of carbonic-aqueous in nature. The re-equilibrated inclusions show annular morphology as well as necking phenomena.

The estimated CO_2 isochors for the primary inclusions intersect mineralogical PT box of the rocks at around 5.5 -7.2 Kbars in between 575-750°C which broadly coincide with the peak metamorphic conditions of the area. Since these fluid inclusions show textural evidence for entrapment during the growth of the host high-grade minerals, we interpret the high-density CO_2 fluids to be traces of a Co_2- rich synmetamorphic fluid that was present during the peak metamorphism. Whereas secondary CO_2-H_2O appear to have been trapped late, during uplift as their isochors intersect at downside of P-T path. Thus, the coexisting CO_2 and CO_2-H_20 inclusions were entrapped at 4.8Kbars;600°C, marking the waning of carbonic regime and the beginning of aqueous regime leading to the simultaneous entrapment of CO_2 mixed CO_2-H_2O inclusions along microfractures.

The morphology of re-equilibrated inclusions reveal that the exhumation process was very fast occurred during decompressional regime along a clockwise PT trajectory. The carbonic fluids probably derived from carbonate lithologies and transported from local distance. The peak sillimanite grade metamorphism in Pangong-Tso involved an initial phase of crustal thickening (peak metamorphism), followed by near-isothermal exhumation and final cooling and retrogression.

Variation in pattern of magnetic fabric due to changing stress field and angle of convergence during formation of the Ladakh Batholith

The trans-Himalayan Ladakh Batholith is a product of calc-alkaline magmatism triggered by subduction of the Indian Plate beneath the Eurasian Plate along the Indus-Tsangpo Suture Zone (ITSZ). In this work, the Indian part of the Ladakh Batholith has been studied using magnetic fabric analysis, magneto-mineralogy and U-Pb LA-ICPMS zircon geochronology. The batholith is dominantly I-type with presence of two-mica granites in its central part. Magnetomineralogy suggests that the batholith is largely ferromagnetic with the presence of magnetite as the principal carrier of magnetic susceptibility. The mesoscopic and magnetic fabric are concordant and show wide variation from NNW-SSE to E-W for different facies at different part of the Batholith. Anisotrophy of Magnetic Susceptibility (AMS) and petrographic study also suggest that the batholith has not suffered any major post-solidification deformation and retains its original igneous fabric. It is inferred that this magnetic as well as the mesoscopic fabric has wide variation in orientation due to changing stress field caused by varying angle of convergence between the Indian and Eurasian plate during solidification of different facies. U-Pb zircon geochronology of a rhyolite from the southern part of the batholith gives a crystallization age of 71.7±0.6 Ma, coeval with the ~68 Ma magmatism in the northern part of the batholith. However, much younger magmatism is recorded by a 35.5±0.5 Ma two-mica granite from the central part of the batholith. This is the youngest magmatic pulse reported from this region so far and is at least 10 Ma younger than the last reported calc-alkaline magmatism related to subduction. The magnetic fabric of the two-mica granites is at a high angle to the regional trend of the batholith. It is proposed that these two-mica granites were emplaced as fracture fills due to shearing along the ITSZ when the angle of convergence became minimum during late Eocene-Oligocene times.

Nature of Ophiolitic Melange in eastern Ladakh

Field mapping on 2,50,000 scale suggests that the W42N trending Khasi Ophiolitic Melange (KOM) was emplaced earlier than the W30N trending Zildat Ophiolitic Melange, and has an angular difference of about 12°. The emplacement of Khalsi, Zildat ophiolitic mélange and Nidar ophilitic complex at different times and places reflect complicated kinematics of their deformation along the Indus Suture Zone. The amount of angular discordance and the mean palaeomagnetic Declination/ Inclination value amongst the ophiolitic units is inferred as the differential vertical as well as horizontal rotations probably as a result of anticlockwise rotation of the Indian plate simultaneous to collision.

Basal Lesser Himalayan Sequence - a Paleo-proterozoic arc

The lower Lesser Himalayan sequence marks the northern extremity of the Indian plate and is considered as a passive margin. However, following evidence suggest a continental arc setting. Presence of igneous intrusions and volcanic rocks at this level across the Himalaya with their ages around 1780-1880 Ma indicate a long igneous process. Detrital zircon ages in clastic rocks cluster around 1800-1900 Ma with a unimodal distribution in some rocks, mineralogy and chemistry of meta-sedimentary rocks suggest a volcanogenic source, whereas trace element chemistry of orthogneisses and metabasalts are more consistent with either an arc or a collisional setting. Moreover intercalation of volcanics with clastic sediments and absence of Proterozoic metamorphic ages do not support a collisional origin. An arc model further underscores the profound unconformity separating lower-upper Lesser Himalayan rocks indicating that a paleo-proterozoic arc may have formed the stratigraphic base of the northern Indian margin.

Paleo-Proterozoic granitoids of Himachal Himalaya

Field, microstructural, and Anisotropy of Magnetic Susceptibility (AMS) studies were carried out on Paleo-Proterozoic Wangtu Gneiss of the Himachal Himalaya to understand its structural evolution during the Cenozoic Himalayan Orogeny. The Wangtu Gneiss is bounded by the Vaikrita Thrust (VT) to the northeast and the Munsiari Thrust (MT) to the SW. The regional structure consists of upright large scale folds trending NW-SE. Microstructures show pre-Himalayan magmatic fabric (here referred as D1) overprinted by high temperature deformation fabric ($D2_A$) followed by late low temperature superposed deformation fabric ($D2_B$). The AMS fabric has a discordant relationship with the corresponding mesoscopic fabric and near VT, the magnetic lineation demarks the intersection between the mesoscopic and magnetic foliations. The

PROGRESS IN MISSION MODE PROJECTS

mesoscopic fabric is related to a deformation event at a relatively higher temperature ($D2_A$) that transformed this Paleo-Proterozoic granite into granitic gneiss and is caused by overthrusting of the High Himalayan Crystallines along the hanging wall of VT. The AMS fabric is developed during a later low temperature deformation ($D2_B$) which occurred after locking of the thrust and characterized by superposed folding and exhumation of the Wangtu Gneiss. The magnetic fabric does not correspond to any visible mineral fabric, hence it is inferred that the magnetic fabric is the resultant of $D2_A$ and superposed $D2_B$ fabrics.

Component 1.3 :
Field anisotropy of magnetic susceptibility and petrographic studies in the Himalaya

(A.K. Dubey, S.S. Bhakuni, R. Jayangondaperumal and Koushik Sen)

Many of the orogenic belts have several aspects in common, e.g. arcuation in their trend, tectonic subdivisions from foreland foothill belt to inner core consisting of high grade metamorphic rocks, pre- and syn-orogenic metamorphism, fold- and thrust belts, early and superposed deformation, reactivation of faults, plane of basal decollement at depth etc. However there are certain features that are characteristic of an orogenic belt and these features help in formulating a model for its structural evolution. Some of the characteristic but enigmatic problems of the Himalaya are as follows.

1. The earlier Deep Seismic Section (DSS) profile across the Himalaya reveal a number of vertical faults without any plane of decollement (Kaila et al., 1978). However acceptance of thin-skinned tectonics in some of the orogenies, led to emergence of another seismic profile which displays a prominent plane of basal decollement and various thrusts emanating from the plane (Allegre et al., 1984). It is also to be noted that nearly all the available seismic data reveal a large number of activities below the projected plane of decollement (e.g. Dey and Kayal, 2003).
2. There appears to be a major inconsistency between surface and subsurface fold geometries. The exposed large-scale fold structures are polyharmonic and normally show a rounded profile but the subsurface folds are sometimes shown with typical kink band geometry without any second order folds so that the structures can be used for palinspastic reconstruction. With the same rheological properties of rocks, the variation of fold geometries across the ground surface remains unexplained. The footwall deformation and geometric problems that are associated with the ramp-flat thrust model (Ramsay, 1992) are also ignored.
3. In crucial areas of the Himalaya (e.g. the Hazara-Kashmir Syntaxis), there is no simple correspondence between local overthrust directions and relative plate motions (Bossart et al., 1988). Hence kinematic evolution of the structures needs a careful study.
4. Most of the finite strain data have come from two-dimensional cross-sections and arrive at a single inference that the strain values are higher near a thrust. Correlation of strain with the early and superposed deformation is lacking except a few cases (e.g. Jayangondaperumal and Dubey, 2001; Dubey et al., 2004).

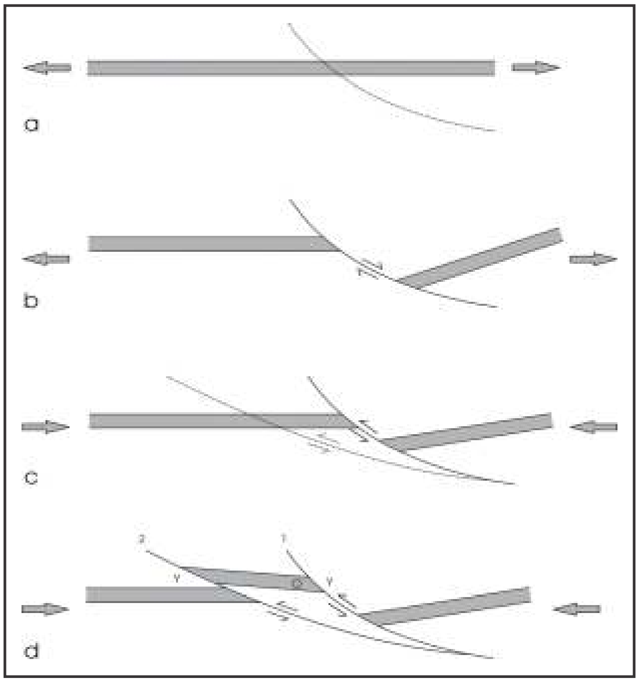

Fig. 5: A simplified diagram illustrating occurrence of younger rocks in the hangingwall of a thrust. (a) Initial disposition of a layer in a normal stratigraphic sequence and initiation of a listric fault. (b) Normal faulting during pre-Himalayan rift phase in the region. (c) Reactivation of the fault as thrust during the Himalayan orogeny and initiation of a new thrust in the footwall. (d) Locking of thrust 1 prior to reaching the null point and displacement along thrust 2. The younger rock (Y) now occurs in the hangingwall of thrust 1 and older rock (O) in the footwall.

5. Hanging wall of the Vaikrita Thrust is characterized by younger rocks as compared to the footwall. This is in sharp contrast to the model of thrust tectonics.

The above features are explained with the help of an inversion tectonics based model (Fig. 5; details as in Dubey, 2010).

Paleoseismic investigation was carried out at Marbang Korong Creek within the meizoseismal area of the 1950 Assam earthquake along the northeast Himalayan Frontal Thrust (HFT) of India. Structural, stratigraphic, and growth-stratigraphy relations observed in a trench show that displacement on the HFT has led to development of a surface scarp at the mouth of Marbang Creek subsequent to cal 10112 yrs. BP and that the most recent contribution to scarp growth dates to an earthquake post cal 2009 yrs. BP. It remains a matter of speculation whether or not the most recent event deformation is the result of the great 1950 Assam earthquake that is reported on the basis of intensity data to have occurred in this region.

Component 1.4 :
Geochemistry and isotopic studies of source rocks and riverine phases in the Western Himalaya

(S.K. Ghosh, R. Islam and Santosh K Rai)

Component 1.4a :
Sedimentological and geochemical attributes of the Proterozoic (1800-600 Ma) clastic and associated volcanic succession of the northwestern Lesser Himalaya

(S.K. Ghosh and R. Islam)

During the period under review, the work is mainly focused on the correlation and basin tectonics aspect of Proterozoic siliciclastic packages of the Lesser Himalaya using sedimentological, petrographical and geochemical data sets. The Lesser Himalaya bounded in the north by Main central Thrust (MCT) and Main Boundary Thrust (MBT) in the south. There are significant lithologic variations between the northern and southern parts of the Lesser Himalaya of Garhwal and Kumaun, and thus the region is divided geologically into a northern as Inner Lesser Himalaya zone-ILHZ and southern as Outer Lesser Himalaya zone-OLHZ. The age and correlation aspects of these zones still remain inconclusive. The Proterozoic succession of the Lesser Himalaya (Damtha Group =Jaunsar Group) preserves a thick pile of coarsening upward argillite and siliciclastic shallow marine shelf deposits. In general the lower part of the shelf succession is characterized by transgressive argillite dominated (Chakrata Formation=Chandpur Formation) succession with signatures of deposition in shallow marine shelf setup with frequent influence of tidal and occasional storm activities. With brief period of intertonguing of argillite and siliciclastic facies it passes upward into a regressive facies (Rautgara Formation=Nagthat Formation), comprises sand bodies, often amalgamated as extensive sand sheets. The development of a thick coarsening up sand dominated succession overlying an argillite dominated shelf sequence with a sharp interface and points to an abrupt fall in relative sea level with consequent changes in the depositional processes.

Compositionally, the siliciclastics falls in arenite and wacke groups with detrital proportions: $Q_{78}F_8R_{14}$; Mx_{11}. The wackes are abundant in the lower argillite facies and less commonly with upper siliciclastic facies .There is a marginal variation observed in the detrital proportions of OLHZ ($Q_{78}F_8R_{14}$; Mx_{11}) and ILHZ ($Q_{79}F_4R_{17}$; Mx_{12}).

Geochemical data exhibited strong negative correlation of SiO_2 and Al_2O_3 (-0.98) because in sedimentary rocks, the content of Al_2O_3 and SiO_2 are controlled by aluminous clay and quartz content respectively. On the basis of these ratios the whole argillite- siliciclastic assemblages can be seen as mixing of illite and quartz end member with quartz greywacke defining the intermediate position. Strong correlation of K_2O with Al_2O_3 (0.94) and moderate correlation with Fe_2O_3 and Na_2O (0.61 and 0.60 respectively) indicate importance of weathering in the source area in controlling the abundances of these elements. Many other chemical criteria of Lesser Himalaya also support a mixed source area lithology consisting of granite to granitic gneisses, sedimentary and basic volcanic rocks. In addition, presence of depositional sedimentary structures cross, parallel, rippled and convolute stratifications indicate a similar depositional set up both in OLHZ and ILHZ. Based on the vector structures we recognize the source rocks were placed in southern side and consist of basement granite and granitic gneisses of Banded Gneissic Complex (BGC) and Bundelkhand Granite (BG) overlain by the thick sequence of Aravalli-Delhi Supergroup, followed by sedimentary packages of Vindhyan Supergroup.

The study further adds about the palaeotectonic understanding of which visualizes that the beginning of amalgamation of the supercontinent took place around 2.4 Ga, involving craton of south Australia, east Antarctica, India and north China. After initial assembly, following a long period of high standing supercontinent and continental erosion, the North Indian craton experienced intracontinental extension and mafic magmatism at 2 Ga to 1.8 Ga that led to the opening of rift related basins like Lesser Himalayan basin, Bijawar and Gwalior basin in Bundelkhand block, Aravalli basin in Aravalli block. Therefore we emphasize that the early rifting episode in Bundelkhand block is preserved as penecontempo-raneously deposited volcanic and siliciclastic sequence in Lesser Himalaya and Bijawar basins. The transition from rift related setting to passive margin / intracratonic setting is evidenced from sedimentological data of Lesser Himalaya.

Component 1.4b :

Geochemical and isotopic studies of source rocks and riverine phases in the head waters of the Indus and Ganga: Implications for weathering and erosion in the North West Himalaya

(S.K Rai, S.K. Ghosh and R. Islam)

Quartzites are one of the major clastic sedimentary rocks in the Himalaya that had deposited in the Tethys Ocean basin and exhibit varying chemical composition, protoliths, age (pre-Himalaya) and depositional settings. In this study, geochemical and isotopic composition were determined in the quartzite samples collected form the either side of MCT zone of the Garhwal Himalaya to know whether their provenance and nature of the protoliths are similar.

Figure 6 shows that the provenance of the Lesser Himalayan Quartzites (Kaliasaud - Alaknanda region; e_{Nd} ranging from -20.8 to -23.5) are different than those from higher Himalayan quartzite (LHQ) ranging from -16.5 to -19.6 (except one sample -27.7 which is similar to the earlier studies [1]). This indicates that the Higher Himalayan Quartzites are the remnant of more juvenile source than that of the Indian craton and therefore Indian basement may not be the source for these rocks. The depleted values from the lesser Himalayan Quartzites indicate a more evolved crustal source showing affinity towards origin of India basement. However, the two isotope plot ($^{87}Sr/^{86}Sr$ & e_{Nd}) indicate about their overlapping protoliths which is to explain with more isotopic data in this region.

A new programme (Isotopic and Geochemical studies of hydrothermal springs in the NW Himalaya,

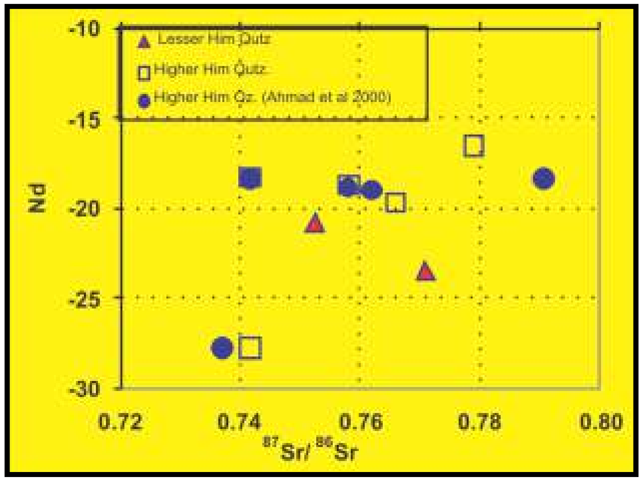

Fig 6: $^{87}Sr/^{86}Sr$ & Nd of the Himalayan Quartzites near the MCT zone of the Garhwal Himalaya (India).

India) has been initiated as a part a PhD thesis work. This is aimed at to address the questions including: (1) how the Himalayan Orogeny influences the long term CO_2 concentration of atmosphere through its degassing during the processes of Metamorphism. (2) Whether it is significant in comparison to the weathering of silicate rocks in the Himalaya. Towards this, a field campaign was undertaken in the Garhwal Higher Himalaya to collect water samples from the thermal springs and rivers near the MCT zone. Major ion, trace elements; Si/Ge & (isotopes; $^{87}Sr/^{86}Sr$, $\delta^{13}C$, $\delta^{18}O$ etc.) are being measured on these samples to estimate the contribution of hot spring in major ions budget of Ganga Headwaters and their impact on the long term CO_2 efflux to the atmosphere.

Component 1.5 :

Geological and geophysical characteristics of Malari and Lower Palaeozoic Kinnaur Kailash Granites

(S.S. Thakur, S.K. Rai, Koushik Sen, Gautam Rawat (Coordinators B.R. Arora and S. Sinha Roy)

Component 1.5a :

Analysis of geological and geophysical characteristics of the Malari Leucogranite, Garhwal Higher Himalaya: Evaluating the effect of Channel Flow along the South Tibetan Detachment

(S.S. Thakur, S.K. Rai, Koushik Sen, Gautam Rawat, Coordinators B.R. Arora and S. Sinha Roy)

Metamorphic evolution of HHCS rocks

The Higher Himalayan Crystalline Sequence (HHCS) exposed in Malari-Joshimath area, NW Himalaya bounded between hanging wall of MCT (Main Central Thrust) and foot wall of STDS (South Tibetan Detachment System) is characterised by high grade metamorphism. The lithounit show metamorphism from kyanite grade to sillimanite-kfeldspar grade. The main lithologies observed in this unit are psamites, pelitic schist, pelitic gneiss, quartzofeldspathic gneiss and augen gneiss. The Main central thrust which separate HHCS from LHS (Lesser Himalayan Sequence) occurs in the form of shear zone and commonly known as MCT shear zone. Shear zone is commonly consists of mica schist and pelitic schist with minor quartzite bands.

The common mineral assemblages observed in pelitic rocks of the HHCS are kyanite-biotite-muscovite-plagioclase-quartz, biotite-muscovite-plagioclase-quartz, kyanite- garnet-biotite-muscovite-plagioclase-quartz, garnet-biotite-muscovite-plagioclase-quartz and sillimanite-garnet-plagioclase-kfeldspar-biotite-quartz. Tourmaline and ilmenite are common accessory phases. At lower structural level kyanite appeared as a small needle shaped crystal in HHCS rocks. Rocks of MCT shear zone are commonly garnet bearing with numerous inclusions of ilmenite, quartz, biotite and chlorite. These garnet porphyroblasts are commonly characterised with curved or spiral inclusion trails.

EPMA analyses of selected rocks samples from HHCS show that most of the garnets are almandine-rich whereas a few of them are grossular-rich. In one sample grossular content in garnet is observed about ~38 mol %. Most of the garnets are homogeneous; a few of them are chemically zoned. X_{Mg} values [XMg= Mg/(Mg+Fe)] of biotite vary from 0.3-0.5. Plagioclases are sodic and X_{Ca} value ranges from 0.22 to 0.29. P-T calculations yielded by using different geothermometric calibrations suggest that within HHCS metamorphic temperature increases from lower structural level to higher structural level.

Geophysical Observations

To evaluate geophysical characteristics of the region Magnetotelluric (MT), observations are taken at five places namely Tapovan, Lata, Jumma, Malari and Farkyan. Logistics and field conditions do not allow for MT observations in the north of South Tibet Detachment zone. Malari station is occupied for long period investigations and time variations are recorded for one month at southern side of Dhauli-Ganga River. Time series is processing for MT and Geomagnetic Depth Sounding (GDS) transfer function utilizing Welch overlapped section averaging with robust approach based on Huber regression M-estimation. Figure 7 shows sounding curve for LMT for period 10 sec to 10000 sec.

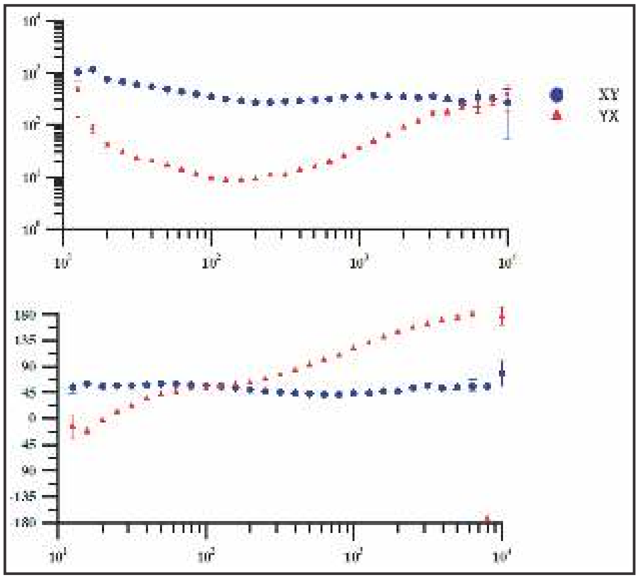

Fig. 7: LMT sounding curve at Mallari.

The characteristic observed feature of sounding curve is phase above 90° in both polarization and variation of apparent resistivity curves. Phases for both polarisations are in same quadrant and above 90° after 400 sec period. Apparent resistivity in XY polarization steeply decrease to approximately 10 ohm m in the period band of 10 to 100 sec and then rises to 300 ohm-m in the period band of 300 sec to 10000 sec whereas YX polarization does not show steep variation in apparent resistivity. This characteristic behaviour of sounding curve shows complex resistivity variation beneath the station and indicating 3-dimensional induction or anisotropic behaviour of background geoelectrical structure at lower crustal depth level. Pseudo section of XY polarization indicates resistive body up to 10 sec period and having conductive feature above 500 sec at extreme north (Fig. 8). It may be noted that LMT01 is having MT response from period 10 sec to 1000 sec.

It is planned to observe magnetic field variation for GDS transfer function at one or two places in the north of STD as it require less space and logistics. Dimensionality analysis and modelling of MT transfer function is in progress.

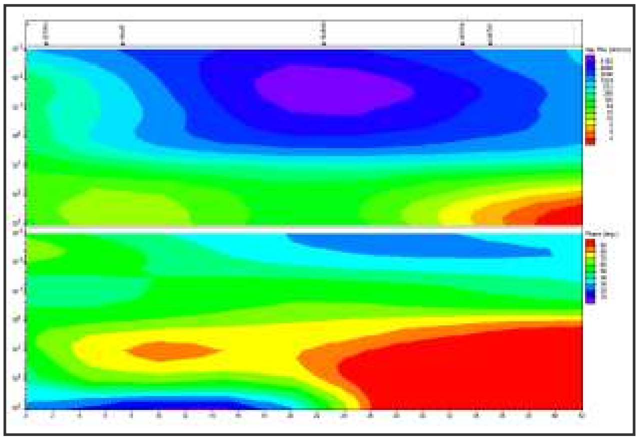

Fig. 8: Pseudo section of XY (North-South) Polarization.

Component 1.5b :

Study of Himalayan metamorphism in the Sutlej River valley of Himachal Himalaya

(S.S. Thakur)

In the Sutlej River Valley, xenoliths of various dimensions have been observed embedded in ~500 Ma old Kinnaur Kailash Granite. There are two types of xenoliths observed based on nature of rock type i.e. mafic xenoliths and pelitic xenoliths. Mafic xenoliths are commonly 5-10 cm long, elongated shaped body, sporadically distributed in the Kinnaur Kailash Granite. Most of them are fine grained and massive. The size of the pelitic xenoliths ranges from 5 to 20 cm in length. They are commonly oval to elliptical shaped body and rarely show partial resorption by the host pluton. The common mineral assemblage observed in pelitic xenoliths is bt-pl-qtz±grt±ms with ilmenite as accessory phase. In garnet bearing pelitic xenoliths, most of the garnet porphyroblasts are enhedral shaped crystals with numerous randomly oriented inclusions. Biotite, quartz and ilmenite are commonly found as inclusions in these porphyroblasts.

The common mineral assemblage in mafic xenoliths is cpx-hbl-pl-q-ilm±grt±sph. In most of the mafic rocks, pyroxene altered into hornblende; and commonly rim around pyroxene. BSE image of clinopyroxene shows micro scale exsolution texture. Corona of garnet is observed either around plagioclase and clinopyroxene. EPMA data show that garnet in high-grade schist xenoliths are widely varying in chemical compositions. In sample XN8, garnet is chemically homogeneous whereas zoning is observed in sample XN12 and XN13. Garnet in sample XN8 is Ca and Mn rich. It has 25-26% spessartine, 27-30% grossular, 02% pyrope and 42-45% almandine component. In sample XN12, garnet is Ca rich which has 15-21 mol% grossular, 07-09 mol% spessartine, 09-10 mol% pyrope and 61-66 mol% almandine components. Localised zoning of Ca content is observed in this sample around plagioclase inclusions. Garnet in sample XN13 is Mn rich and shows zoning of Mn and Ca. Clinopyroxene is Mg rich and falls under diopside-hedenbergite solid solution series. Its X_{Mg} value varies from 0.51-0.60.

Chemical composition of plagioclase widely varies in different samples. In XN8 it is of oligoclase variety and contain 21 to 30% anorthite component. In XN12, this mineral shows normal chemical zoning where X_{an} value [X_{an} = Ca/(Ca+Na+K)] increases from 0.7 to 0.9 from core to rim. Xenoliths XN8, XN12 and XN13 contain biotite. All analysed biotites are Fe rich. The X_{Mg} value of biotite [X_{Mg} = Mg/(Mg+Fe)] ranges from 0.37 to 0.42. Mn content in biotite is very less and it is <0.62 wt%.

P-T estimates obtained from TWQ and Thermocalc software in combination with conventional geothermobarometry show that xenoliths have attained the metamorphic pressure of about ~6-9 kbar and temperature reached up to ~ 700 ºC. Solvus temperature yielded for plagioclase-orthoclase exsolution textural assemblage of sample XN13 is about ~450-500 ºC.

Component 1.6 :

Thrust zone geochemistry, fluid-rock interaction and mineralogical studies - implications for tectonic evolution in Uttaranchal Himalaya

(P.K. Mukherjee and T.N. Jowhar)

Petrographic and mineralogical studies were carried out and XRF and EPMA data was generated on samples from Bhaironghati granite, Gangotri granite and Higher Himalayan crystallines. Total 51 samples from Bhaironghati granite, Gangotri granite and Gneisses from metamorphics were processed and subjected to statistical and Geochemical interpretation. Harker Diagrams and various Geochemical plots are generated for petrogenetic studies and interpretation of the granitoids. Geochemical data was subjected to Principal Component analysis and Cluster Technique was employed for classification and discrimination. 17 samples from the Gangotri granite and 23 samples from the Bhaironghati granite were subjected to Principal Component analysis using their major and minor elements SiO_2, TiO_2, Al_2O_3, FeO (T), Mno, Mgo, Cao,

Na_2O and K_2O. For both the granite units 99% of the Variance can be explained by SiO_2, Na_2O and K_2O. Using the de la Roche R1-R2 multicationic diagram it is interpreted that large volumes of felsic liquids can be generated by low degrees of partial melting of felsic crust which may form large batholiths of anatectic leucocratic granites. Gangotri granite (23Ma) and Bhaironghati granite(500 Ma) show distinct trends in their geochemical behaviour. The variation plots of major oxides with SiO_2 and various discrimination diagrams suggest that Gangotri granite have formed by process of fractional crystallization and these granites were derived from crustal source by syn-collisional process.

The EPMA data were obtained on samples of Higher Himalayan Crystallines from Sainj-Lohari Nag-Gangotri Section by utilizing Cameca SX 100 microprobe at WIHG. P-T Calculations/estimates have been done on these rock units by using computer program winTWQ version 2.34 (Berman, 2007). In the Lohari Nag-Sukhi-Gangotri section Sillimanite-Kyanite-mica schist gneiss pass gradually into migmatite with the development of leucogranite veinlets along the main foliation. The grade of metamorphism here reaches upto sillimanite-muscovite grade of middle amphibolite facies. Geothermobarometric estimates and migmatization of the gneissic rock suggests partial melting under water-rich conditions at pressures of 9-10 Kbar and temperatures of 650-750^0 C. Garnet preserves prograde zoning and experienced minimal diffusional modification or retrogression.

A brief field trip was carried out in Bhujan section. Deformed and undeformed (least deformed) protolith sample pairs were collected from the Ramgarh thrust zone. These include two contrasting rock types, quartzite-phyllonite and granite gneiss-phyllonites. The samples are analysed for major and trace elemental concentrations including REEs. Geochemical treatment establishes that REEs were relatively conserved during shearing in presence of plentiful fluid at mid-crustal level. Further work is in progress to constrain the time and micro-thermometry to workout the exhumation history of the Ramgarh thrust. For this purpose, an initiative for developing LA-ICP facility was undertaken.

LA-ICP laboratory

Successfully interfaced the Laser Ablation system with the Host ICP system. The analytical protocol has been finalized for analysis of bulk rock samples for trace and REE analysis.

This has far reaching consequences in terms of higher accuracy and precision. The solid sample technique uses the pressed pellets for trace and REE analysis that is otherwise not possible by XRF. It involves no solution, hence cost-effective and fast. Once adopted, it would replace the time consuming, cumbersome and hazardous solution preparation, rendering the wet chemical laboratory activity to a minimum.

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

(Keser Singh)

The tectonic evolution of the Chamba Thrust Sheet has been worked-out and thereby the structural inconsistencies related with the folding pattern and thrusting, have been resolved to an extent. A brief resume has been presented below.

The Chamba succession, occurring south of Zanskar Shear Zone, has developed a number of regional folds. Two such regional scale synclinal structures were reported independently from this succession viz., one developed within and toward its southwestern border, generally referred to as the Chamba syncline with vergence toward SW and other, the Tandi syncline developed eastward with vergence toward NE. There is very little or no structural data available from the area between these two synclines. These two regional scale synclinal structures were explained by two different tectonic events, viz., the NE vergent Tandi syncline by a NE directed nappe stacking which preceded the principal SW directed Himalayan deformation responsible for the formation of SW vergent Chamba syncline. The development of NE vergent Tandi syncline remains enigmatic in context of the dominantly SW-directed, synmetamorphic folding and nappe thrusting in the Himalaya. However, formation of the NE vergent Tandi syncline was explained by assuming a nappe stacking toward the NE that preceded the SW directed main Himalayan deformations. Lack of definitive evidence for NE nappe stacking prior to SW directed Himalayan deformation, to explain the NE vergent Tandi syncline, render this proposition debatable.

Similarly the contact relationship of the Chamba succession with the underlying units i.e., the Panjal Thrust Sheet (PTS) and the HHC has offered divergent views. Nature of contact of the Chamba succession with the underlying units is crucial in deciphering its folded sequence.

The Tethyan rocks exposed as the Chamba Thrust Sheet has been thrust over the Higher Himalayan Crystallines (HHC) and the Panjal Thrust Sheet (PTS) along the Chamba Thrust. Although the Chamba Thrust Sheet (CTS) is metamorphosed to anchizonal grade and younger relative to the underthrusted HHC and the Panjal Thrust Sheet (PTS), still it occupies the structurally highest level in the thrust stack, thereby exposing different segments of the thrust geometry. The orientation of different structural elements with respect to the Chamba Thrust from one area to other has been worked-out and accordingly the geometry of Chamba Thrust has been classified. On the basis of structural elements (D_1), the NW-SE trending and NE dipping segment extending from Brahmour to Bhaderwah has been described as the Chamba Thrust (frontal); the E-W trending segment extending from Bhaderwah to Kilar as Chamba Thrust (lateral) and the NW-SE trending and SW dipping segment extending from Kilar to Phindru as Chamba Thrust (trailing) respectively. The geometric analysis of the Chamba Thrust indicates that the Chamba Thrust Sheet is tectonically bound along its strike extension by its lateral zones, while the frontal zone demarcates its southwestern boundary and the trailing edge the northeastern boundary.

Analysis of the geometry and folding pattern within the Chamba Thrust Sheet reveals regional folds were developed during the southward translation of the Chamba Thrust Sheet. The structural mapping of the area between the Chamba and Tandi synclines further reveals that these synclines are ultimately connected with each other by the two anticlines and a very open undulating syncline in the area in between. The structures described above fit well into an asymmetric box fold geometry, since axial planes of the two anticlines dip opposite, but towards each other. Therefore, these anticlines were interpreted as the two hinges, and the Chamba and Tandi synclines as the eastern and western flanks of an asymmetric box fold. This box fold is described here for the first time as the *Hadsar-Chobia box fold*, which is c. 80 km long and c. 35 km wide and formed during the D_1 deformation phase. The undulations in the region between the anticlines have developed during the D_2 deformation phase without any noticeable change in the geometry of the box fold. The base of Chamba Thrust Sheet has acted as a ductile-brittle substrate, which is why the Tethyan rocks also occur south of the Zanskar Shear Zone and over the Higher Himalayan Crystallines (HHC).

Field work details

Field work has been undertaken in the Lahaul-Kishtwar region for about 20 days from 13-9-2010 to 29-9-2010 to understand the contact relationship of the Higher Himalayan Crystallines (HHC) with the overlying Tethyan rocks of the Chamba Thrust Sheet. This contact has specially been important, because there are few places in the Himalaya where the Tethyan rocks have been reported south of the STD/ZSZ as in the Chamba region. Field studies include generation of structural data that includes, 1) mesoscopic analysis-to decipher different phases of deformation, 2) nature of contact between the two belts and 3) the P-T conditions along the contact zone. Numbers of rock samples were systematically collected to study the micro-structural evolution-for this purpose around 80 oriented samples were collected and around 50 samples for P-T conditions. Integrating the Structural and the metamorphic data, and with the preceding field data, will improve our knowledge about the evolution of these thrust sheets; particularly how a part of the Tethyan rocks (Chamba nappe) have occurred south to the HHC, in spite of the fact, that the northern contact between the HHC and the Tethyan sequence is extensional (normal fault); and still rely on concept that the Higher Himalayan Crystallines have moved southward in a tectonically controlled combined thrusting along the Main Central Thrust and extension along the Zanskar Shear Zone (South Tibetan Detachment).

MMP - 2 : CLIMATE-TECTONIC INTERACTION

Component 2.1 : Climo-tectonic studies in the Lahaul-Spiti-Ladakh region with special emphasis on Quaternary environmental change

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

The Spiti river originated from the Kunzum La (4950m) flowing in the NW to SE direction makes its confluence with Satluj River at Khab (2830m). Several glacial, glacio-fluvial, fluvial and lacustrine deposits are found in the Spiti valley. Fluvial deposits predominant along the course of Spiti river between Losar, Kaza, Sumra, Sumdo, Salkhar and Leo areas. Alluvial fans are deposited at the mouth of tributary channels covering the of Spiti river flood plain laterally. These Quaternary deposits are the repository of palaeoclimatic signatures in the area.

The Spiti valley slopes are covered by the small and large taluses indicate climatic conditions and fast rate of physical weathering in the area. The taluses head starts 200m down of ridge predominantly covering the valley slope and some of them are forming collision taluses and terminate to the valley floor. Near Lari a collision talus is more than 2km wide and 1.5 km high indicate fast weathering and cold desert environment prevailing since late Quaternary period in the area. Along the right valley slopes they are confined between 4400m-3520m while along the left valley slopes they are confined between 3720m-2520m indicating the impact of insolation in their development and variation of weathering process in a microclimatic zone.

The presence of debris columns indicates that during the past the climate was relatively wet in Spiti valley as compared of today. This is also evident by the presence of large inter locking glacio-fluvial debris fan in the Spiti valley. The 3-4 level of alluvial fan and river terraces are indicating impact of neotectonic activity in the area. A series of small dry lakes between 3650m to 4500m along the left valley slopes about 800m to 900m from the present Spiti river oriented in NE-SW direction between Sonam and north of Dankar villages indicate a probable fault following the strike of country rocks most likely of neotectonic origin. Another series of small dry lakes between 4280m to 4380m near Geti village indicates their neotectonic origin. The NE-SW aligned drainage parallel to Spiti river along the right side of the valley in the middle section of Spiti valley indicate a major lineament in the region which may be of neotectonic origin.

Glaciers in the Spiti valley receded faster due to less precipitation or blockade of monsoon currents in the region due to fast uplift of Higher Himalaya as indicated by the highly folded and deformed structural conditions of country rock. The Kunjum La glacier which is origin of Spiti river is about 7km long and about 1-1.5 km wide forming a horn at its head portion and has its snout at 4760m. Spiti river is formed by the joining of Takche Nala, Pingun La Tokpo and Kabjima Nala Near Takche the valley is around 2.5km wide filled by glaciofluvial material brought by these channels north of Lato Gompa. This indicates the fast retreat and melting of glacier during the recent Quaternary period. Along the left valley slope a wide bench marked by distinct slope break between 4500m-4800m indicate a former surface of past glaciations. The glaciers in the Spiti valley are relatively small valley glaciers and show the impact of insolation in their altitudinal extent. The snout position of north facing glaciers lies between 4900m-5000m while south facing glaciers have their snout at 5320m-5400m and northwest facing glaciers lower limit is at 5280m.

The related aspect of equilibrium line altitude (ELA) requires meticulous inquiry since this responded to climatic and tectonic environment of the region. This is very essential as the ELA parameter is being extensively used to calculate ice volumes and decipher trends in climate change. Accurate mapping coupled with extensive dating of the relict ELAs will help establish the chronology of events besides understanding geodynamic influence over the climate change including its oscillations. On the basis of moraine which are more intact in the north and northeast facing glaciers have ELA around 5400m-5500m respectively.

The geomorphic features and drainage anomalies indicates that the Spiti valley has rejuvenated during the Quaternary period. The Fan terraces deposited at the mouth of the tributary channels along the Spiti valley show upliftment natures. Thick sequences of past debris flows which are 50-70m from the Spiti river bed indicates rapid mass movements and high glacial melt during the Quaternary period. These fluvial glacial deposits of past mass wasting show the development of earth pillars indicating reduction in precipitation and increased drier conditions.

The Lahul-Spiti region represents a typical alpine environment having been glaciated extensively during the Pleistocene. The present day glaciers lie higher up in the region and the perpetual snow cover is thinly distributed, more particularly in the Spiti sub-region, which is relatively more cold and dry than the Lahul sub-region. The major glaciers that once moved in the region include the former Chandra glacier fossil traces of which can be found as far as Tandi and beyond probably to Chamba. At least three levels of glaciation have been recognized by Kulkarni et al. (2006) in the Chandra valley. This glacier occupied the axial part of the Rohtang-Keylang (=Chandra) antiform although no axial fault or fracture is indicated by any structural study so far. But the depth of the glaciated valley produced by this former glacier and the smooth slopes on the right side suggest the structural influence in this antiform by way of an axial fracture which gets deviated from the axis in the Tandi area. There are no true lateral moraines in the glaciated Chandra valley except in its upper reaches in the Chandra Tal-Samundra Tapu area. This apparently suggests a phase of rapid wash out during interglacial period probably due to steep valley sides where retention could be least and high intensity rain when the region was still in the active influence of monsoon due to relatively low height. There are some large transverse moraines left over by the side valley glaciers, which indicate a phase of glacial advance after the withdrawal of the former Chandra glacier.

Component 2.2 :

Environmental magnetic study of selected paleo- and present day glacial lakes in Central Higher Himalayan, India

(Narendra Kumar Meena)

This project pertains to reconstruct paleoclimate near glaciers and its correlation with other global data. The field work was carried out in Renuka Lake. Though, Renuka Lake is not a glacial lake by origin but data of a low altitude lake was much needed for correlation point of view, two long core samples were obtained from lake. The grain size analysis of the previously sampled gangotri fluvio-glacial profile has been done for 80 samples. The profile is dated 1.7 ka using OSL dating technique. The Chorabari fluvio-glacial profile also dated 2.9 ka.

The geochemical analysis of the Chandra Tal lake has been completed and compared with the environmental magnetic data on basis of two AMS ^{14}C ages. The oldest age of ChandraTal is calculated 10.5 ka BP at 56 cm depth, whereas another age at the depth of 24.5 cm shows 3.7 ka BP. Therefore, the ChandraTal provides entire Holocene climate fluctuation records for first time from that part of Himalaya (rain shadow). Lithologically top to 45 cm sediments contain blackish clay to fine silt while rest 45 to 56 cm exhibits medium silt. At first observation the magnetic susceptibility (Xlf) in ChandraTal is governed by the magnetic mineralogy as both Saturation Isothermal Remnant Magnetisation (indicator of magnetic mineralogy) and magnetic susceptibility exhibits similarity. Both the parameters display decreasing trends when Indian summer monsoon intensified. The similar trend of the magnetic susceptibility has been reported as indicator of aeolian input by winter monsoon winds from Huguang maar lake, China (Fig. 9). The dominance of the Single Domain magnetic grain supports our observation that magnetic concentration of the ChandraTal is possibly controlled by aeolian dust migrated with winter monsoon winds. Though, the magnetic data of the ChandraTal is independently sufficient to interprete Holocene climate fluctuations in context of winter monsoon winds, but it is always good to have multi proxy data. The titanium content emerged as one of very strong proxy of summer monsoon variation.

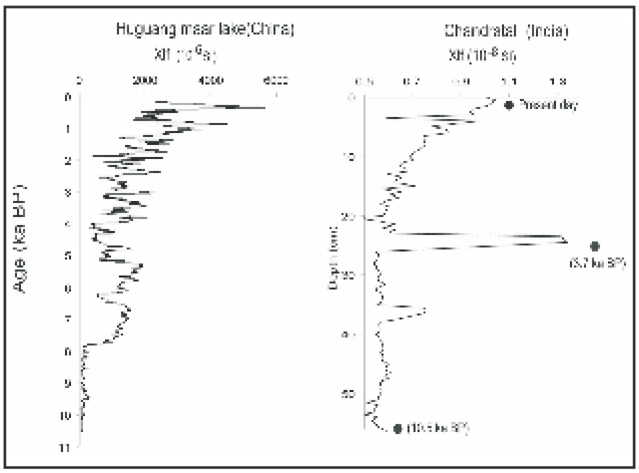

Fig. 9: Display magnetic susceptibility of Huguang maar lake and ChandraTal, both the graph shows similar trend.

It's always advantage to use Ti content in small lakes where heterogeneity of sediment input remain very low due to small catchment. The presence of heavy metal such as Ti in lake sediments depends on the monsoon rainfall. Therefore, the Ti content in the ChandraTal sediments during Holocene optimum indicates intensification of summer monsoon. On the other hand, the low Ti content during 3.7 ka BP indicates moderate monsoon. The lowest values of Ti content recorded at depth of 7 to 11 cm and 48 to 56 cm indicates failure of Indian summer monsoon. The Ti- content of the ChandraTal display an excellent correlation with widely used summer monsoon data sets e.g Arabian Sea (G.Bulloides), Dongge cave, Oman cave ($\delta^{18}O$) and Cariaco basin Ti content.

Component 2.3 :

Tectono-climatic evolution of Alaknanda-Bhagirathi river system in NW Himalaya

(Pradeep Srivastava, R. Islam and B. Sharma)

This year eight new sections, along the river Bhagirathi, located at Gangotri, Bhaironghati, Bhatwari, Malla, Latta Sera, Netala Gyansu, Atheli Dunda, and Margaon sections were studied. Detailed geomorphic analysis using the Digital Elevation Model (DEM) and field investigations was carried out. The type of terrace configuration and sedimentary environment was ascertained by preparing the sedimentary lithologs. Total number of 21 samples were collected and processed for Optically Stimulated (OSL) dating. Terraces which are present in between Bhatwari (Upstream of MCT) and Dharasu (near NAT) are studied and are found neotectonically governed terraces. The extensive terrace sequences are present downstream of Dharasu but most of the terraces are submerged in the water of Tehri reservoir. Terrace sequences in the upstream area are having bedrock at their base and can be termed as the strath terraces on the other hand terrace sequence downstream of the MCT are fill terraces and have broadly four levels of terraces as the area is highly populated as compared to the upper reaches. In the Bhagirathi river valley two phases of aggradation had occurred; first from ~55 ka to 18 ka and from 10 ka to 2 ka. The major phase of aggradation is around 35-20 ka when most of the terraces are deposited. The Chemical Index of Alternation as calculated from terrace risers in Bhagirathi valley at Dharasu suggested that the deposited sediments are more or less pristine or have suffered least weathering. Further the sediments are mainly sourced from Higher Himalaya.

Additionally, luminescence behaviour of different quartzitic rocks of Lesser Himalaya was studied. The study indicated a consistent increase in luminescence sensitivity after every cycle of erosion and deposition.

Studies of palaeolake deposit from Dhauli Ganga Valley, Higher Himalaya

A paleo-lake section at the junction of Girthi gad and Dhauli Ganga (upper Alaknanda catchment) has been studied in detail. 48 samples for sedimentological and mineral magnetic analysis were collected and are under process. Five samples from bottom to top were collected for OSL dating. The dating results indicate that the lake spanned between 13-7 ka. This work was carried out in the collaboration of Prof. Y.P. Sundriyal, HNB Garhwal University, Srinagar.

Component 2.4 :

Paleoclimatic and Tectonic study of the Quaternary-Holocene Speleothems from NW and NE Himalaya

(V.C. Tewari)

In recent years speleothem records have received attention, as speleothems represent one of the few continental archives that can match the ice core records (as in the Arctic and Antarctic polar ice cores) in resolution and age control for time periods older than the Holocene. Stalagmites and Stalactites (Speleothems) are formed in the caves and are regarded the most significant archives of paleoclimate. Speleothems are limestone deposits within the caves. The ground water trickling through cracks in the roof of caves (Fig. 10) contains dissolved calcium bicarbonate which is transferred into calcium carbonate and precipitated out of water solution and forms a ring of calcite on the roof of the cave. Stalagmites are formed as a result of evaporation and precipitation from the solution after the trickle water falls from the stalactites. (Fig. 10). During 2010, Speleothems from the Chulerisma and Patalbhubaneshwar caves of Uttarakhand were studied for paleoclimate interpretation. Samples were collected for the sedimentolgical facies , carbon and oxygen isotoic variations in speleothems for warm and cool (dry and wet) periods. Speleothems are least altered deposits and very reliable to study the Monsoon pattern of the past.The long term rainfall and

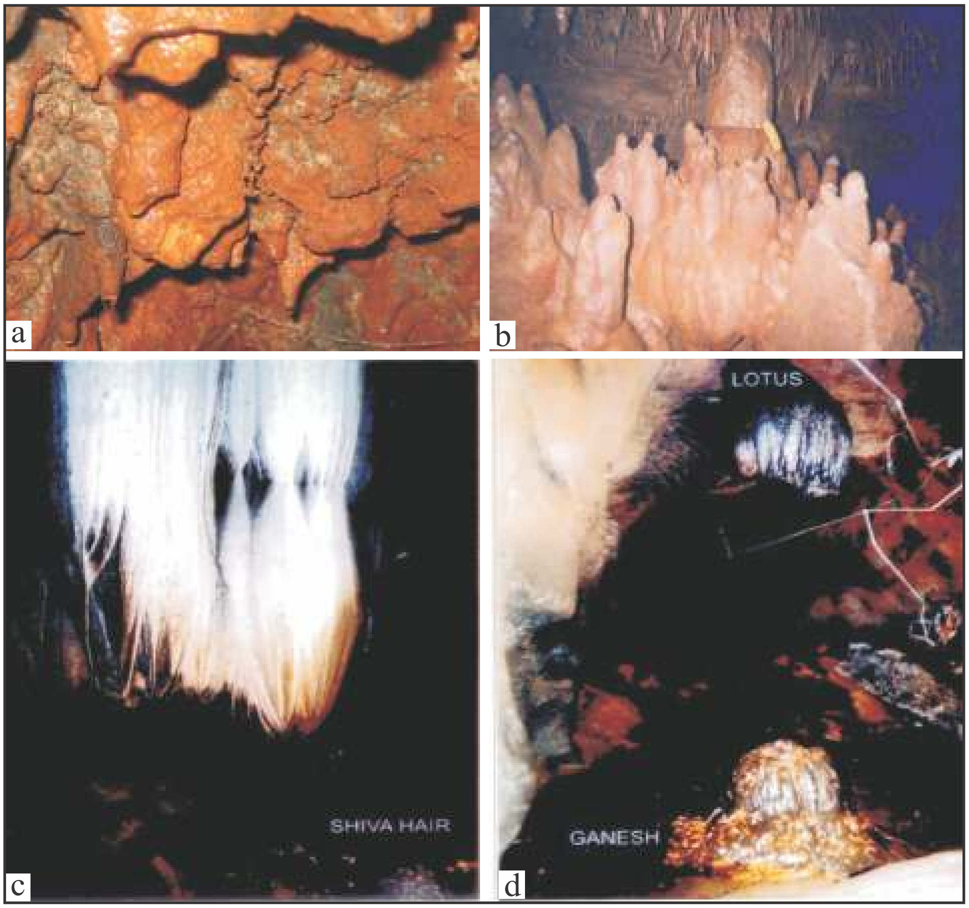

Fig. 10: Speleothems from Chulerasim and Meghalaya (**a, b**) and Patalbhuvaneshwar (**c, d**).

precipitation variability over the Himalaya is not well established. Negative oxygen isotope values have been recorded for speleothems from both the Chulerisma cave and is consistent with the data available from other caves , indicating higher monsoon rainfall.

Cave deposits or Speleothems are natural archives of the paleoclimate record and abundantly found in the Himalaya from NW to NE India , where calcium carbonate is precipitated as flowstones, stalactites and stalagmites. Himalayan speleothems may provide important record of palaeoclimate and palaeomonsoon since they are not subjected to diagenesis, erosion and terrestrial deposits. Miocene to Holocene palaeoclimatic, paleoceanographic, palaeomonsoonal studies from the tropical and monsoonal regions of Indian ocean and subcontinent and SE Asia has been attempted in recent years (Anil Gupta, 2010, 2011; Fleitmann et al., 2003; Johnson et al., 2006; Sinha et al., 2005; Yadav, 2005; Tewari, 2009, 2010). Carbon and oxygen isotopic variations in speleothems especially stalagmite growth laminae is used for interpreting the amount of rainfall (Tewari, 2010). In the present work, two very important speleothem deposits have been studied from the Kumaun Himalaya in 2010 and salient features are described. These caves are located in the Chulerasim near Chaukhutia and Patalbhubaneshwar near Gangolihat town of Almora and Pithoragarh districts of the Kumaun. The samples were collected from caves for the sedimentological microfacies of the speleothems , carbon and oxygen isotopic ratios of the stalactites and stalagmites for palaeoenvironmental and palaeoclimatic interpretations. All these caves lie in the high monsoonal region therefore, it is quite significant to study the strength of Indian Summer Monsoon (ISM) and decadal scale seasonal variations.The high resolution 230 Th dating of stalagmites from these unexplored caves will help in calculating the amount of rainfall due to South west ISM and their exact timing of formation and decadal scale monsoonal variation. It is highlighted here that during the month of September 2010 when the field work was carriedout , there was heavy rainfall in the whole Uttarakhand region and in Dehra Dun city itself the record of rainfall of last forty years was broken.

The Chulerasim and Patal Bhubaneshwar caves are situated in the Lesser Himalayan Meso-Neoproterozoic Gangolihat Dolomite Belt. The dolomite is stromatolitic and cherty and was deposited in the tidal flat (shallow marine) environment. The caves are not well ventilated, narrow and a variety of flowstones, hairy thin stalactites, broad and wide stalagmites have been recorded. (Fig. 10 a-d). In the laboratory, the petrographic thin sections of the speleothems were studied for microfacies and sedimentological parameters. The Chulerisma and Patalbhubaneswar speleothems are made up of stalactites and stalagmites. (Fig. 1 a,b, d). The stalactites show wavy laminations of alternating dark and light bands of calcite and the possible presence of bacteria to form calcite precipitation.The microfacies of the stalactites show radiaxial fibrous calcite. Possibly the Mg has triggered the formation of radiaxial fabric. Microbial precipitation of the carbonate is revealed by the presence of microstromatolitic structures and probable cellular microbiota. The culture experiments may demonstrate the role of microbes (PCR amplification of ^{16}Sr RNA genes (^{16}Sr DNA) in the stalactite formation. Other carbonate mineral present is aragonite formed in fresh water. Various types of light (carbonate) and dark (organic) laminae is related to the microclimatic decadal scale seasonal variations. Powder samples prepared for the Geochemical and carbon and oxygen isotopic variation in these speleothems are currently under analysis in various laboratories and will be used further for the paleoclimatic interpretations.

The variation of δ^{18}O in stalagmites is generally related to the precipitation amount during the monsoon season. The oxygen isotopic composition of speleothem calcite from tropical and monsoon locations are primarily controlled by the δ^{18}O value of precipitaton. δ^{18}O values of regional precipitation and that changes in calcite δ^{18}O over time primarily reflect changes in the amount of monsoonal precipitation. Cave calcite also contains information about the isotopic composition of meteoric precipitation, is widespread and can be dated with 230Th. Thus, a detailed high resolution O isotope speleothem data from the Himalaya is currently being produced by the investigator which may give well dated record of palaeomonsoon history. Fleitmann et al. (2003) and Tewari (2009, 2010) have interpreted that the western part of Indian Summer Monsoon (ISM) in Oman and Yemen, the oxygen isotope ratios of stalagmite calcite primarily show variations in the amount of rainfall with more negative δ^{18}O indicating higher monsoon rainfall . In the earlier study by the investigator (Tewari, 2009, 2010) also, negative δ^{18}O values have been recorded from the Himalayan speleothems (Brahmakhal and Sahastradhara caves). A detailed study of other unexplored caves in the Himalayan region and their Th dating is essential and will be undertaken to further confirm these results and propose a model for palaeomonsoonal variation.

Another important aspect is being studied regarding the relationship between tectonically displaced speleothems due to earthquakes and movement of the tectonic plates in the Shillong Plateau with special reference to the NE monsoon (Fig. 10c). The intensification of Indian monsoon may spin the earth's tectonic plates. There could be a relationship between movement of the Indian Plate over the last ten million years and the intensification of the Indian Summer Monsoon (ISM). The climate change must have effected the monsoon which increased the rainfall in the Meghalaya (Cherrepunji/Sohra) as per the annual rate of increase in rainfall by four meters annually and this might have enhanced the speed of the Indian Plate by one cm per year. Therfore the detailed study of the cave deposits of the NE region has direct impact on the climate change , monsoon variability and earthquakes.

Component 2.5 :

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

(N.R. Phadtare)

Chandra Tal peat deposit

Multi-parameter paleoclimate records (pollen data, organic matter content, and mineral magnetic analysis) of AMS radiocarbon dated lacustrine sediments underlying the Chandra Peat deposit in Lahul and Spiti area have precisely documented, for the first time, as the Younger Dryas (YD) cold event in NW Himalaya. Pollen data and mineral magnetic record indicating significantly wet and warm conditions before 12880 cal yr BP, point towards the Ållerød interstadial climate. The prominent decrease in local (meadow) and regional (desert steppe) vegetation indicating major climate shift towards cold and dry conditions around 12880 cal yr BP, marks the initiation YD event. This cold/dry climate further intensified until 11640 cal yr BP and terminated with gradual reappearance of local as well as regional flora, indicates the end of YD

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cold event with initiation of the Holocene wet and warm conditions. Floristic signatures and mineral magnetic record indicate that in NW Himalaya, the YD cold reversal was probably gradual compared with its abrupt change in northern high latitudes.

Late-Pleistocene Lake deposits of the Leh Valley

The Spituk paleo-lake

The Spituk paleo-lake profile resting over T0 surface of the modern Indus River documents a rapid change in depositional environments from fluvial, lacustrine to aeolian in response to the Mid-Pleistocene to Holocene (~90 to 8 Ka OSL ages) climatic variations. Studies based on lithofacies, mineral magnetism and OSL dating infer fluvio-lacustrine environments terminating at ~55 Ka (24m above T0) followed by a variety of glacial fluctuations (varved lake, aeolian dunes and the glacial outwash deposits) within same continuous profile. The facies inter-fingering without any notable intermixing of the two contrasting sources: A) the granitic source from Ladakh batholithic glacial domain on right bank and; B) the recycled sedimentary source from the Indus Formation from left bank; that are also characteristic of ferri- and antiferromagnetic mineralogy, respectively. The lower part (< 24m) characterizes inter-fingering lacustrine and fluvial environments with attempts of lake-formation aborted by the fluvial excursions from source (B). While the upper part (>24 m) shows persistent glacial environments dominated by the source (A) characterizing glacial varve lake conditions followed by cold arid aeolian phase ending with glacial outwash around terminal Pleistocene leading to rapid incision during early Holocene.

Lake out burst record

The outburst record of this paleo-lake was also investigated for climate and tectonic implications. The sediment package is uniquely displayed by megascopic (meter scale) and intense injective liquefactions, slumping and gliding of the lake beds, and mega-scouring by gravelly outflow with enclaves of dry lake beds. The arrangements and morphology of these structures indicate the following sequence of processes that might have occurred during the lake outburst:

- Increased hydrostatic compression due to raised lake levels,
- Sudden release of compression due to outburst, followed by,
- Geomorphic re-adjustments for the slope stability.

These processes have developed the sediment features that are distinct in magnitude, morphology and intensity from commonly reported seismites in the NW Himalayan region.

Investigation of the Leh cloud burst (Aug. 6, 2010)

The post-facto investigation of geomorphic signatures and sedimentation occurred due to extensive flash floods triggered by the recent major cloud burst in and around Leh, was undertaken. Field documentation infers it as a series of cloud bursts longitudinally spread over a stretch of ~275 km along the northeastern ridges of the Indus River. The sequence of events such as lateral channel cutting, sharp incision in channel axis, boulder line-up and the double layered slurry deposits; and their distribution in upper, middle and lower reaches indicated that the initial stage of cloud burst caused lateral stream cutting in upper reaches with lowest sediment:water ratio. The intermediate stage characterises hyper-concentrated flow from 1st as well as 2nd order streams primarily due to funneling effect, recharging of debris, and buoyant flow of boulders. Following the sediment mass deposition in terminal stage, the sediment-starved downward flow, recharged by continued rainfall, resulted into a unique self-incision producing a deep sharp cut in the channel axis started from middle reaches, continued up to base of the lower reaches in down-valley. The viscous mud-rich flow, buoyantly carrying the boulders unconfined to its channel, joined the main valley gradients in lower reaches causing maximum damage to settlement on banks and the older stable surfaces. This cloud burst record witnesses the vulnerability of Leh Valley to cloud burst and resultant flash floods.

Component 2.6:
Late Cenozoic fluvial deposits in the sub-Himalaya between Ravi and Satluj Rivers interaction of tectonics and climate

(Rohtash Kumar and N. Suresh)

Main focus of the study was to understand the variability in the sedimentation pattern in the Neogene and Quaternary succession of the Sub-Himalaya between River Ravi and Satluj, referred as Kangra sub-basin (KSB). The Late Cenozoic deposit studied includes Late Quaternary deposits in the Soan Dun (post Siwalik in age) and the Siwalik Group.

Evolution of Late Quaternary deposits in the duns, NW Sub-Himalaya

The Soan Dun, a longitudinal structural valley in the NW Sub-Himalaya, is extended between Satluj and Beas rivers in the east and west respectively. The Siwalik mountains demarcates the northern and southern margin of the valley. The drainage system in the Soan Dun is controlled by Soan and Sohan rivers and their tributaties. The stratigraphic successions in the Soan Dun, exposed as alluvial fans and fluvial deposits, are dominated by sand-mud litho-units with rare occurrence of gravels. A series of alluvial fans, deposited by the ephemeral streams draining the surrounding Siwalik mountains in the north and south, were documented from the dun. These fans are abruptly truncated by the Soan River, resulting toe erosion. Based on quartz OSL dating, two set of fan sequences are identified in the dun. The oldest fan sequence, exposed in the southeastern part of the dun, is deposited between 36-29 ka and the youngest fan sequence, observed in the northwestern part, is deposited between 23-10 ka. The termination phase of older and younger alluvial fans are occurred in the increased monsoon phases and are correlated to climate change. Both the older and younger fan deposits have been subsequently entrenched by streams and the surfaces are cut off from any sedimentation.

In the southern margin of the Dun, thick fluvial deposit (10-45 m thick) is observed in a paleo-gorge cut across the detached Siwalik Hills. This fluvial deposit is traceable for more than 22 km laterally and 12 km longitudinally. However, the deposit is abruptly terminating along the HFT. Lithologically, this deposit is dominantly comprised of gravel and grey sand facies. Sand bodies exhibits sheet geometry, laterally and vertically amalgamated, multistoried, separated by major planar and inclined erosional surface. Along the erosional surface, mud balls up to 30cm thick are present. The clasts composition of the gravel beds dominantly consist of quartzite, both pink and white, with minor granite probably derived from north of Main Boundary Thrust (MBT), similar to the modern Satluj River composition. The facies characteristics are altogether different from the Dun deposit and fluvial architecture suggests their deposition by a major river, probably by Satluj River. The depositional phase of this fluvial succession is terminated around 29 Ka.

The alluvial fans in the northwestern part of the Dun (i.e. younger fan sequence) has thrusted contact with Middle Siwalik rocks along the Soan Thrust whereas the oldest fan sequence, exposed in the southeastern part of the dun, have unconformable contact with the Upper Siwalik rocks. In the hanging wall of the Soan Thrust, uplifted Late Quaternary deposit, similar in age as the top of the older fan sequence, is observed. This indicates tectonic activity north of the Himalayan Frontal Thrust (HFT), which suggests out-of sequence thrusting during Late Pleistocene. The aggradation in the paleo-gorge in the detached Siwalik hills occur in response to climate, however, abandonment of deposits and lateral avulsion of paleo-Satluj River are primarily controled by tectonic activity after 29 ka along the HFT.

Siwalik Rocks

The Neogene succession, represented by Siwalik Group is classified in to Lower, Middle and Upper Siwalik sub-group. Reversal magneto-stratigraphically constrained Siwalik succession exhibits temporal and spatial variability in response to southward orogenic growth of the Himalaya, variable crustal loading and flexural subsidence as well as altered climate. More systematic and continuous records are available for the Neogene succession, north of Jawalamukhi Thrust, in Himalayan foreland basin (HFB) consisting three distinct stratigraphic-sedimentologic successions. Conceptualized tectonic model on the evolution of Kanga sub-basin (Fig.11) exhibits that prior to 10Ma, this basin record major tectonic uplift along Chail Thrust, however due to intensified monsoon around 10 Ma, erosional unloading result intense exhumation of Dhauladhar ranges and sediment flux was deposited in to the basin. New mountain front developed around 6 Ma with intensified monsoon, hinterland uplift, development of intra-foreland thrust system and onset of deposition of Lesser and Sub-Himalayan derived sediments in the proximal foredeep depo-centre by intense deformation along Main Boundary Thrust (MBT). Based on vector properties, the paleo- drainage was along the basin axis from NE to SW direction. The depositional model of the Kangra sub-basin is represented by a wide channel belt in the confined valley, internally showing a braided morphology, enclosed within fine-grained overbank sediments in order of 1 to 3m thick mudstone. However, thick mudstone succession (>30m) within the clustered sandstone bodies is in response to availability of accommodation space. In respect to present study, it is difficult to visualize the change in accommodation space at particular interval without any evidence of tectonic activity or climatic variation. Moreover, absence of major incision phase, except minor scoring, there is no evidence of geomorphic base level change. Thick mudstone

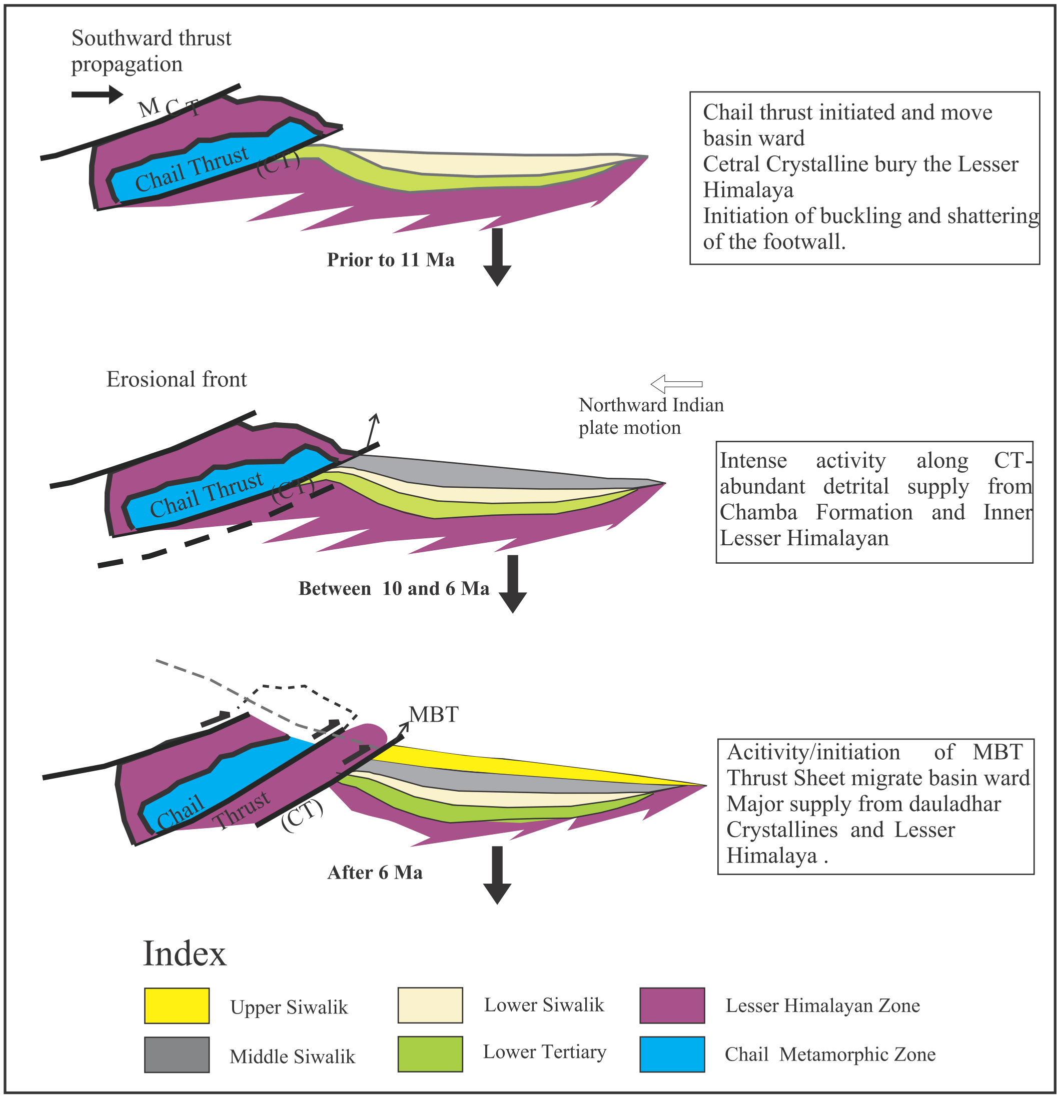


Fig. 11: Cartoon diagram exhibiting the thrust sheet dynamic and foreland basin evolution.

facies associated with thick sandstone facies deposited by braided rivers suggest rapid deposition during times of widespread overbank flooding and development of extensive floodplain. The deposition of thick pile of floodplain succession is governed by change in the hinterland tectonic or climate variability which control catchments hydrology, sediment supply, uplift rate and/or drainage basin expansion. Long-term variability of all the three floodplain sequence inferred from sedimentation pattern differs in term of pedogenesis and temporal arrangement of facies. The first sequence shows gradual up section increase in pedogenesis, indicate major river gradually incised its floodplain making an upland floodplain. Whereas, last two sequences is marked by high variability in temporal arrangement of pedogenic mudstone representing avulsing river system.

Component 2.7 :

Tectono-Climatic studies in Quaternary sediments and kinematic history of thrust sheets along the Eastern Syntaxial Bend, Arunachal Pradesh

(D.K. Misra, Pradeep Srivastava and B.K. Choudhuri)

Fieldwork was carried out in the Kameng Valley of western Arunachal Pradesh. The river flowing from North to South cut through the Proterozoic to Cenozoic rocks that occur in the form of five thrust bound tectonostratigraphic units. In ascending structural order from south to north these are: 1. Siwalik Group,

2. Gondwana Group, 3. Miri Group, 4. Bomdila Group and 5. Sela Group. The Bomdila Group of rocks does not occur to the south of Kalatang in the footwall. Within the Bomdila Group, the Bomdila gneisses have intrusive relationship with the overlying schist of Dirang Formation. The rocks of the Miri Group occur at two different tectonic levels, one as persistent belt in the foothills and the other in the tectonic window beneath the Bomdila Thrust sheet in the Lesser Himalaya. Within the Miri Group, the Buxa Dolomite has a conformable contact with the underlying Miri Quartzite in the foothills. Towards north in the Lesser Himalaya, the Buxa Dolomite lies below the Miri Quartzite due to thrust tectonics. Field studies coupled with interpretation of topographic maps resulted in the identification and delineation of active faults. Recent movements on the faults have caused pronounced deflection of rivers and streams. Movements along faults 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 and uplifted fluvial terraces.

Apart from this a soil profile developed on granodiorite was identified at Anini in the Dibang Valley and sampled to understand the geochemical processes involved in pedogenic alteration of this rock under a given climate and tectonic setup. The samples are analyzed and the further study on the geochemical dataset is under progress. The peat deposit that was sampled earlier has now been studied using mineral magnetic susceptibility. The samples are also sent out to BSIP, Lucknow for pollen and phytoloith analysis and to PRL, Ahmedabad for 14-C dating.

This year work was also carried out in Subansiri Lower Part. The Siwalik Group rocks of the sub-Himalaya exposed at the dam site area extends in a belt from Kameng through Subansiri to Siang district. The Main Boundary Thrust (MBT) defines a tectonic boundary, separating the Siwalik Group from the overlying rocks of the Gondwana Group. The Likabali-Along road section, lying ~50 km west of the Subansiri, is the best exposed section. Here the Siwalik Group is divisible into three units (Jain et al, 1974). The basal unit (A) consists of pebble bed at the base succeeded upward by bluish grey micaceous sandstone, nodular silty shale and olive green shale. Pebble sandstone and conglomerate contain clasts of sandstone, quartzite, basalt, chert, slate and schist. Thin coaly streaks and lenses up to ~10 cm in thickness occur at various levels. The middle unit (B) essentially comprises of 2000 m thick conglomerate with interbeds of sandstone. Boulder, Cobbles and Pebbles of quartzite, sandstone, volcanic and schist and granite occur in sand to grit size matrix. The clasts are rounded to sub-rounded. The upper unit C consists of monotonous grey hard micaceous sandstone with shale and siltstone alternations. The Siwalik Group exposed in Arunachal sub-Himalaya cannot be strictly classified into lower, middle and upper Siwaliks as described in northwest Himalaya. Major part of the Siwalik is buried under Brahmaputra alluvium plain.

Petrographic Studies

Nearly 10 fresh samples (unweathered) fine to medium grained, indurated and poorly durated sandstone samples were collected from various sections for detailed petrographic studies. The petrographic analysis was carried out using point counting method due to the less grain size variability within true mineralogical difference. The thin section analysis was carried out for these samples of fine- to medium-grained sandstones. In each thin section more than 500 grains are examined by measuring their size and angularity and sphericity, grain to grain contact, inclusions and alteration. The rock fragments are identified based on their characteristic texture and mineralogical association.

The sandstones constitute quartz, feldspar, rock fragments, mica, dense minerals, cement and the matrix. The quartz is identified as monocrystalline and polycrystalline, while the quartz monocrystalline are again identified as undulose and non undulose types. The quartz shows variability in undulation pattern. Quartz grains constitute an average of 39% of the volume. The majority of quartz grains are sub-angular (52%) to sub-rounded (40%), with minor (<8%) rounded to well rounded quartz grains, of the total quartz population. Due to reaction with calcareous cement, the boundaries of quartz grains have become irregular. Fractured quartz with micro-cracks is also present. Both Na-feldspar (Plagioclase) and K-feldspars (orthoclase, microcline) are present in variable amounts, with an average of nearly 3% of the total sand-silt fraction. The plagioclase feldspar includes mainly albite-oligoclase, whereas alkali feldspar include mainly microcline, orthoclase and perthite. The plagioclase feldspars commonly exhibit albite twinning. Inclusions are commonly seen in potash feldspar (orthoclase) grains. Feldspars are mostly subangular and range in size from fine sand to very fine sand (0.20-0.10mm). Like quartz grains, inherited roundness of feldspars has also been modified due to pervading calcareous cement along cleavage and twin planes. Most of the microcline grains show interlocking and or interpenetrating perthitic texture and are usually fresh. Plagioclase grains are commonly sericitised, specially in the samples, which has high calcareous cement. This suggests that the amount of plagioclase may have been reduced during the diagenesis process. Rock fragments constitute about 23% on an average volume percentage. The rock fragments are mostly medium to coarse grained, subangular to subrounded in nature. The grain shape or angularity of the fragments is partially modified due to calcareous cement reaction. The fragments consist of nearly 55% sedimentary, 39% metamorphic and 6% igneous rocks. Micaceous minerals are also present in sandstone and occupy less than 6% of the sandsilt fraction. Mica flakes are generally polycrystalline, elongated, twisted and kinked. At places biotite shows alteration into chlorite. Heavy minerals are less than 5% of the total framework grain, of which non-opaque about0.5-2%. The non-opaque heavies include garnet, tourmaline, epidote, staurolite, kyanite, zircon and rutiles. The opaques are mainly hematite, limonite and magnetite. The cement in this sandstone is mainly of two types as i) carbonate sandstone and ii) Ferruginous. Calcites are the major cement of the sandstone and constitute about 16% (average) of the total sandstone component. The calcite cement is micro to crypto crystalline in nature and occurs mostly as pore fillings. The iron oxide cement is usually hematite and limonite which occurs as patches around detrital grains. The silica cement is found either as pore filling material or overgrowths on detrital quartz.

MMP - 3 : BIOSTRATIGRAPHY & BIODIVERSITY - ENVIRONMENT LINKAGE

Component 3.1 :
Evolution - Radiation and Extinction of Bioevents in the Cambrian Ordovician successions of the Zanskar- Spiti Himalaya, their relation to Global Event Stratigraphy and preparation of database of the Himalayan Trilobites

(S.K. Parcha)

The Spiti Basin exposes excellent sections of Palaeozoic-Mesozoic successions. It displays largest marine and richly fossiliferous sedimentary succession. In the Lower Cambrian succession abundant and diverse assemblage of ichnofossils along with some Annelid worm and scratch marks were reported. The ichnofossil assemblage recovered from the Debsakhad and Parahio members of the Kunzum La Formation, is of much stratigraphic importance, due to the relationship of the morphospecies with the genetic body forms; and their rare association with body fossils. This discrete stratigraphic distribution of ichnofossil and body fossil is important for deciphering the Neoproterozoic- Cambrian transition in absence of body fossils in this region. The diverse assemblage of ichnofossils present in the Spiti Valley spanning the Precambrian- Cambrian boundary, appear to be very useful for the global correlation of this section. The distribution pattern indicates up-section increase in taxonomic and morphological diversity. The proliferation of ichnofauna could be due to the extensive evolutionary changes, which have been reported from the well known sections. The ichnofossil assemblage indicates that the ichnocenosis is dominated by a high behavioral diversity ranging from suspension to deposit feeders. Majority of the ichnofauna from the Lower Cambrian succession of Parahio section appears to be produced by trilobite or arthropods; whereas some of them might have been the trails of crustacean, priapulid worm, polychaetes and polyphyletic vermiforms. It is also observed that only few forms like *Nereites*, *Skolithos*, *Monomorphichnus* extend in the Parahio Member (Middle Cambrian); whereas, some are confined to the Debsakhad Member (Lower Cambrian). The present assemblage of ichnofossil can be correlated with other contemporaneous horizons of Tethyan as well as Lesser Himalayan regions. The presence of ichnofossils below the body fossil horizons of early Cambrian is noticeable in Zanskar, Kashmir, Kumaun and Garhwal as well as in the Spiti basin.

The Middle Cambrian succession of the Spiti Valley in general and Parahio Valley in particular contains a various trilobite assemblages. These assemblage of trilobite genera helps to understand the paleoenvironment of Parahio section and also correlate it with the adjoining sections and with other Cambrian successions. Two new species of *Pagetia* were identified from the Middle Cambrian succession and one species of Opsidiscus

The Ordovician-Silurian succession exposed in the Spiti valley is assigned to Thango and Takche formations. The Thango Formation shows a sharp and angular contact with the underlying Kunzum La Formation. The Thango Formation in its upper part shows the development of carbonate bands which demarcate the beginning of the Takche Formation. The studied sequence in the Pin valley of the Spiti Basin yielded a rich assemblage of calcareous algae, bryozoans, cephalopods and brachiopods. However, the present analysis is mainly based on the calcareous algae and on the bryozoanal flora.

During the present studies microfaunal assemblages of calcareous algae and bryozoans were reported from the Shian Kogma and equally from the Farakah Mud sections. Earlier workers have also reported some calcareous algae from the Ordovician succession of this region. However, the present collection of the microfaunal assemblage is from the lower beds. The genus *Monilliporella* was recorded for the first time from the Pin section of the Spiti Basin. The genus *Vermiporella* is reported from the Ordovician successions of Estonia, Kazakhstan; Southern Scotland and also from the Canadian, Arctic and in the Hudson Bay. Keeping in view its wide geographical distribution of the *Vermiporella*, it can be considered as a marker for demarcating Middle Ordovician succession in the Spiti basin.

It seems that calcareous algae were little developed during the Cambrian, but their diversification might have taken place from the Middle Ordovician onwards. In the Pin area the Spiti basin might have colonized by calcareous algae during Middle and Upper Ordovician which extends up to the Early Silurian succession in this region. The bryozoan fauna reported from the Thango as well as in the Takche formations indicates an age range from Late Ordovician to Silurian. The bryozoan assemblages reported from the Pin section shows close similarity with the forms reported from the Siberia, Mongolia; Kazakhstan and equally from the southern China and Russia

The Muth Formation is one of the most striking marker horizons, and has been traced throughout the northwestern Himalaya from Kashmir to Nepal. The present studies were carried out in the sections exposed in the type locality Muth (Muth Village) and in Farakah Muth of the Pin Valley, in the Spiti Basin. The succession also contains different sedimentary structure like, cross bedding, low angle truncation, interference ripple marks and several cylindrical and spindle shaped structures. The most striking sedimentary structures which are present in the Muth Formation are the cylindrical shaped structures. Within the cylindrical structures there are many concentric layers that cut across the strata at right angle. It seems that these structures are the fluidization pipes and were formed by the channeled ground water while the surrounding sediments remained unfluidize.

The petrological studies indicate that the succession contains more than ninety percent of quartz grains. The study reflect that at the base the percentage of quartz grain and their maturity is less, but it becomes gradually high, as we go higher in the succession. In some studied sections quartz shows undoluse extinction and at places opaque minerals and sericite are also present. The lithology in general shows moderate to wellsorted and subangular to subrounded grains from base to top.

Component 3.2 :

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

(Meera Tiwari)

As part of ongoing research programme aimed to explore signatures of early life, occurrence of a distinct microtubular structures known as ambient inclusion trails (AITs) were discovered within stromatolitic dolomite of Gangolihat Formation, Lesser Himalaya. This is the first reported occurrence of AITs from India. A biological process is considered for the genesis of AITs in the Gangolihat Formation. Understanding the precise relationship between a specific signature or specific organism in a rock and the environment it represents is vital to the meaningful search for early life. AITs are distinct microtubular structures formed by migration of a mineral in a rock substrate. They exhibit several noncrystallographic morphologies such as curved and helical types among others. Mode of field occurrence, association, and petrographic textures suggest that AITs are indigenous to the host rock. Based on the physico-chemical conditions necessary for the formation of AITs, involvement AITs, a distinct class of microtubular structures, are intriguing components of the geological record. The distinguishing features of the AITs in the Gangolihat Formation are the presence of pyrite crystal at the end of the microtube, longitudinal striations and angular cross-section. These morphological characteristics are consistent with those proposed by Wacey et al (2006, 2008) to distinguish AITs from euendolithic microborings, trace fossils and other cyanobacterial filaments. Wacey et al. (2008) suggested that these trails have biological origin, created by 'biogenic burps' i.e. decaying organic remains can generate sufficient gas pressures to move mineral grains.

Specimens of cyanobacteria *Nostoc* sp. with 'Heterocysts' observed from Krol E of Kumaun Lesser Himalaya. These specialized cells fix *nitrogen* (N2) in the air using the *enzyme nitrogenase*. There is an abundant supply of nitrogen in the earth's atmosphere, however, unavailable for use by most organisms until it is turned into nitrate or ammonia. It is an essential element for the growth of almost all forms of life, especially plants. In order for nitrogen to be used for growth it must be "fixed" (combined) in the form of ammonium (NH_4) or nitrate (NO_3) ions, which is then used to make proteins and other important compounds. Heterocysts (Gr. Hetero=different; Cyst=swollen and encapsulated cell), are large, thick-walled, apparently empty specialized nitrogen-fixing cells, found between normal cells. Such behavior is highly unusual in prokaryotes and may have been the first example of multicellular patterning in evolution. Once a heterocyst has formed, it cannot revert to a vegetative cell, so this differentiation can be seen as a form of apoptosis. Since, nitrogenase is inactivated by oxygen, the heterocyst create a microanaerobic environment, in order to keep oxygen out of the cell. Heterocyst of Cyanobacteria performs its unique biochemical mechanism of nitrogen fixation and is valuable in the present life status of the mother planet earth. Considering that heterocyst development is arrested under anaerobic conditions and that the rate of heterocyst differentiation is enhanced by increases in PO_2, the evolution of heterocysts may have accompanied the initial appearance of oxygen-rich environments in Earth's history. Cyanobacterial heterocysts appeared, when PO_2 first reached levels that inhibit nitrogenase activity.

Additional trace fossils from Tal Formation exposed in Mussoorie and Garhwal Syncline were collected. Specimens of the Genus *Archaeonasa* sp., and *Trichophycus sp.* are very important as it is discovered for the first time from Tal Formation.

A large number of acritarchs are reported from Infrakrol and Lower Krol Formation of the Krol Belt. A comprehensive study of these acritarchs to prepare a monograph of Ediacaran acritarchs is under preparation.

Component 3.3 :
Terrestrial and aquatic biota from the nonmarine post-Subathu horizons of the Kangra Valley, Himachal Pradesh

(B.N. Tiwari)

Miocene Rodentia from Dharmsala Group in Kangra Valley, Himachal Pradesh, a step forward in the past coeval Himalayan faunal records

Pre-Siwalik nonmarine packages in the Western Himalaya yield rare vertebrate and associated fossils that are precursory to well known Neogene diversified vertebrates and related forms. Therefore first fossil rodent material from Dharmsala Group in Kangra Valley as a sequel to earlier *Deinotherium* report from these horizons representing rather onset of middle Miocene Climatic Optimum (MMCO) is an important record. Rodent material from the grey facies of the Group comprise an isolated molar and an incisor fragment. Though the molar has inadequate crown details due to incomplete preservation but has distinctive dimensions leading to its assignment to *Hodsahibia,* a baluchimyine taxon; this taxon is known from relatively younger Miocene horizons in Pakistan.

Precisions concerning the distribution and identification of Miocene hominoids fromIndia

The paper takes into account palaeoanthropological research of the Indian Subcontinent on account of the abundance of middle and late Miocene hominoid fossils from well known localities at Ramnagar (Lower Siwaliks) and Hari Talyangar (Middle Siwaliks), but there are less well known occurrences in the literature, such as the material from Dhara and Nungarh near Kalagarh in Pauri Garhwal District. Reports of the discovery of hominoid fossils at other poorly known localities at Ramchand Ridge and Dhiran near Ramnagar (Jammu & Kashmir) and Bandal (Himachal Pradesh) formed the basis for claims that hominoids existed in the subcontinent earlier than the Chinji zone. If so, then current views of hominoid palaeobiogeography would need to be modified to the extent that an earlier passage of large hominoids out of Africa towards the Indian subcontinent than is generally accepted, would need to be postulated. We also examine a claim for the persistence of large hominoids up to the Mio-Pliocene boundary (ca 5.5 Ma) on the basis of a tooth found near Bharari, east of Hari Talyangar.

The paper examines the soundness of the basis of claims for the presence of pre-Chinji large bodied hominoids in the region and for their persistence in the subcontinent up to the end of the Miocene epoch. If our assessment of the ages of the Indian fossils is correct, then it is concluded that large bodied hominoids survived in the subcontinent from ca 13 to ca 8-7 Ma.

Ostracoda from Siwalik Group of Mohand area of District Saharanpur as a part of geological and paleobiological studies

Aim of the endeavor is to document the large sample of tiny fossil carapaces of Ostracoda from Neogene Siwalik Group of Mohand area with geological and paleobiological inferences to sum up the report. I begun with a meager sample of small thin shelled Ostracod carapaces recorded from the rodent locality in Mohand area. It was an isolated molar of *Parapodemus* (murid) and now we report a large sample from a new nearby locality which is hardly half a km away and stratigraphically younger in age; it comprises relatively bigger sized ostracods besides charophytes, gastropod shells plus opercula, few fish teeth and their large number of otoliths (hearing stones).

While scanning washed residue of samples from Siwalik dark grey mudstone horizons of Mohand area in search for micromammalian elements we recovered many microfossils as by-products; ostracods, one of such groups of microfossils, thus collected form subject of this study.

The fossil yielding grey mudstone unit belongs to the Middle Siwalik Subgroup and is exposed in Mohand Rao and along the Saharanpur - Dehra Dun Road (Fig. 12). For these ostracods, convenient maceration begins by treating sun-dried bulk samples with kerosene for 30 to 50 minutes and then transferring in water to pulverize them for washing and screening with a set of different size meshes (10,20,40, 60, and 100 ASTM nos.); dried washed residues in the sieves were scanned for microfossils under the binocular microscope.

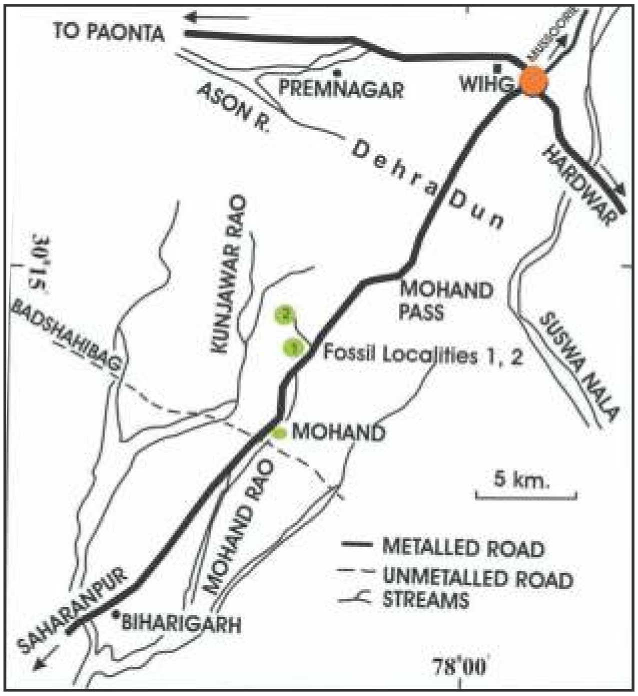


Fig. 12: Locality map.

Presence of more than four ostracod species (Fig. 13) in the diverse assemblage makes the effort rewording in understanding food-web that existed in aquatic milieu in late Miocene in this part of the Siwalik Basin; earlier paleontological studies and as-yet-unpublished discovery of rodent taxon (*Parapodemus)* ascertain the age assigned to the Mohand assemblage.

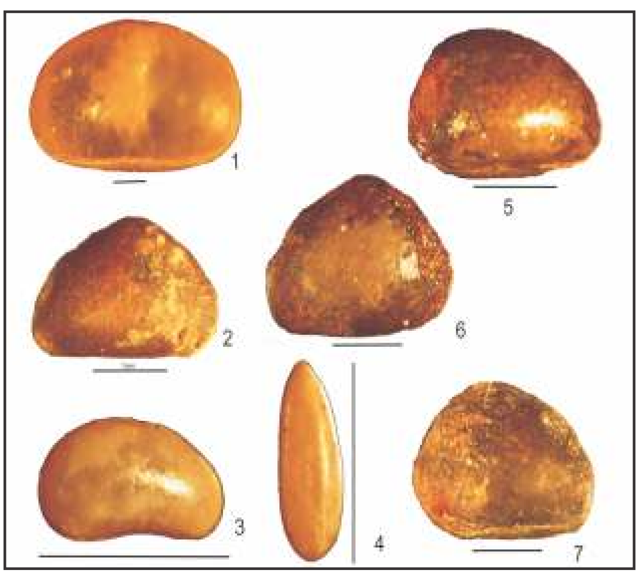


Fig. 13: Mohand Ostracoda.

We are doing elaborate study of the Mohand Local Fauna in view of presence of variety of otoliths in the assemblage co-occurring with gastropods and ostracods; otoliths are rare and hitherto unreported from the Siwalik Group of western Himalaya.

Further, we notice dominance of ostracods and gastropods (that lived and thrived in the shelter of thick charophyte growth in shallow water bodies) over the fishes represented by teeth and otoliths; this observation leads us to state that during the deposition of these fossil bearing horizons in the basin predators in the form of fishes were not so effectively dominant and that is why we are getting hundreds and thousands ostracods and tiny shells of gastropods.

Miocene freshwater gastropods from Siwalik of Doon Valley and Dharmsala of Kangra Valley, western Himalaya: Implications for the evolution of Asian Pachychilidae (Caenogastropoda)

In recent years, fossils have extensively been used to calibrate molecular phylogenies of living organisms. Thanks to such studies we have gained new insights into the temporal and spatial patterns of evolution of many different organisms. These studies have revived discussions about longstanding biogeographical paradigms, such as the significance of Gondwanan plate tectonics for the evolution of distributional patterns among the recent biota, for instance. However, the validity of hypotheses based on fossil evidence depends on correct hypotheses on the phylogenetic relationships of fossil and living taxa through times. In a perfect world, such hypotheses would be based on synapomorphies that connect taxa unambiguously. In the real world, however, paleontological studies rely on limited evidence. For example, the study of fossil molluscs is usually restricted to shells. Since even neontological studies often fail to identify synapomorphic characters of the shell in given groups, paleontological accounts take into account overall similarity of shell shape, size and/or sculpture in order to evaluate the fossil record. This procedure, however, is prone to errors when similarity is caused by homoplasy.

In recent years, our understanding of the freshwater Cerithioidea, a diverse, non-monophyletic assemblage of gastropods with a worldwide distribution, has improved considerably. One of its constituent families, the Pachychilidae ## are of special concern here. Molecular phylogenetic data suggests that the Pachychilidae represent an independent freshwater colonisation. During or subsequent to the invasion of freshwater, several genera have undergone shifts in their life history strategies, which involved the repeated evolution of viviparity and the correlated development of anatomical adaptations, such as brooding structures and modifications of the embryonic shell. Most pachychilid genera in Asia were delimited with respect to synapomorphic characters, including embryonic shell features. Therefore a correct systematic placement of fossil pachychilids is now possible by evaluation of embryonic shell features. A large number of gastropods were recorded from the new locality in Mohand area which is hardly half a km from the first rodent locality and beside that other exciting fossil are present in our assemblage. The presence of gastropodes in our collection motivated to us to see its relevance in broader aspect in the context of Himalaya. The presence of *Brotia* in our collection and recorded from Nepal, Kasauli, Ladakh and South East Asia reflects their palaeobiogeographical importance. The gastropods are associated with charophytes which provide shelter to them to protect them from predator.

In Mohand area which is situated in southern side of Dehra Dun re-entrant and part of Siwalik basin, here we have reported first time plentiful gastropods from new locality named as otoliths locality, beside that we have recovered other micro fossils ostracods, fishes remains, isolated rodent. They can taxonomically assigned to *Planorbis sp.*, *Bithynia sp*, *Gastropoda gen. et* sp. *indet*. Here *Planorbis sp. and Brotia sp* both taxa were reported from coeval horizons at Kasauli in Himachal Pradesh (Fig. 14). The molluscan remains occur in topmost level of the greyish mudstone from Mohand locality and are found in immense in numbers in the localized pockets.

A full-size significant assemblage of freshwater gastropod fossils from Middle Siwalik comprises four taxa; of these three are assigned to Thiaridae, Planorboidae and Bithyniidae. These freshwater gastropods of three different families lived in riverine to stagnant waterbodies of the Siwalik Basin. In the collection most of the forms are juvenile ones and few are adults, the freshwater pulmonates best developed in ponds/eutropic lakes of small or moderate size.

The *Brotia sp.* which is more significant in the among fossils which support the out of Asia hypothesis and their records from Malaysia and Thailand also.

So more work should be needed to understand the paleobiological of gastropda and a great number of

Fig. 14. Neogene gastropds showing four different types of gastropdes, Palnorbidae, Bithynidae, Thiaridae and Gastropoda *indet*.

populations of charophytes offered cover to protect from predator like carnivores fishes in our collection.

Component 3.4 :

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

(Kapesa Lokho)

The study of the Bhuban Formation were continued from the Assam-Arakan basin, Northeast India for its biostratigrapgy and paleoenvironmental reconstruction. The Bhuban Formation (Surma Group) of the Mizoram (Assam-Arakan Belt) is a Late Oligocene to Late Miocene marine siliciclastic deposits, dominated by sandstones and silty shale successions. The stratigraphic and tectonic framework analysis of the Bhuban Formation of the Mizoram region was carried out by Ganguly (1975) and Ram & Venkataraman (1984). Recently, magneto-stratigraphic and foraminiferal biostratigraphic studies on the Middle and Upper Bhuban Formations

(Mizoram region) were carried out by Tiwari et al., (2007); Lokho & Raju (2007); Lokho et al. (2011), respectively. Sediments of the Middle Bhuban Formation (Surma Group) of the Miocene age are studied from Durtlang and Chanmari sections, Aizawl district, Mizoram, Northeast India. The studied sections comprises of a bioturbated thick and thinly bedded sandstone-silty shale facies. These sediments consist of high density and low diversity feeding and resting trace fossil genera which includes Ophiomorpha isp., Teichichnus spiralis, Skolithos isp., Psilonichnus upsilon (Figs. 15 and 16) and horizontal Burrows.The trace fossil assemblages occur mainly in silty-shale, rich in organic materials that suggest a low oxygen environment. Sedimentary structures associated with these traces are mainly cross bedding, flaser bedding and slump structures. Considering the distribution of the *Psilonichnus* ichnogenus across an integrated ichnological-sedimentological framework, the present work suggests that the stratigraphic intervals of the Middle Bhuban Formation, in which they occur, are interpreted to have been deposited under a shallow, marginal-marine channel complex dominated by tidal channels developed in an inactive, brackish-water portions of a delta plain.

Fig. 15: (a-d) *Skolithos* isp., **(e-g)** *Psilonichnus upsilon* of Middle Bhuban Formation, Mizoram.

Fig. 16: (a). *Ophiomorpha* sp., **(b, e)** *Teichichnus spiralis*, **(c,d)** horizontal burrows from Middle Bhuban Formation, Mizoram.

Due to rarity of fossils, particularly microfossil markers in the post Eocene successions, lithostratigraphic classification formed the basis for correlation in the Northeast basins of India. In this regard, two charts viz. Chart NE: Biochrono-stratigraphy, Microfossil Markers and Sequence Surfaces Northeast India and Megachart IVB: Stratigraphic units, Paleobathymetry (Paleo-environments), Thickness and Major Hiatuses of the Phanerozoic of Northeast India, Bangladesh and Myanmar were prepared and published for easy references of the stratigraphic units of the above mentioned regions .

A reconnaissance survey was undertaken for paleontological studies in the ophiolitic mélange belt of Manipur, Northeast India. The collected samples were processed for microfossil studies and recovered benthic and planktonic foraminifers. The picked foraminifers are under identification and interpretation. Some of the identified planktonic forams are- Globotruncana linneiana, Pseudo-textularia excolata, P. elegans, Heterohelix globulosa, Rugoglobigerina hexacamerata?

Component 3.5 :

Faunal, sedimentological and geochemical study of Late Cretaceous-Early Tertiary sequences of NW and NE Himalaya

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

Component 3.5a :

Biotic, mineralogical and geochemical investigations of Early Tertiary sequences of NW Himalaya (and selected Paleocene-lower Eocene sections of western India) with reference to India-Asia collision

(K. Kumar and N.Siva Siddaiah)

Black shales rich in organic matter (2.6-11.8 wt% TOC) occur extensively in association with marly limestones in the early Paleogene Subathu Formation (Fig. 17). The mineralogy and geochemistry of these shales is important in evaluating their energy potential. The black shales are ~20-35m thick and exposed throughout the NW Himalaya. They are black to brownish-black, massive to finely laminated and consists of kaolinite, illite, quartz, calcite, feldspar, berthierine/chamosite, rutile and kerogen. Pyrite occurs in traces as fine disseminations. They consists dominantly of SiO_2, Al_2O_3, Fe_2O_3 and CaO followed by TiO_2 and K_2O, while MgO, Na_2O, P_2O_5 and MnO have a concentration of <1 wt%. The most abundant trace elements (in ppm) are Zr (77-648 ppm), Sr (54-285),

Fig. 17: Black shales in the basal part of the Subathu Formation in contact with chert breccia at Kalakot, Jammu and Kashmir.

Ba (12-358), Zn (25-151), V (92-364) and Rb (0.5-126), whereas other elements occur in amounts <100 ppm. $CaCO_3$ and TOC contents in the black shales show an inverse relationship. A sharp increase in TOC to a maximum of 11 wt % is found at the base of the unit and gradually decreases upwards to 2.5 wt %, while $CaCO_3$ varies from 1-14 wt %.

The total REE content of black shales ranges from 177.35 to 470.61 ppm, which are higher than that in associated marly limestones (SREE= 92.31 ppm). Their chondrite-normalized REE patterns are similar for all the samples, displaying sloping LREE (La_n/Sm_n = 3.1-4.46), relatively flat HREE trends, with a minor positive Ce anomaly (1.1) and with a distinct negative Eu anomaly (0.5-10.69). The observed shale-like chondrite-normalized REE patterns of black shales and associated limestones indicate that REEs were derived from a terrigenous source. REE contents in black shales are controlled by clays and partly by organic constituents. The difference between the most and the least REE-enriched samples is due to variable amounts of quartz.

Black shales of the Subathu Formation were deposited under anoxic conditions during low sea level, which is reflected by the occurrence of shallow-marine and non-marine sediments in the sequence and the preservation of organic matter indicates deposition under dysoxic conditions associated with increased flux of organic matter. The geologic setting, mineralogy and characteristic geochemistry of the early Paleogene organic-rich carbonate succession in the Himalayan basin suggests its potential as an organic-carbon source. Further systematic multi-disciplinary research is warranted to get insights in to the relation between collision, climate, provenance and preservation of energy resource.

The higher vertebrate faunal groups that received focus during the reporting year include birds, artiodactyls and creodonts, while among the lower vertebrates frogs were taken up. Some of the important non-vertebrate biotic remains studied included fossilized fruits and some very well preserved trace fossils and body fossils of wood-boring molluscs found associated with early Eocene vertebrate fauna.

Fossilized remains of fruits are relatively uncommon in the geological archives owing to their generally delicate nature and rather quick decomposition after their detachment from parent trees. Since well preserved fossilized fruits have short transport to burial histories (their burial is quick and usually not far from the source plant), they have great potential to provide useful information about the character of forest which hosted their plant producers. A small collection of well-preserved fossilized fruits of dicotyledonous trees and shrubs recovered from the Early Eocene (~53 Ma) subsurface beds of the Cambay Shale Formation in an open-cast lignite mine near Surat, western India were described (Fig. 18). Four distinct types of fruits closely similar to the fruits of modern taxa, viz., *Ziziphus xylopyros, Combretum decandrum, Terminalia chebula* and *Lagerstroemia*

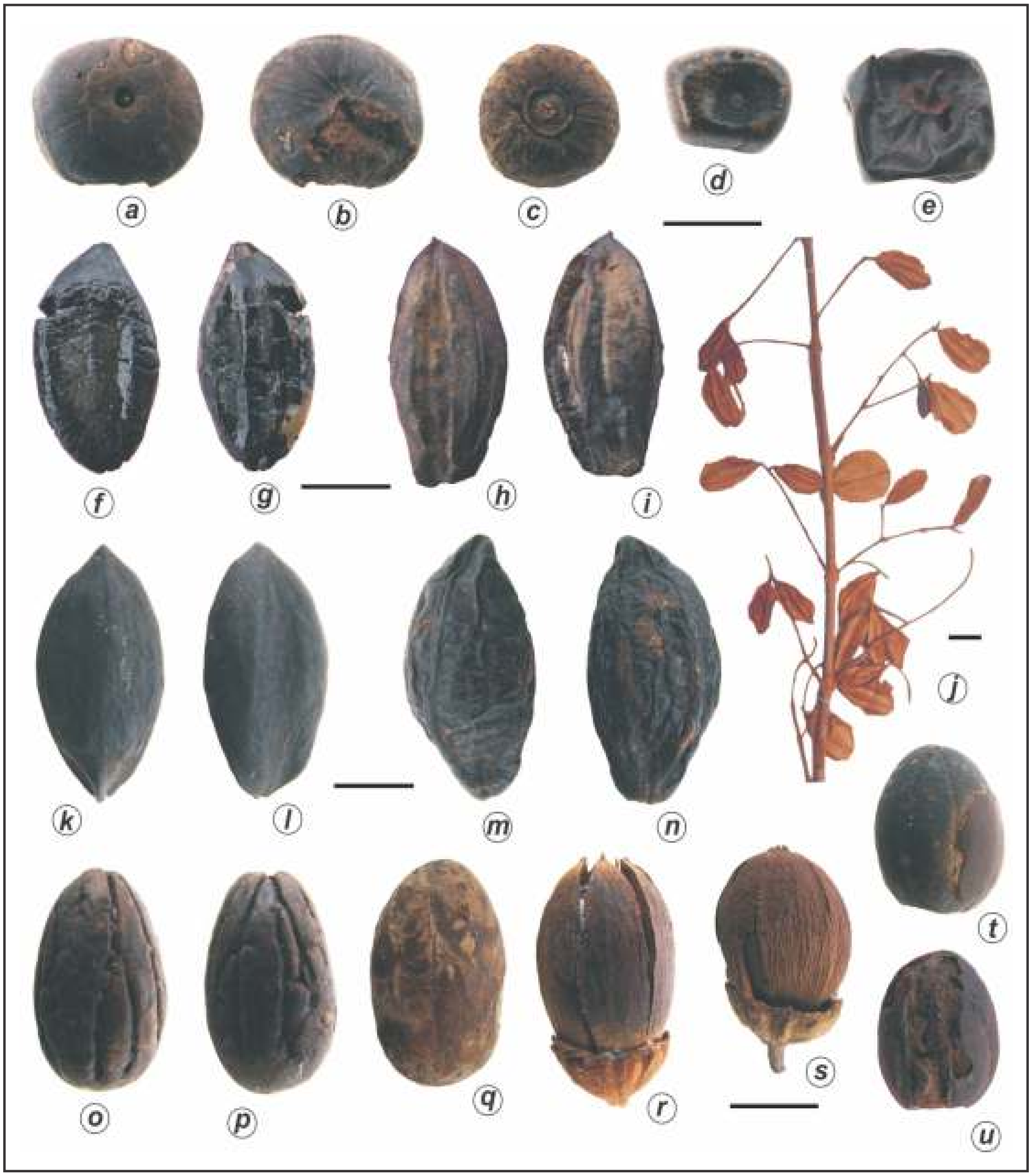


Fig. 18: Early Eocene fossil fruits and seeds from Surat, western India (a, b, d, f, g, k, l, o, p, q, t and u) compared with fruits of modern taxa (c, e, h, i, j, r and s) in top (a), bottom (b) and lateral (all others) views. **a, b, d**: *Ziziphus eocenicus* n. sp., petrified fruits **a, b,** WIF/A 601 (holotype); **d**, WIF/A 602; **c, e**: *Z. xylopyros* Willd. (CNH sheet nos. 22705 and 15026); **f, g**: *Combretum vastanensis* n. sp., carbonized fruit WIF/A 603 (holotype); **h, i, j**: *C. decandrum* Roxb. (CNH sheet nos. 3019 and 2946); **k, l**: *Terminalia cambaya* n. sp., carbonized fruit WIF/A 604 (holotype); **m, n**: *T. chebula* Retz (CNH sheet no. 163499); **o, p, q, t, u**: *Lagerstroemia sahnii* n. sp., petrified fruits, **o**, **p**: WIF/A 605 (holotype); **q**: WIF/A 606, **t, u**: WIF/A 607; **r, s**: *L. flos-reginae* Retz (CNH sheet no. 1425). Scale bars equal 10 mm.

flos-reginae, have been identified. Their present day distribution indicates that all of them were deciduous types that grew under moist tropical conditions. The deposition of highly fossiliferous lignite beds containing a host of plant-debris, fruits of both trees and shrubs, mangrove palms, and fossils of a large variety of vertebrate animals from diverse communities, e.g., coastal river bank, terrestrial and arboreal, suggest that a dense tropical forest with several stories of vegetation somewhat similar to the

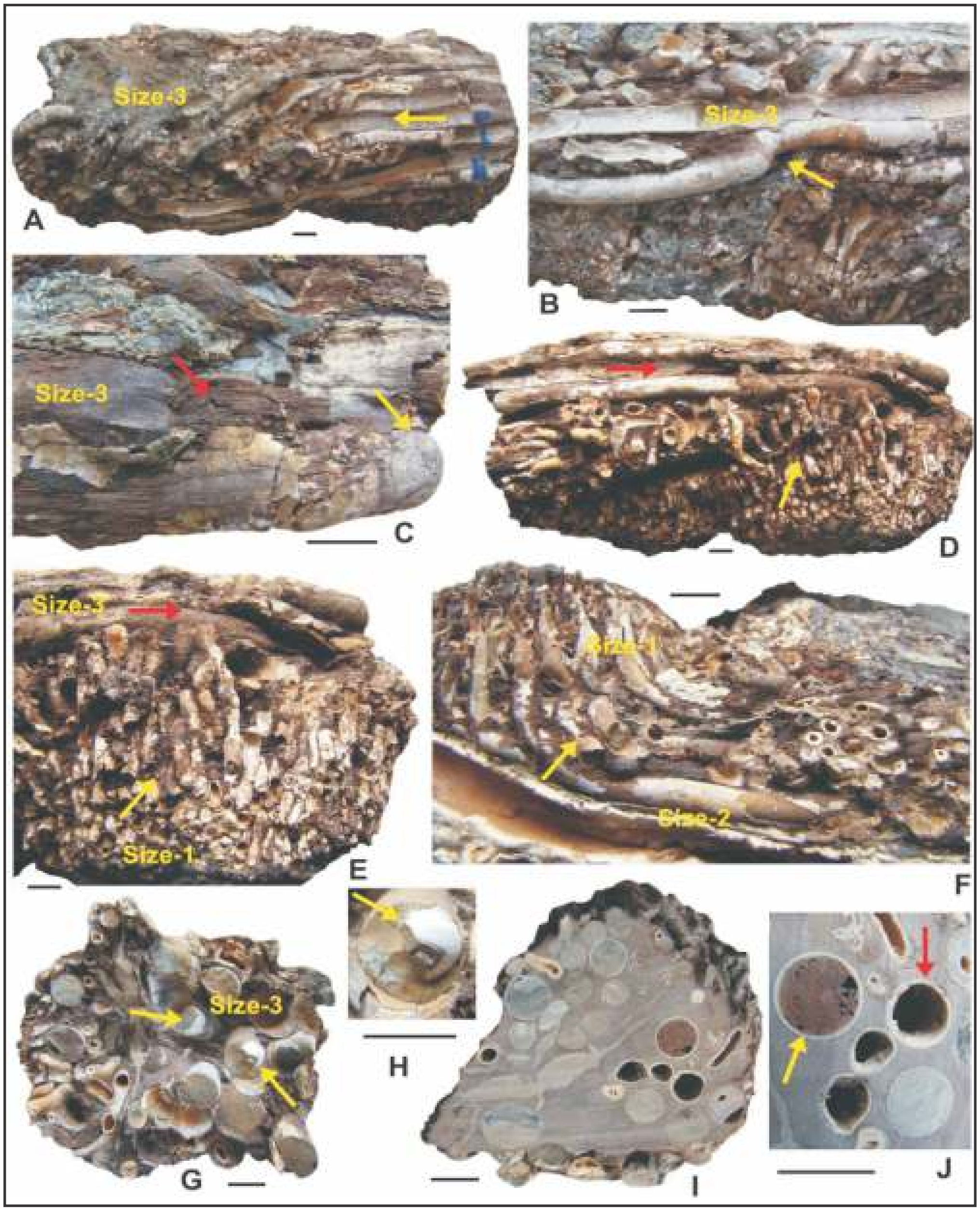


Fig. 19: Teredinid-infested fossil wood with natural casts of *Teredolites longissimus* borings (trace fossils) as well as body fossils (shell valves) of the causative teredinid (bivalved Mollusca) from the Vastan Lignite Mine, western India. **A–C**: WIF/A 611, **A**. showing large elongated size-3 borings along the wood grain, **B**. showing sinuous nature, **C**. showing well preserved wood grain (marked with red arrow) and terminal end of a boring (marked with yellow arrow); **D–H**: WIF/A 612, **D**. different sizes of borings running along (red arrow) as well as across (yellow arrow) the wood grain, **E**. magnified view of the same, F. showing 'L' shaped borings, **G**. size-3 borings in cross-section showing shell valves (marked by arrows), **H**. magnified view of a teredinid shell in a boring; **I–J**: polished cross-sections of WIF/A 611, showing nature (circular or distorted) of borings and their internal calcareous linings. Scale bars equal 10 mm.

present day coastal deciduous forests of Karnataka may have contributed to the formation of the extensive Lower Eocene lignite deposits of western India. The high diversity of fauna and flora in the Vastan mine has earlier been related to past global warming events.

Allochthonous log-grounds with well preserved borings referable to the ichnospecies *Teredolites longissimus* and body fossils of the causative borers from the Early Eocene beds of western India were studied. The record of *T. longissimus* from India is significant because trace as well as body fossils including shells and pallets of the trace making animals have been found preserved together. The body fossils of bivalve borers found with *T. longissimus* include several typical trilobed shell valves belonging either to Teredininae or Bankiinae or both (Teredinidae, Mollusca) and a couple of fragmentary pallets ascribed to *Bankia* isp. (Figs. 19-21). Evidences of traumatic as well as attritional mortality are observed. Three sizes of *T. longissimus* preserved in log-grounds mostly appear to represent animals at different stages of maturity and/or successive infestation episodes rather than a diversity of forms. However, variations in shell morphology of borers suggest involvement of at least two teredinids*Bankia* isp. and an unidentified taxon possibly representing *Nototeredo*. A majority of small *T. longissimus* (diameter=1.5-4 mm) are seen initiating across the wood grain and later bending to follow the orientation of grain indicating that larvae preferred to initiate boring across the wood grain. Based on the state of preservation of xylic material and shape of the substrate most of the studied teredinid-infested log-grounds are considered as relict log-grounds (*sensu* Savrda et al., 1993). The wood substrate (*Aglaia*, Meliaceae), which acted as host to boring molluscs was

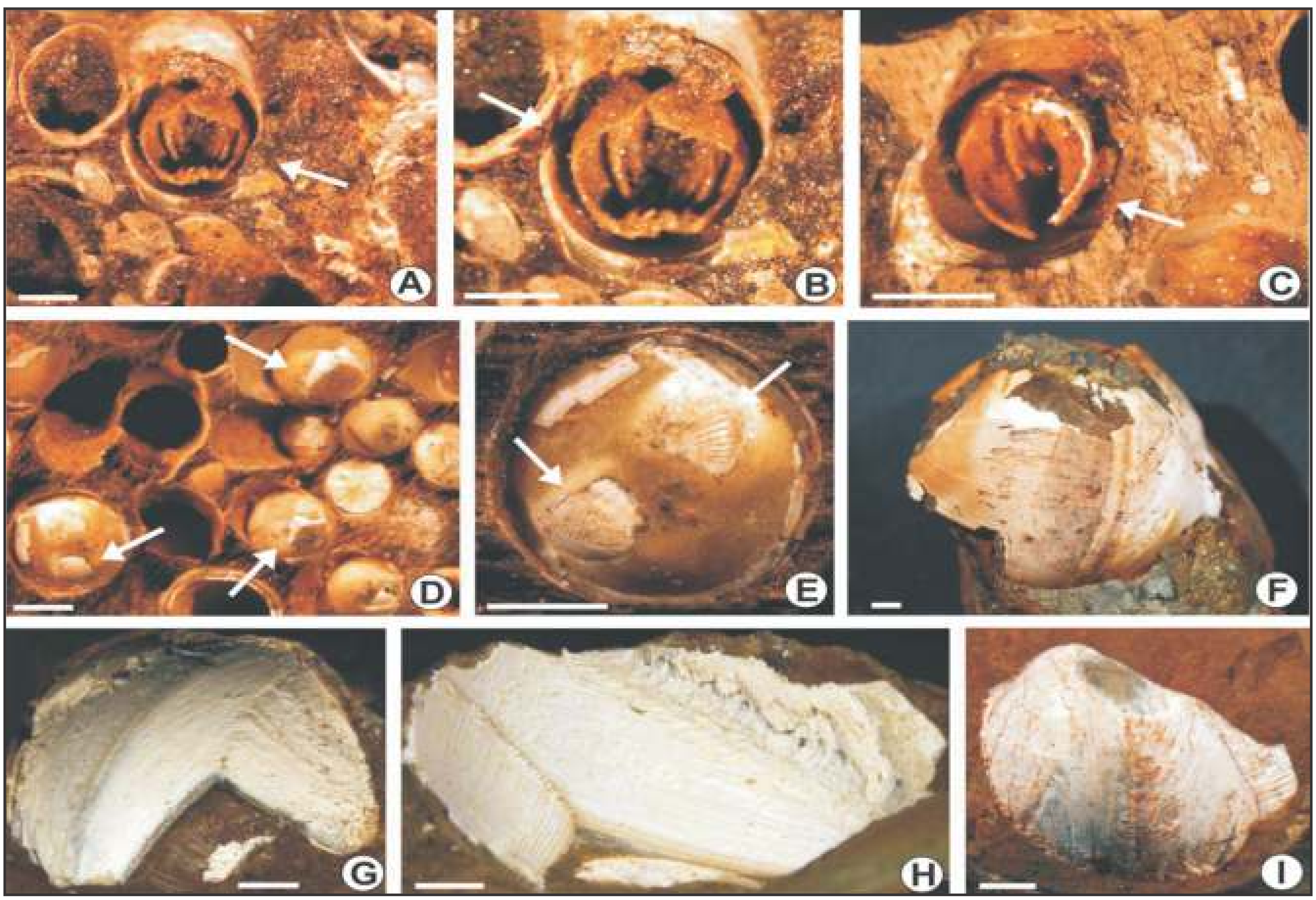


Fig. 20: Body fossils (shell valves) of teredinid bivalves (Mollusca) found with in *Teredolites longissimus* borings and their casts (trace fossils) from the Vastan Lignite Mine, western India; **A–E**: WIF/A 609, **A–C**. shell valves seen at terminal ends of borings in top view (peeping in to the boring), **D–E**. shell valves seen at the terminal ends of borings in bottom views; **F–I**: trilobed shell valves, F–H. WIF/A 612, shells with base of their anterior lobe almost at a right angle to the middle lobe; **F** is a nearly complete shell with both valves; **G–H** are part and counterpart of another shell valve; **I**. WIF/A 610, nearly complete shell valve with base of its anterior lobe at >90 degrees angle to the middle lobe. Scale bars equal 1 mm.

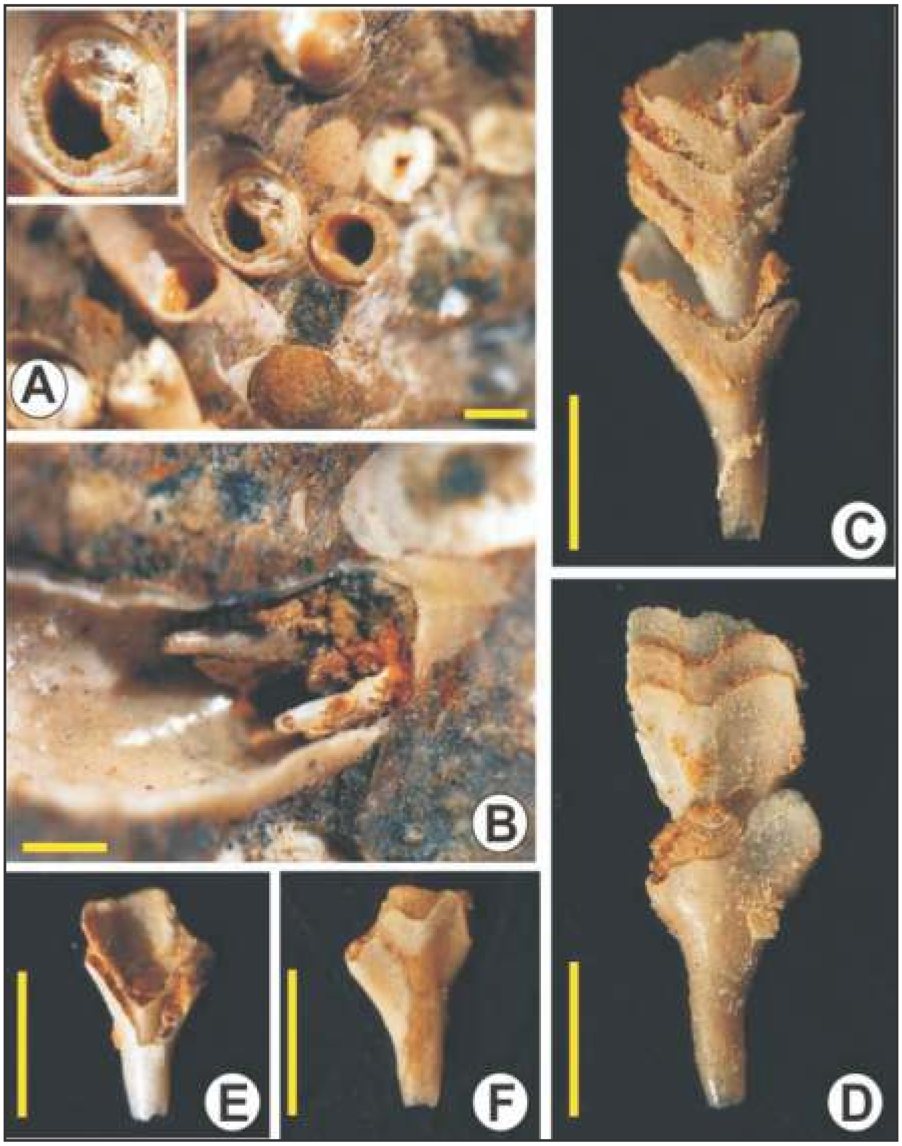


Fig.21: Body fossils (pallets) of teredinid bivalves (Mollusca) found with in *Teredolites longissimus* borings (trace fossils) from the Vastan Lignite Mine, western India; **A–B**: WIF/609 posterior parts of borings with pallets—stalks are jutting out, blades are embedded in matrix; **C–F**: pallets of *Bankia* isp. in outer (C,E) and inner views (D,F); both pallets are from the same tube. Scale bars equal 1 mm in image A and 0.5 mm in B–F.

transported to the marine realm from its natural habitat of inland moist tropical forest by a river or stream. Post infestation it was buried in a near shore lagoon or a tidal flat area as also corroborated by the biotic content (invertebrate, vertebrate as well as plant fossils), mangrove roots and bioturbated hardgrounds, the sedimentary facies as well as the overall depositional setting of the early Eocene succession of western India.

Fossil remains of frogs from the Early Eocene sections of western India comprise numerous, diverse and well-preserved ilia, and vertebrae and some limb bones (Fig. 22). Several families are represented in the collection. A peculiar abundant frog with a zygosphene-zygantrum complex on vertebrae is similar to the aquatic toads presently known from Eurasia. It was already capable of displaying the Unken reflex, which is a passive defense posture adopted by toads, frogs and salamanders when threatened by predators. A preliminary study suggests that while some of the frogs had typical Laurasian affinities mainly with Europe others support Gondwanan affinity. More detailed analysis is underway. It may be mentioned here that European

Fig. 22: Nearly complete left ilium and ischium bones of an early Eocene frog, *Indorana* in lateral (A1), posterior (A2), dorsal (A3) and medial views (A4).

affinity has also been inferred for several early Eocene mammals from western India, such as artiodactyls, rodents, primates and bats.

Oxygen isotope composition ($\delta^{18}O$) of fossil bone and teeth enamel phosphate (bioapatite) is an important tool for estimating the isotopic composition of past environmental water. Inferred $\delta^{18}O$ of environmental water, based on the analysis of teeth and bones of shark, other fish and some terrestrial mammals from the Himalayan foreland and western Peninsular Indian successions show strong correspondence with respective animal habitats (Fig. 23). The freshwater $\delta^{18}O$ values seem to suggest that monsoon like precipitation may have been active even during the Eocene-Oligocene period, but our data set is too small to be definitive on this.

Seven days field work was carried out in Kalakot (Rajauri)-Kanthan (Reasi) area of Jammu and Kashmir to study the chert breccia that underlies the Subathu succession, and the black shales of the lower part of the Subathu Formation. The preliminary study of chert breccia has indicated its volcanic nature.

Twenty days field work was carried out in the Paleocene and Early Eocene sections of western India for prospecting of vertebrates and associated biotic remains. The new collection includes jaws of credodonts, tillodonts and indobunids among mammals and frogs and agamids lizards among amphibians and reptilians, respectively, and numerous postcranial elements comprising vertebrae and limb bones of mammals, frogs and snakes. Apart from these a bunch of 8 vertebrae of a large shark and hundreds of vertebrae of other fish were also found. About 50 kg of screen-washed matrix and 350 kg of fossiliferous sediments were brought for processing in the laboratory.

From Himachal Pradesh, the processing of bulk samples taken from a bone bed in the lower part of the Subathu Formation was started. It is suspected that this horizon will yield vertebrate remains similar to those that are being recovered from the early Eocene sections of western India.

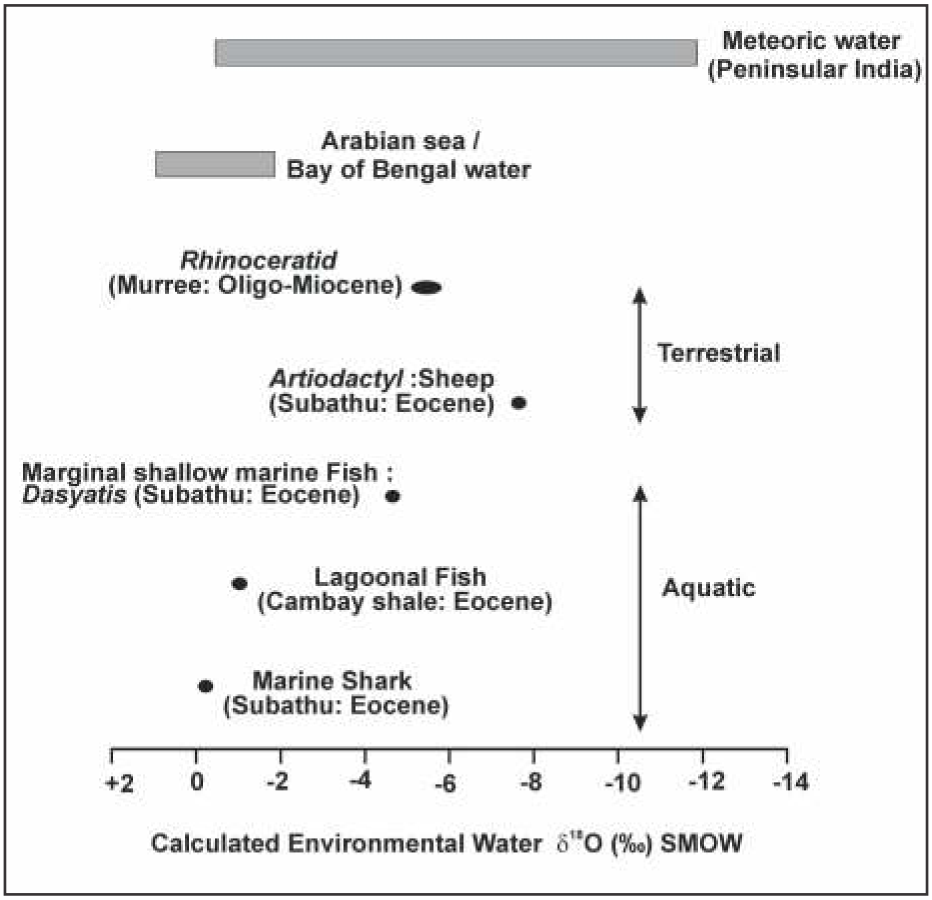


Fig. 23: $\delta^{18}O$ of environmental water calculated from enamel and bone phosphate $\delta^{18}O$; note marine value for shark fish and fresh water values for terrestrial mammals; other fishes show a mixed water signal.

Component 3.5b :

Cretaceous-Tertiary and Paleocene-Eocene boundaries in Um Sohryngkew section, Meghalaya: interdisciplinary study and global correlation

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

The largest Mesozoic-Tertiary sedimentary basins of the NE India includes the AssamArakan region, covering NE states of Assam, Arunachal Pradesh, Meghalaya, Nagaland, Manipur, Mizoram and Tripura. The thick sedimentary pile of Late Mesozoic to Cenozoic age is deposited in the shallow shelf, inner and outer ramps to basin facies. Two distinct shelf and basin sedimentation has been recognised. The sediments of the inner and outer shelf are well developed in the Garo, Khasi and Jaintia districts of Meghalaya, North Cachar and Mikir hills as well as subsurface sections of Upper Assam. The basinal sedimentation has been recorded from the Naga hills, Manipur and Surma valley, South Cachar, Tripura and Mizoram areas.

The foraminiferal-algal limestone of the South Shillong Plateau indicate high-energy shallow marine carbonate ramp conditions and very slow sedimentation rate (Fig. 24). A correlation of eastern and western Neotethys has been attempted which shows most of the foraminifera are common in both the regions. It suggests a close paleogeographic connection between the South Shillong Plateau, Meghalaya, Himalaya and the western part of Neotethys, including the Paleogene Adriatic carbonate platform (PgAdCP), which was situated in the central part of the ocean.

Palaeogene stratigraphic sections of South Shillong Plateau, Meghalaya , NE India has been studied in the field and in the laboratory with special emphasis on sedimentation pattern, biotic assemblages and carbon and oxygen isotopic variations. These shallow marine platform carbonates are mostly characterized by the occurrence of larger foraminifera and corallinacean algae. The Mawmluh Quarry, Mawsynram and

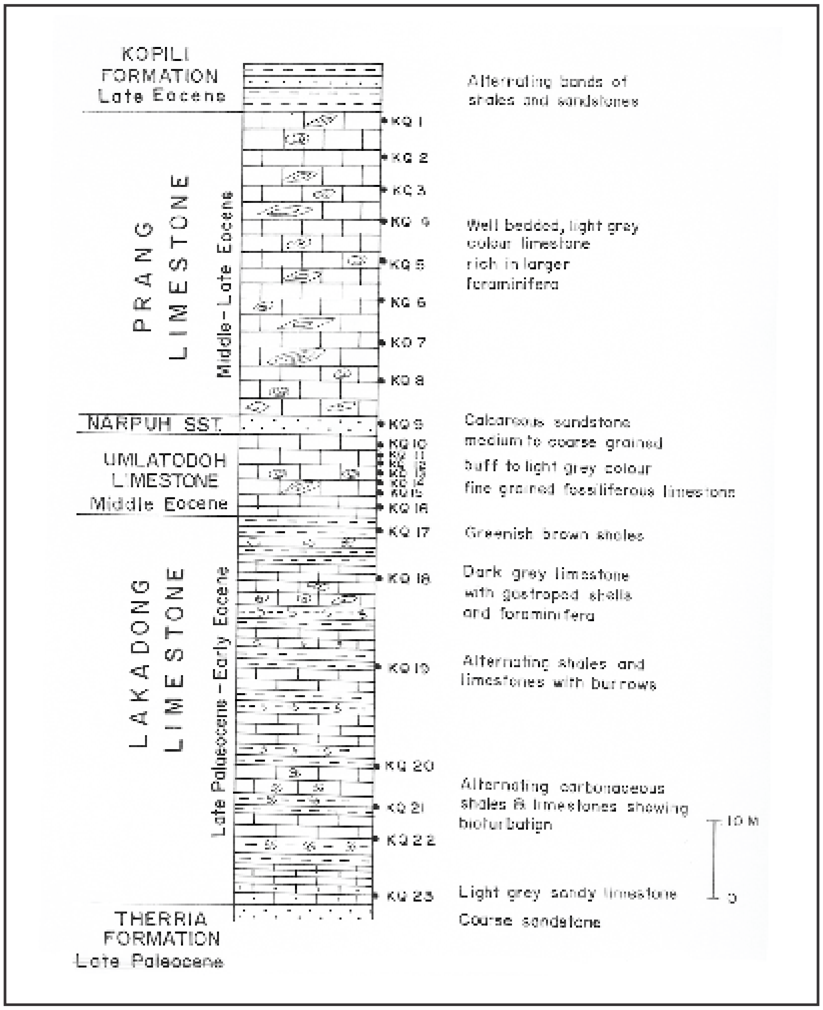


Fig. 24: Litholog of the Late Paleocene Late Eocene succession of the Kommorah Limestone Mine, East Khasi Hills, Um Sohryngkew section, Meghalaya.

Mawsmai sections, to the North, and Um Sohryngkew River section near Therria, Komorrah Limestone Mine section and Shella River section to the South, belong to same Shillong Plateau.The northern sections consists of Lakadong Limestone and Lakadong Sandstone. The Lakadong Limestone consists of foraminifera and algae belonging to Late Paleocene (Thanetian) and Early Eocene, mostly early Ilerdian. The southern Um Sohryngkew River section includes Langpar Formation, Lakadong Limestone, Umlatodoh Limestone and Prang Limestone which contains foraminiferal taxa of early Ilerdian and middle Eocene (early Lutetian) across PaleoceneEocene boundary.These measured stratigraphic sections) record an almost continuous sedimentation from the Late Paleocene (57.5 Myr) to the early Ilerdian (54.0 Myr), encompassing a time-span of about 2.5 Myr. This continuity of sedimentation is sometimes interrupted by hiatuses of 5 kyr, since the beginnig of the early Lutetian.

The Komorrah Limestone Mine in the Um Sohrynkew River section, represent shallow marine sedimentation in the south Shillong shelf during Paleocene to Late Eocene in which Langpar, Therria, Lakadong, Umlatodoh, Narpuh, Prang and Kopili Formations in ascending order were deposited without any sedimenological break as strongly supported by transitional sedimentary facies variations and occurrence of larger planktonic foraminifera and algae.

The calcareousalgal foraminiferal assemblage of the western Tethyan realm in Mediterranean region (Adriatic platform in Italy and Slovenia, Tewari et al.

2007) is correlated with the eastern part of the Neotethys in Turkey, Greece, Pakistan and Meghalaya. The sedimentary facies and calcareous algae of the Lakadong Limestone indicate slow rate of sedimentation and their growth on shallow water environment in carbonate ramp. The symbiosis relationship between coralline algae and foraminifera has been observed in the microfacies analysis (Tewari et al., 2010). It was a shallow eastern Neotethys sea extended in the Himalaya as evidenced by the algal-foraminiferal biota, sedimentary structures, facies and new carbon isotope excursions across the Paleocene-Eocene transition from the northeastern region of India (Fig. 25).

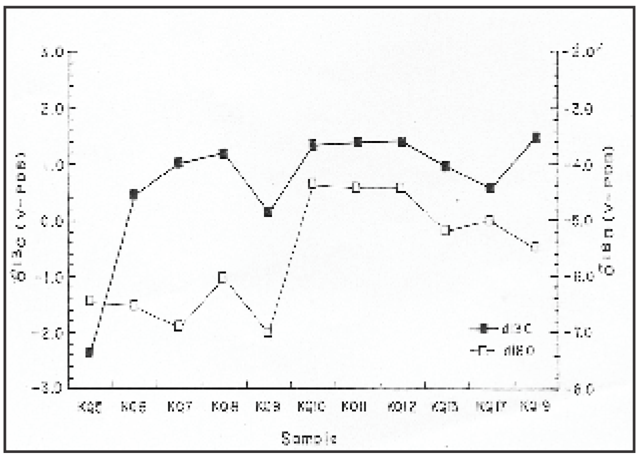


Fig. 25: Carbon and oxygen isotopic variation across Late Paleocene to Late Eocene in the South Shillong Plateau, Meghalaya.

The ongoing microfossil investigation of the Langpar Formation near Cherrapunji in the East Khasi Hills, Meghalaya is yielding smaller benthic and planktonic froaminifera, significant in view of biostratigraphy and paleoenvironment. The studied outcrop is of about 7-8 mts consisting of alternation of shaly marl and light brown carbonaceous shale (Fig. 26). Processing of the rock samples, identification and SEM photography of the recovered microfossils is in progress. Reconnaissance survey for microfossil was carried out in parts of west Khasi Hills, Meghalaya where Jadukata Formation of the Cretaceous age is exposed. The Jadukata Formation consisting mostly of sandstone blocks has yielded microfossils. The detailed study is in progress.

Molecular study of fossil resin (amber, Fig. 27) from the Late Cretaceous Mahadeo Formation of Meghalaya was undertaken in collaboration with S. Dutta of IIT Bombay and others for the first time. Resin samples from the well known Um Sohryngkew river section in the East Khasi Hills district were analysed using Curie point pyrolysisgas chromatographymass spectrometry and thermochemolysis gas chromatographymass spectrometry to help elucidate their botanical source. The major pyrolysis products and methyl-esterified thermochemolysis products found in the resin were abietane and labdane type diterpenoids with minor amount of sesquiterpenoids. The exclusive presence of both labdane and abietane diterpenoids and the lack of phenolic terpenoids seem to suggest that the Cretaceous resin was derived from Pinaceae (pine family) conifers. However, the minor contribution from Cupressaceae (another conifer family) cannot be

Fig. 26: About 8 mts thick section of the Langpar Formation near Cherrapunji consisting of alternation of shaly marl and light brown carbonaceous shales yielding microfossils.

Fig. 27: Amber in the sandstone of the Late Cretaceous Mahadeo Formation, Um Sohryngkew section, Megahlaya.

completely ruled out. This is the first evidence of presence of pines in India during the Late Cretaceous.

The yellowish brown clay sample collected from K-T section exposed on the east bank of Um Sohryngkew River in Meghalaya is considered to be close to the potential K-T boundary layer. The sample consists mainly of 66.33 wt. % SiO_2, 15.06 wt. % Al_2O_3, 1.08 wt. % TiO_2, 2.91 wt. % Fe_2O_3, 0.87 wt. % MgO, 4.06 wt. % K_2O, 1.02 wt. % Na_2O, 0.093 wt. % MnO, 1.27 wt. % CaO, 0.157 wt. % P_2O_5 and 5.64 wt. % loss on ignition (LOI). It has 629 ppm Ba, 212 ppm Cr, 168 ppm V, 11 ppm Sc, 9 ppm Co, 1.4 ppm Ni, 9.5 ppm Cu, 34 ppm Zn, 10.4 ppm Ga, 27.6 ppm Pb, 59.6 ppmTh, 114.2 ppm Rb, 5.6 ppm U, 88 ppm Sr, 72.7 ppm Y, 1150 ppm Zr, 18.4 ppm Nb, and 445.34 ppm REE. The sample is enriched in light-REE (80 to 300 x chondrite), depleted in heavy-REE (22 to 40 x chondrite) and has a moderate negative Eu anomaly (Fig. 28). The very low contents of Ni and Co in the sample do not support the presence of meteoritic impact component at least in this sample. However, the observed high concentration of Zr and REE does not rule out the involvement of volcanic component.

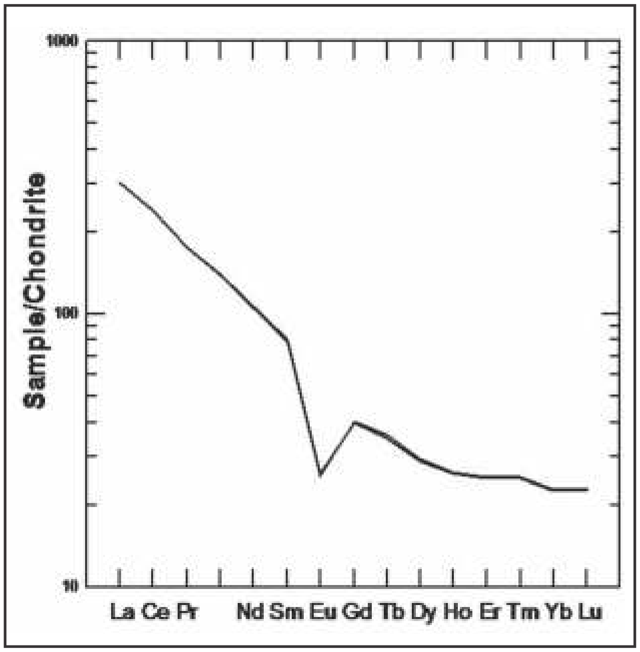


Fig. 28: Chondrite-normalised REE pattern of brown clay sample close to the potential K-T boundary layer in Um Sohryngkew River section, Meghalaya.

MMP - 4 : SUSTAINABLE NATURAL RESOURCES

Component 4.1:
Mineralisation 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.

(R.S. Rawat)

50 granites samples collected during the last two year's field work and 12 samples collected this year from the Inner Garhwal and Himchal Lesser Himalaya were subjected for homogenization experimental and XRD studies. Majority of the studied samples were from Palaeozoic and Proterozoic granitic bodies, besides a few from Tertiary granitic bodies; and are ranging in space and time. The X-Ray Diffraction study of the alkali feldspars of the granitoids have revealed that they have low structural state (intermediate to maximum microcline) i.e. these are triclinic alkali feldspars, although lack the typical cross hatched twinning of microcline. Once the structural state is detrmined, 50 samples of alkali feldspars from the granites were subjected for their melt temperature determinations through homogenization experiments in the Experimental Petrological Lab during 2010-2011. After the homogenization of each sample at 1050^{0}C for 48 hours duration, the runs were quenched in cold distilled water and it is observed that the original white alkali feldspars (microcline) had changed to flesh coloured (orthoclase) after the experimental runs a physical indicator of phase transformation in the feldspars i.e. from a low temperature (low structural state) to a high temperature (high structural state)- a triclinic to monoclinic phase transformation i.e. from microcline to orthoclase.This observation of change in colour in the natural starting materials from white colour to pink or flesh colour is again due to the cation exchange between the containers and the experimental runs (starting materials) at high temperature i.e. the traces of iron present in the platinum crucibles is responsible for this- a further confirmation of earlier observations of Rawat (2000 & 2009). 50 such experimental runs were completed this year (including repeatition of earlier spoilt runs, as well as 12 samples collected during this year). Further, alkali feldspars samples from this year's field work subjected for their structural state determination through XRD study, which again indicated that the alkali feldspars of the granites ranging in space and time are of low structural state i.e. are intermediate to maximum microcline, although lacked the typical cross hatched twinning in them. The granitic bodies in the field show a variation in the textures, which is modified by the subsequent events i.e. deformation and metamorphic events. At least four varities can be delineated in the field on the basis of grain size and their cross cut relations with each others (Figs. 29 A, B & C). Similarly, there are distinct phases of basic magmatism very fine grained and schistose type is of pene-contemporaneous nature within the quartzitic formations and at places this type had dykes / sills of coarser basic materials (gabbroic) with pillows structures, besides the specks of polymetallic sulphides. The field and laboratory data on the studied granites will be used in the modelling of their petrogenesis and characterization in space and time.

The field study on the mineralisation in the Uttaranchal during this year- particularly on the polymetallic sulphides along the Bhilangana, Balganga, Amritganga, Jadganga, Asiganga, Bhagirathi, Yamuna, Tons and Pabar Rivers indicated good prospects in this region. Infact, at places along the courses of Tons, Yamuna & Bhagirathi Rivers particularly near the big meanders, the local people are panning the clastic sediments for the precious metals a time tested practice in Uttarakhand like at many other places in Kumaun and Garhwal (Rawat,2009).

The field observations during this year on the lithologies, structure and tectonics of the visited region in the Uttaranchal Himalaya were reinterpreted to know their relationship with the sub-surface geology and its bearing on the mineralisations and in the stability of the region. It is concluded that the Himalayan mountain chain in this region of Uttarakhand in the Indian Sub- Continent had witnessed many major earthquakes in the past (Uttarkashi Earhquake of 1991) and the major landslides (Varunavat in Uttarkashi) in Uttarakhand are the surface manifestation of the basement and later remobilised Himalayan structures due to the movements in the basement with its associated structures. The sub-surface structures (ridges, depressions, folds and faults etc) and the basement (Indian Shield) are continuously moving northward beneath the Himalaya (underthrusting) and as such are responsible for the major earthquakes in the Himalaya and major active landslide zones (Fig. 29 G). At many places in the Purola area in the Uttarkashi District, the Aravalli trend is observed - like in many other places reported by the author (Rawat, 1980, 2002 & 2009). At this stage in this region, the work by the author is contradictory to the hypothesis of earlier workers (Pal, 2000 & 2009) i.e. the lithlogy on the northwestern and southeastern side, across the Delhi-Haridwar- Harshil Ridge are not continuing from Himachal to Garhwal- Kumaun and the DHH Ridge did acted as a barrier for the sediments from Himachal side to the Garhwal-Kumaun side. In fact, the author found many evidences for the continuity of rocks from NW to SE over this ridge but needs a detailed study in future.

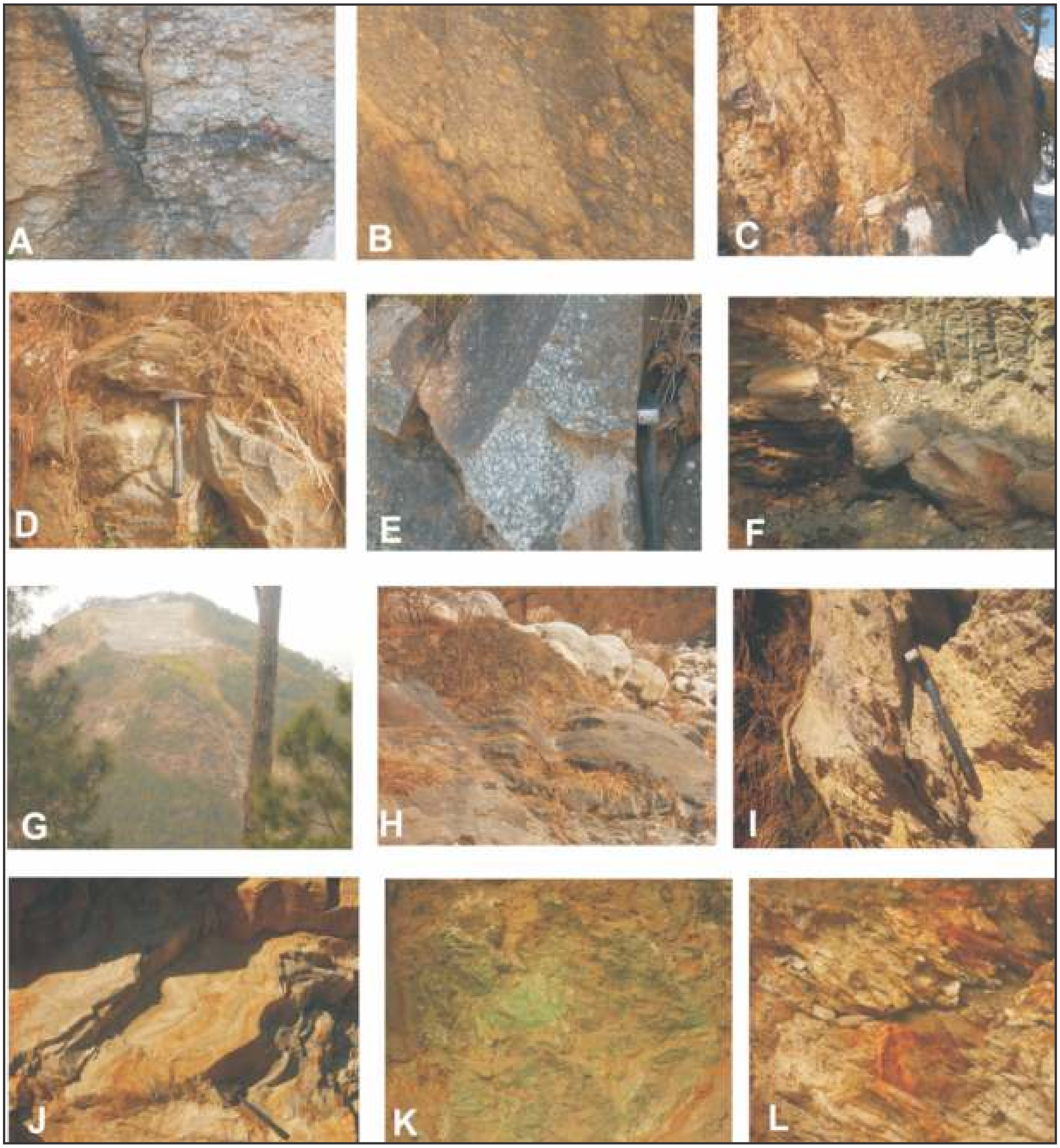


Fig. 29: A) Porphyritic Ghuttu Granite, **B)** Foliated Ghuttu Granite, **C)** Sliver of country rock in the Ghuttu Granite, **D)** Pillow structure in the Gabbroic rock, **E)** Assimilation of magmas yielding hybrid rocks, **F)** Two types of basic magmas, **G)** Varunavat landslide zone at Uttarkashi, **H)** Mineralized veins at Yamnotri, **I)** Syngenetic mineralized zone near Sukhi Top, **J)** Highly folded mineralized zone, **K)** Mineralisation at Tamba Khani and **L)** Minearlized zone at Tiuni.

Further, the study of complex fluids vis-à-vis the field study on the mineralization in this region of Uttarakhand, indicated that the lithology and the tectonc set up of the area play a vital role for the potential mineralization. Keeping this in mind, new mineralized zones were located at a number of places in the Uttarakhand Lesser Himalaya during this year's field work (Figs. 29 I to L). The present study indicated that the mineralization is syngenetic, which had remoblised during the Himalayan Orogeny and also migrated to the other host rocks. The field study in Uttarakhand Himalaya when combinrd together with the mineral paragenesis study clearly indicated the influence of deformation and metamorphism on the granitic plutons, on other associated hosts as well as on the associated mineralisations. However, there are locations in the core part of the same big granitic body, where the feldspar phenocrysts are quite fresh, rounded as well as undeformed in nature.

Component 4.2:

Petro-mineralogical studies related to mineralization, metallogeny and environmental assessment in Himalaya

(P.P. Khanna, N.K. Saini, K.K. Purohit, Rajesh Sharma, D. Rameshwar Rao and A. Krishnakant Singh)

Component 4.2a :

Geochemical investigation of soils and stream sediments in the south - east foothills (PinjoreUna Dun) of Himachal Himalaya

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

A total of 97 bulk stream sediment samples covering an area of over 600 sq. km. collected from Pinjaur Dun were studied to understand their geochemical characters in general and rare earth elements (REE) fractionation in oxygenated surface environments in particular. The samples consist dominantly of SiO_2 (67.8 to 85.4 wt.%), Al_2O_3 (3.7 to 14.7 wt.%), Fe_2O_3 (1.6 to 7 wt.%), MgO (0.7 to 2 wt.%), CaO (0.3 to 3.5 wt.%), Na_2O (0.4 to 1.9 wt.%), K_2O (0.7 to 2.7 wt.%) and low amounts of TiO_2, P_2O_5 and MnO. Loss on ignition (LOI) ranges from 1.6 to 13.4 wt.%. They have relatively high concentration of Zr (122 to 1988 µg/g) and variable sum of REE (ΣREE= 122-319 µg/g). The chondrite-normalized REE patterns are LREE enriched (La_N/Sm_N = 3.14 - 4.2), relatively flat HREE (Gd_N/Yb_N = 1.7 - 2.59) along with moderate -ve Eu anomaly. Many samples have relatively higher normalized abundances of REE compared to average upper continental crust (UCC). REE abundances of the analyzed samples show a +ve correlation with TiO_2 and MnO. The Chemical Index of Alteration (CIA) of studied samples range between 38 and 77 which indicate low to moderate weathering. REE in the stream sediments can have two primary sources, the host lithologies and hydromorphic accumulation. Many of the samples from the study area are substantially enriched in their REE concentrations relative to upper ontinental crust indicating, in part, the elevated REE concentrations of the host lithologies compared to the upper continental crust. The observed geochemistry of Pinjaur Dun sediment samples probably reflects both the mechanical dispersion/erosion of catchment's host rocks and the hydromorphic (aqueous phase) transport and transfer of REE from the aqueous phase to the stream sediments. The high $(La/Yb)_N$ ratios along with the major and trace element chemistry in the samples suggest dominantly of a felsic provenance and deposition in an environment dominated by a particulate terrigenous source.

Field Work

One week field work was carried out in Pinjaur-Una Dun, Himachal Pradesh. 54 samples of sediments were collected from Soan river and its tributaries. Samples were dried. Fraction of 63 micron was separated from the bulk samples. Further processing of samples is under progress.

Preparation of standard reference material

The data obtained from analysts for our two proposed reference samples: DG-H and AM-H was compiled and statistically evaluated for upgrading the derived values for DG-H and proposing new working values for different elements for AM-H. The whole dataset is to be communicated in the form of a research paper for publication.

Component 4.2b :

Mineralization, Metallogeny and the petrological investigations of host rocks in Kumaun Region, Uttarakhand

(Rajesh Sharma and D. Rameshwar Rao)

Carbon isotope work is carried out on graphite from Kumaun Himalaya, as the carbon isotopic ratio ($^{13}C/^{12}C$) in graphite has potential for discriminating its origins. It is evident that the $\delta^{13}C$ values for the studied graphite vary from -23.2 to -31.7 ‰, with a mean of -

29.08. The high value of -23.2 is obtained only for one sample from Champawat Granodiorite Formation while other values (cf. -29.4 and -31.7‰) are from Gumalikhet Formation. There is no difference between $\delta^{13}C$ for the graphite from the central part and from the eastern part of Almora nappe. The obtained $\delta^{13}C$ values suggest that Lesser Himalayan graphite is crystallized from the biogenic carbon during the metamorphism of the host sediments. The temperatures for garnet - biotite zone which are host rocks for the graphite, are also calculated by mineral phase thermometry using EPMA. The mineral temperature calculated using various calibrations range from 521 to 572°C. Whereas, temperatures of graphite separated therein are 558 and 568ºC.

In continuation of our earlier studies the petrochemical studies of granitoid rocks from eastern Kumaun region were also studied. It is to be noted that generation of granitoid rocks in subduction related process is not only observed in the younger mountain belts such as Trans-Himalaya, but world wide, there are also reports from Proterozoic and Archean times. While studying the petrochemistry of the granitoids of Askot, we were first to report that the leading edge of Lesser Himalaya in eastern Kumaun region is a continental arc and granitoid rocks are formed in an arc magmatism. Later, Kohn et al. (2010) have also proposed a Paleoproterozoic arc model on the northern margin of the Indian plate. In the reporting year we have further studied the granodiorites from Chhiplakot klippe and eastern Almora nappe and confirmed the arc magmatism for the generation of granitoid rocks of these regions, and thereby proposed that the Paleoproterozoic assemblage at the base of Lesser Himalayan sequence at around 1800 Ma represents a continental arc.

Further, the fluid inclusion work on the samples from Chiplakot Crystalline Belt is conducted to understand the exhumation and deformation. Raman spectrometry of some fluid inclusions in the gneisses is carried out. An early fluid record is noticed in the discrete fluid inclusions present as isolated ones and in the restricted trails. Such inclusion trails terminate within the quartz grains wherein fine granulation has not occurred and therefore they survived the last stage of recrystallization. Within these earliest inclusions carbonic-aqueous fluid is entrapped wherein the homogenization of CO_2 at +1.6°C indicates density of 0.92 g/cm^3. Large inclusions show increased internal pressure because of the uplift. Subsequent fluid inclusions with immiscible carbonic- aqueous composition are present in the north-south trending Fluid Inclusion Phase developed along the oblique fractures.

Component 4.2c :

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)

Generally, in the continental flood basalt provinces, basalts are associated with the felsic volcanics, although the volume of felsic volcanics varies from one flood basalt province to another. The origin of felsic volcanics in flood basalt provinces is of much petrogenetic interest as there is no common petrogenetic model for the genesis of felsic rocks and a crustal component may or may not play a role in their formation. Production of felsic rocks by partial melting and fractional crystallization of crustal rocks accompanied by assimilation of the upper crust have been explained. This process is considered more appropriate for large volume of silicic magmas in the flood basalt provinces. However the small volume of silicic magma bodies in continental flood basalt provinces is derived from a basaltic parental magma by fractional crystallization or partial melting.

The continental flood basalt affinity of the mafic volcanics cropping out extensively in the Siang Window of Eastern Himalaya comprises voluminous mafic volcanics and minor amount of felsic volcanics. The study area is predominantly occupied (~ 95% by volume) by mafic volcanic rocks. At places, mafic volcanics occur in close proximity with the felsic volcanics. Systematic field study of the area reveals that the felsic rock units can broadly be grouped as - Extrusive phase: dacite, rhyodacite, rhyolite with minor amounts of welded tuff. Rhyodacite-rhyolite are medium to coarse grained, dark grey to greenish brown colored and occurred (Lat. 28^{o}21$^/$.59 N; Long. 94^{o}57$^/$.54 E and Lat. 28^{o}21$^/$.22 N; Long. 95^{o}039$^/$.73 E) closely associated with the basaltic and agglometatic flows. The dacite in composition occurs as intrusive-like masses (Lat. 28^{o}21$^/$.25 N; Long. 94^{o}57$^/$.70 E; Lat. 28^{o}21$^/$.20 N; Long. 95^{o}03$^/$.25 E and Lat. 28^{o}22$^/$.50 N; Long. 95^{o}03$^/$.75 E) within the basaltic flows (Fig. 30a). The contact between rhyolite and tuffaceous rhyolite is sharp without any morphological change. Dacite consisting of plagioclase, quartz, feldspar and fine groundmass is composed of amphibole, muscovite,

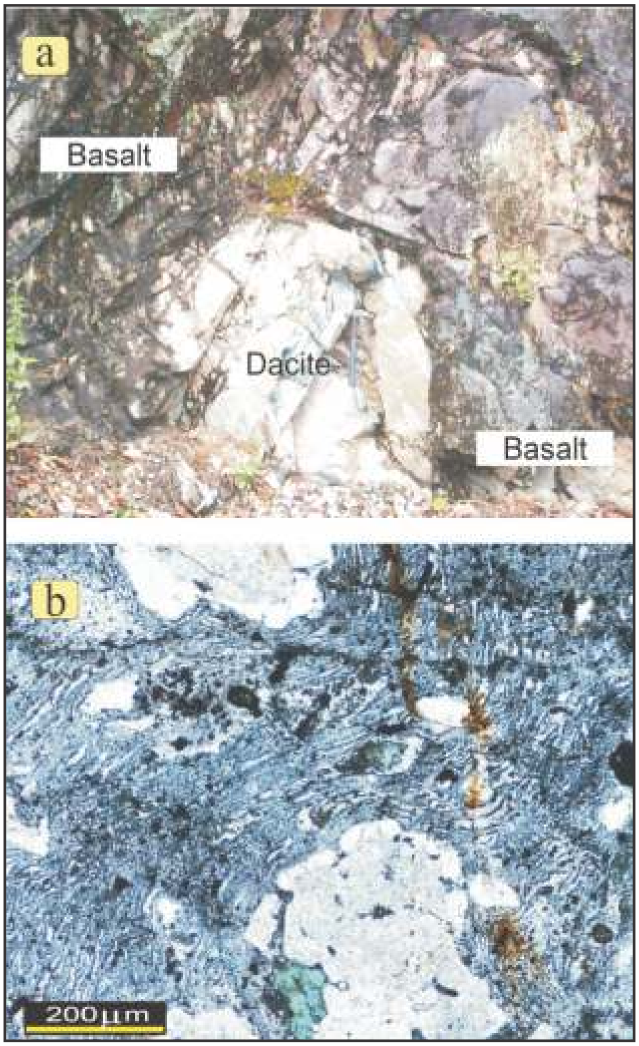


Fig. 30(a). Felsic volcanic as intrusive within basalt (Lat. 28°21'.25 N; Long. 94°57'.70 E) **(b)**. Welded-tuff showing feldspar phenocrysts**,** quartz, stretch glass shards with some iron oxides in tuffaceous groundmass showing flow banding.

feldspar and iron oxides. Few samples contain phenocrysts of feldspar and quartz set in a felsic vitrophyric groundmass. Rhyolite shows phenocrysts of feldspar, plagioclase, quartz, amphibole and groundmass is composed of feldspar, muscovite, quartz, iron oxides. Welded-tuff showing feldspar phenocrysts, quartz, stretch glass shards with some iron oxides in tuffaceous groundmass showing flow banding (Fig. 30b).

The felsic volcanics are ranging from dacite-rhyodacite-rhyolite in compositions (67-75 wt.% SiO_2) with high Ba (459-1313 ppm), Sr (151-797 ppm), Zr (373-574 ppm) and low Rb (72-166 ppm), Nb (18-80 ppm). These felsic rocks have distinct geochemical trends and separated from the mafic volcanics (47-57 wt.% SiO_2) by a silica gap but display some similarity in terms of enriched LREE (La, Ce, Pr, Nd, Sm) - LILE (Rb, Ba, Th, K) with distinct negative anomalies for HFSE (Nb, P, Ti) which strongly suggest their eruption/emplacement in a rift tectonic environment. The relatively well-defined geochemical trends obtained for the felsic volcanics of Siang Window, along with the progressive increase in Eu anomalies toward more-evolved compositions, combined with results of the geochemical modelling, support the idea that a fractional crystallization process has played a major role during the evolution of these felsic volcanic series.

Field, geochemical including petrogenetic modellings suggest that the less evolved dacites could have been formed after the low degree of (~15%) partial melting of mafic parental magmas, where the silica-rich rhyodacites-rhyolites could have formed after fractional crystallization of 55% plagioclase, 30% biotite, 5% amphibole and 10% magnetite from a dacitic parental magma. It also further suggest that a continental rift tectonic magmatism in the Eastern Himalaya probably provides the appropriate conditions for the origin of the voluminous mafic volcanics at the early stage of magmatism where the felsic volcanics generated at the final stage of magmatism and similar evolutionary mechanism is also reported from the well known continental flood basalt provinces worldwide.

Component 4.3 : Glaciological and hydrological studies of Chorabari and Dokriani glaciers: An integrated approach

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

Glaciology

Glaciations in the Himalayan region started during the mid-14th century, i.e. the beginning of the Little Ice Age". The Chorabari glacier advanced at this time, and it appears to have gone through periods of advances and retreats.

The narrative makes it amply clear that no point harping the bogey of global warming.

- Global warming is already there and it had started much before the advent of man on this earth.

- Yet there have been prolonged periods cooling as evidenced from various stages of advance and retreat of Himalayan Glaciers.
- These are natural phenomenon, controlled by forces much stronger than the man kind.
- Not only controlled but initiated and stopped by those forces alone.
- The human addition in the warming process is a minuscule of what the nature can do.
- This is further supported by the heaviest snowfall in Europe, China and USA last year which has broken records of last hundred years. Even in Europe the snowfall has broken records of last 20 years in the month of November it self.
- But yes we should not forget to respect the nature and should not disrespect by polluting the atmosphere, hydrosphere or even the lithosphere.

According to Joshi, S. and Upreti, D.K., 2010, *Curr. Sci., v.* 99, pp. 231-235, the boulders located at 1 km away from the glacier's terminus having lichen thallus diameter ranges between 110 and 120 mm resulted in the calibration of minimum age of exposure of the boulder as 550-600 years. As per the values of colonization delay and growth rate of two Himalayan glaciers (Dokriani and Chorabari), as Pindari glacier is also a part of that, the dates of the lichens measured by them comes out to be

110/.66 + 72 = 239, 120/.66 + 72 = 254 yrs (as per values of Dokriani glacier)

110/1 + 85 = 1 95, 120/1 + 85 = 205 yrs (as per values of Chorabari glacier)

Since Pindari is also a south facing glacier as Chorabari glacier, the dates calculated by parameters of the later appears to be more correct as compared to the Dokriani values. This suggests that the boulders of these moraines are the part of second phase of advance and retreat of the Himalayan glaciers.

Hydrochemistry

Continuous water samples discharge and suspended sediment data (hydrological data) from Chorabari glacier were collected in ablation period from June to October 2010. The major ion, SiO_2 and trace element in meltwaters are examined to know controls upon solute acquisition by runoff and to estimate solute and suspended sediments yields. The Ca+Mg account for about 85% of the total cation content of runoff when the solutes are expressed in equivalent concentrations. While HCO_3 account for about 75% of the total anion content of melt water in the same units. Hence a strong positive association between HCO_3 and Ca+Mg is observed. The slope of the analysis (1.2) is similar to that identified in high altitude Alaknanda basin in Garhwal Himalaya. Since the slope is greater than unity a small portion of Ca+Mg must be balance by other ions. This excess can be achieved by one or combination of the 1) gypsum dissolution; simple hydrolysis; neutralization of snowmelt NO_3 and SO_4 acid aerosol and acid hydrolysis coupled to sulphide oxidation. All these reaction leads to Ca+Mg/HCO_3 ratio towards 2:1. However slope of 1.2 indicate carbonation reaction (of Ca and Mg silicates and of carbonates) responsible for majority of the alkalinity in Chorabari melt waters. It is observed that SO_4 is most important anion in meltwaters after HCO_3. The average concentration is in excess of marine inputs indicating marine SO_4 in meltwater is supplemented by some other major source. The excess SO_4 probably have crustal source through sulphide oxidation, as gypsum or anhydrite are absent in the catchment. The preliminary interpretation indicates that much of the solute content of meltwater is acquired from carbonate weathering.

In another study of hydrochemistry of surface and groundwater around Tehri reservoir area in Tehri Garhwal district, Uttarakhand, 52 water samples from springs, handpumps and streams were analysed. Water of study area is dominated by bicarbonate contributing ~ 80% in anionic abundance while calcium and magnesium dominates the cationic concentrations with 67% contribution. The spatial variation in ionic concentration, in general, is related to type of source, discharge and lithology. (Ca+Mg)/(HCO_3+SO_4), (Ca+Mg)/TZ+ and other relative abundance plots reflect the requirement of cations from weathering of silicate rocks and the contribution of Na and K in total cations.

In environmental study of waters of Haridwar district, the results show that water is slightly alkaline in nature with a mean pH of 7.4 and EC varies from 148µs/cm to 1330µs/cm with a mean value of 495.5µs/cm during winter season. Among cations Ca and Mg are the major cations and together they account for ~ 97% and bicarbonate is most dominant anions constitute ~73% followed by SO_4 ~ 16%. High (Ca^{2+} + Mg^{2+})/ HCO_3 ratio (1.2) and high (Ca+Mg) /(Na+K) ratio (31) and relatively higher contribution of (Ca+Mg) to total cations (TZ+) indicate that carbonate weathering as the main process controlling the major ion chemistry of the waters in the area. The presence of total coliform and E.Coli and NO_3 at few places in surface (Ganga water) and groundwater shows perceptible sign of anthropogenic activities, possibly due to increased tourist influx during summer and post-monsoon season.

The geochemical and isotopic studies of hot springs of NW Himalaya has been initiated to understand source characterization and contribution of hot springs in the major ion budget of the Ganga river. Samples of hot springs from Garhwal Himalaya have been collected and major ions are analysed. The hot springs in Garhwal Himalaya are associated with secondary porosity and permeability and heat to these springs is supplied by normal geothermal gradient.

Treeline study as a climate marker

Treeline is one of the natural and important climate marker in high altitude mountain ecosystem. To examine the climate change response, effort has been made to quantify altitudinal tree line in Chorabari glacier valley (Garhwal Himalaya) for the period 1962 to present. Field work has been carried out in the month of October to cover more sampling sites along the valley. The past spatial status of treeline is determined with the help of Survey of India topographic map, relevant floristic records and their at-the-spot validation while present status is explored by detailed ground checks. Present and earlier investigations suggest that treeline has shifted towards higher altitudes at the rate of 10.21m/year in Chorabari and 1.70m/year in Dokriani glacier valleys with in the period of 47 years. Treeline shift is attributed to the climate change response while sharp difference of 08.51 m in the treeline rise rate of both glacier valleys under similar climatic domain is strongly suggestive of dominance of local site conditions, i.e., natural as well as anthropogenic traits, rather than regional and global climate pattern.

Other geomorphic attributes such as 1.7 Km aerial distance and 40 m altitudinal difference between the treeline and glacier snout in Dokriani glacier and 3.7 Km aerial distance and 466 m altitudinal difference between the treeline and glacier snout in Chorabari glacier valley, are investigated as a key drivers for variable treeline rise rate. Keeping the impact of other factors uniform, the present investigation conclusively suggest that high proximity and low elevation difference of glacier snout and treeline worked as a deterrent factor for treeline expansion in anthropogenically undisturbed Dokriani glacier. While in Chorabari glacier, low proximity and high elevation difference between treeline and glacier snout along with anthropogenic pressure worked as an incitement factor to the higher rate of treeline dynamics.

The expansion of forest cover into erstwhile snow-ice boundaries due to treeline rise and dominance of broad leaved species, i.e., *Rhododendron companulatum, Betula utilis* is bound to alter radiative energy balance and improve carbon sequestration potential *by more and more* CO_2 *absorption* in alpine ecosystem. *And hence present assumption of* "global warming due to increased CO_2 level" need to be revised especially with reference to high Himalayan Mountains.

In order to contribute towards precision in Lichenometry, the re-measurement of reference lichens from prefixed sites also has been carried out, especially to investigate the impact of micro-climate on lichen growth at different aspects in glacier-moraine environment. The current year observation reported 44.90 mm, 34.05 mm, 27.10 mm, 16.23 mm, and 25.10mm at East facing aspect; 32.33 mm, 37.41 mm, 30.30 mm, 18.40 mm and 24.18mm at South facing aspect;24.8mm, 29.10 mm, 22.20mm,31.20mm and 28.10mm at North facing aspect and 17.68, 24.61, 31.49, 23.61 and 30.25 at West facing aspect respectively.

Component 4.4 :
Mass balance studies of Dokriani and Chorabari glaciers, Garhwal Himalaya

(D.P. Dobhal)

During the period 2009-10, mass balance, snout retreat and hydro-meteorological observations have been carried out for Dokriani and Chorabari glaciers under the long term ongoing glacier monitoring programme of the institute. The data were computed, analysed and the results obtained during the study period are summarized as follows:

Annual Mass balance and Snout retreat

The negative mass balance with specific balance 0.40 m w.e. for Dokriani glacier and 0.70 m w.e. for Chorabari glacier was obtained. However, the annual

Table 1: Mass balance and snout fluctuation of Dokriani and Chorabari glaciers during the year 2008-2009 and 2009-2010.

Parameters	Dokriani Glacier	Chorabari Glacier	Remarks
Sp. Mass bal. (m we)	0.45	0.76	
ELA (m asl)	5016	5065	
AAR	0.65	0.45	
Frontal retreat (m/y)	20	8	
Average Temp. (^{0}C)	13.6	14.3	May to Oct.
Total Precipitation (mm)	1482	1690	May to Oct.

mass balance calculated was negative but magnitude of balance was lower than budget year 2008-09. It is also observed that there is not much difference in summer melting of both glaciers as compared with previous year. The net winter accumulation measured for the year 2009-10 was slightly more (1-2%) compared to the previous year. The equilibrium line altitude (ELA) demarcated was lower by 5-6 m than the previous year. Thus the results indicate that the annual budget of the glacier is more dependent on winter precipitation than summer melting. The study is continuing for further measurement. During the study period the snout of Dokriani and Chorabari has retreated 20m and 12m respectively. The results obtained from Dokriani and Chorabari glaciers during the study year is complied and summary in Table 1 .

An attempt has also been made to study the snout retreat pattern of glaciers in Tons valley (Yamuna River basin). During this study period the Jaundar, Jhajju and Tilku glaciers were mapped and determined net retreat of the glacier snouts for the period between 1962 and 2010. The stable survey point in and around the glacier vicinity were made by Geological Survey of India (GSI) in 1999 were taken as a base line information. The study reveals that overall decrease in glaciers area is ~3.3 km^2 (4.8% of total area) and the snout of glaciers was retreated ~1640 m, ~800 m and ~700 m with an average of 32.8, 15.38 and 13.46 m a^{-1} for the Joundar, Tilku and Jhajju glaciers respectively. The study also reveals that the 19 km long Joundhar Glacier (59 km^2) has been separated in to the two part i.e. North Joundhar (39.31 km^2) and South Joundhar (15.33 km^2). The fragmentation and increased retreat rate of glacier snout is probably a direct consequence of global warming. The present snout of North Joundar, South. Joundhar, Tilku and Jhajju glaciers are located at altitude of 4160 m, 3914 m 4275 m and 4270 m respectively which are about 40-50m above from their position in 1962.

Hydro-meteorology

The glacier melt discharge was completed for entire ablation period (may-October. The Meteorological parameters through AWS were obtained for around year and have been analysed and computed. The mean monthly discharge observed during study period for Chorabari glacier i.e. June, July, August, September and October calculated were 0.6, 2.2, 2.6, 2.0, 0.6 m^3/sec respectively. The total discharge (June-October) was calculated to be 19.7 × 10^{6}m^3. Suspended sediment concentration in the melt water discharge was very high and variable over the entire melt season. Mean monthly suspended concentration for June, July, August, September and October was 400.0, 1307.0, 1210.0, 268.0, 466.6 mg/l, respectively. Mean monthly total suspended loads calculated was 207.0, 314.1, 281.7, 51.6, 19.7 × 10^3 tonnes respectively. The analysis of particle size for suspended sediment is under progress (Fig. 31)

Monthly precipitation recorded for the months of May, June, July, August and September is recorded 154.42, 535.2, 345.79, 636.46 and 18.8mm respectively. During the study period total rainfall calculated was 1690.60 mm. It is also observed that maximum amount of rainfall received in the month of August and September is relatively less in the valley.

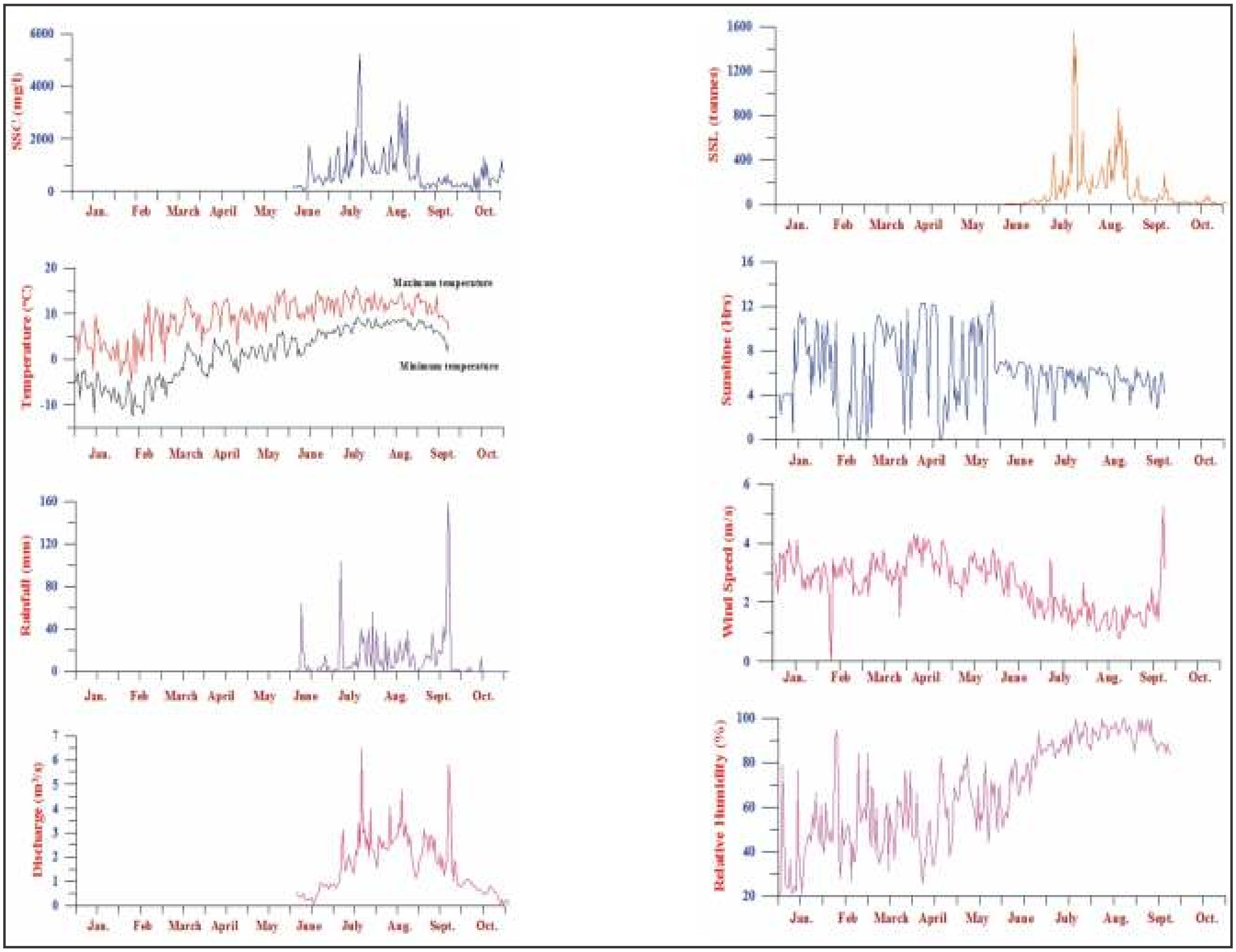


Fig 31: Daily melt water discharge (m^3/sec) and meteorological parameters at Chorabari Glacier during the year 2010.

During the study period mean monthly maximum minimum temperature recorded were to be 10.5, 11.6, 12.5, 12.3, 10.3 °C and 2.2, 4.2, 7.3, 7.9, 5.9 respectively. Similarly mean daily values of relative humidity observed during the different month of melting period (i.e. May, June, July, August, September, and October) was 63.8, 75.9, 90.9, 94.4 and 90.6 (Fig. 31) .

Wind speed and wind direction data were collected at every hour /daily basis for the entire ablation period at the glacier base camp. The data shows that wind speed in the valley generally fluctuate between 1.4m/sce and 3.1m/sce. Sunshine hours for different months during the months of May, June, July, August and September were 7.3, 5.9, 5.37, 5.5, and 4.8 hrs/d respectively (Fig. 31)

Morphological changes

A study was also carried out for reconstructing the fluctuation history of Chorabari glacier. Detailed geomorphic field mapping, moraine sediments samples for luminescence dating (OSL) were collected and analysed. Four glacial stages have been recognized. The glacial stages date 13±2 ka (Rambara glacial stage), 9±1 ka (Ghindurpani glacial stage), 7±1 ka (Garuriya glacial stage) and 5±1ka (Kedarnath glacial stage). The oldest stage (13±2 ka) was the most extensive glaciations in the basin that reached upto an altitude of 2800m towards south of Kedarnath and snout of the glacier was located at Rambara about 5.7km from the present snout position of the Chorabari glacier. The other three stages terminus positions were mapped around ~3000m, ~3300m and ~3500m asl respectively.

Using the Area Accumulation Ratio (AAR) method the mean equilibrium line altitude (ELA) depression of ~373 m for the Rambara Glacial stage was calculated (Fig. 32).

Fig 32: Photograph showing the Different stages of glacier moraine in Chorabari glacier, Mandakini valley. Note the positions of lateral moraines of different glacial stages, younger one Kedarnath Glacial Stage (KGS), Garuriya Glacier Stage (GGS) Ghanurpani Glacial Stage (GhGS) and older one Rambara Glacial Stage (RGS).

MMP - 5 : REAL TIME GEOLOGY FOR SOCIETY: COPING WITH NATURAL HAZARDS

Component 5.1 :
Engineering geological characteristics and study of mass Movements in relation to neotectonic activity and climate change in Uttaranchal and Himachal Himalaya

G. Philip, M.P. Sah, Vikram Gupta, N Suresh, S.S. Bhakuni, and Khayingshing Luirei)

Component 5.1a :
Study of active faults and neotectonic activity in parts of Himachal and Uttaranchal Himalaya between Himalayan Frontal Thrust and the Main Central Thrust

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

The study has been continued along the northwestern Himalayan Front, near Kala Amb, in the HFT system. The HFT in this area is a north dipping thrust, dips 20^{o}-30^{o} due N or NNE. It brings the Middle Siwalik sandstones over the alluvium in the piedmont zone. In the basal part of the hanging wall, the fault (HFT) propagation fold, with a pair of anticline and syncline, has developed. Earlier trenches excavated across the HFT for paleoseismological study showed that the HFT is very active.

A trench excavation survey near Kala Amb across an explicit surface exposure of the HFT was carried out by us in the previous year. The surface expression of the subdued and modified scarp of the HFT could be traced further on both sides. Representative sandy samples from hanging wall and footwall have been dated using optically stimulated luminescence techniques to constrain the chronology. The preliminary analysis shows repeated reactivation of the HFT in this segment resulting into large magnitude paleoearthquakes. Two distinct earthquake faults have been identified in the trench where Middle Siwalik rocks have thrusted over the Quaternary alluvium. In addition to this, the presence of large sized sand injection features (Fig. 33), and their disposition pattern observed in the trench suggests occurrence of another discrete large magnitude earthquake preceding the penultimate event. The cumulative displacement of Quaternary alluvium is of the order of 15 meters which also substantiates multiple paleoearthquake events. It also suggests occurrence of more than three major seismic events in this area during Holocene. We infer that the ongoing north-south convergence between India and Eurasian plates has resulted fault propagation folding and subsequent large magnitude earthquake along the HFT. The displacement of the Quaternary deposits along the HFT indicates its reactivation in the Quaternary. The reactivation of HFT substantiates the seismic potential of the Frontal Himalaya and calls for more concentrated study of paleoearthquakes of this highly populous mountainous region. The study is in progress.

Field and morphotectonic studies were carried out along the frontal part of the Kumaun Himalaya, in Nainital and Champawat districts, Uttarakhand, to understand the status of neotectonics. A set of linear normal faults are observed south of the Main Boundary Thrust (MBT). Along faults sag ponds and paleolakes have developed in the sub-Himalayan terrain. Pits of 2.5 m, 2.15 m and 1.5 m in depths were dug in paleolake. The base consists of angular boulders. The movement along faults, associated with the MBT, may have generated small landslides and rock falls, which deposited into the paleolake as angular boulders. Above this an alternation of soil/mud with charcoal and laminated thin sandy horizon is present. In one of the pits the laminated sandy horizon has been distorted with development of mesoscopic faults, folds, sand dykes and convolute lamination. The elongated paleolakes are oriented parallel to fault traces, and their development is attributed to the neotectonically active normal faulting. In the fault zones the moderately-dipping fault scarps measure about 225 m in height and >3 km in length. Near the Himalayan Frontal Thrust (HFT) the stream has incised the thick deposit of terrace/fan resting on the Siwalik rocks. The strath terrace on the hanging wall of the HFT is back tilted along the HFT (Fig. 34). Soft sediment deformational structures are recognized in terrace deposit. Along the Gaula river

Fig. 33: Sand injection structures well into the Quaternary suggesting induced effect fo the large magnitude paleoearthqake occurred in the area around Kala Amb.

PROGRESS IN MISSION MODE PROJECTS

Fig. 34: Hanging wall of the HFT is covered with back-tilted terrace material. Later the terrace is deformed and offset by brittle fault system that is parallel to the HFT.

valley, a mega fan has been offset by the MBT and associated normal faults (Fig. 35). Later faults have developed in the MBT zone, where fault scarp measures >2.0 km in length and ~37 m in height.

In Ramnagar area along the Kosi river valley, at the top of the footwall of the MBT the Siwalik rocks dip moderate to steep towards N to NE. Due to

Fig. 35: Mega fan at Logar in Gaula River valley offset by normal fault. Small arrows indicate the trace of straight normal fault.

folding, the beds dip gentle to moderate towards S and SW. Based on the structural and geomorphic observations, the development of old and fossilized triangular fault scarps is interpreted in the MBT zone. These scarps are related with the reactivation of transverse faults in the area. Occurrence of active and fresh-looking landslides is concentrated in the MBT zone. Thus the study area has gone through the multiple phases of the Quaternary deformation.

Component 5.1b:

Study of Palaeo-mass movement as evidenced by Palaeo-blockade sites in relation to climate change and neotectonic activity mass in the Satluj valley, H.P., as well as to decipher Engineering geological characteristics of rock mass in the Satluj valley, H.P and Alaknanda valleys, Uttarakhand

(M.P. Sah and Vikram Gupta)

The study carried out during 2010-11 in the upper part of Satluj and lower part of Spiti valleys indicate four phases of channel shift as indicated by the erosional terrace surfaces. These surfaces are either covered with glacial deposits or by lacustrine / fluvial sediments. The lacustrine sequences show involute and convolute structures indicating the periglacial environment and are dated as 65 ka - 41 ka. Most of the Quaternary sediments also show the development of seismites indicating seismic activity that had taken place along the Kaurik - Chango Fault running between village Khab and Chango. The periglacial features and seismites have also been observed near village Kuppa in the Baspa valley. The presence of uplifted Quaternary sediments, distinct benches, burms and long narrow elongated drainage along the Leo Pargil horst confirms that the area had experienced massive rejuvenation and upliftment during the Quaternary period.

The channel gradient of river Satulj south of the Main Central Thrust (MCT) is 6m/km. About 30-35 m high and 10-15 m wide erosional terraces has been observed near Rampur. However the channel gradient between the Main Central Thrust (MCT) and the Tethyan Thrust (TT) is 13.5 m/km and the remnants of 3 - 4 level of erosional terraces and high level whirlpool marks on the quartzitic and granitic rocks have been noted indicating the major Quaternary rejuvenation of the area. Whereas north of the TT, the channel gradient calculated is 8 m/km. The signature of channel blockade of rivers Satluj and Spiti at various locations have been noted,

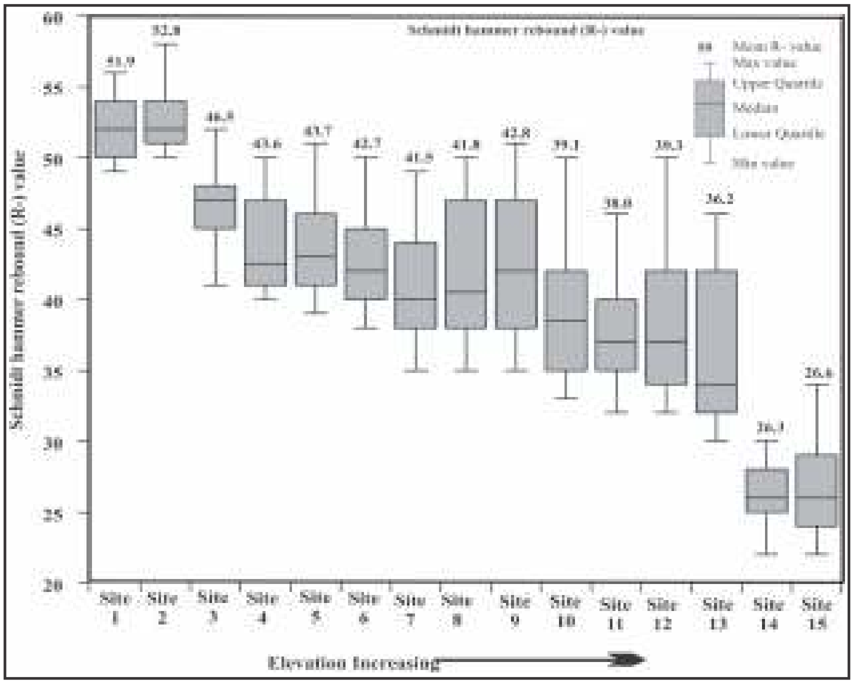


Fig. 36: Box plot for the Schmidt Hammer Rebound values for quartz mica gneiss belonging to the Alaknanda valley at varying elevation.

indicating that the area had witnessed large scale mass movement activity during the geological past.

Engineering geological characterization of rocks of the Alaknanda valley has also been carried out during the year 2010-2011. Data on joints / discontinuities present in all the lithounits in the valley have been collected in the field and has been stereographically analyzed in the laboratory for any possible slope stability and wedge failure. The various lithounits have been characterized on the basis of Rock Mass Rating (RMR) as well as Q-value. Cohesion and friction angle of the lithounits have also been interpreted using Geological Strength Index (GSI) value. The interpretation of data is continuing.

In addition, surface weathering characterization of the Higher Himalayan Crystalline gneisses of the Satluj and Alaknanda valleys has been carried out using Schmidt Hammer rebound (R-value) value. It has been observed that under similar climatic condition, rocks at higher elevation are more weathered compared to those at lower elevations as observed in the lower R-value with increasing elevations (Fig. 36). Also the R-values for the crystalline gneisses of the Alaknanda valley are lower than those for the crystalline gneisses of the Satluj valley. This is mainly attributed to the varying proportion of mineral constituents of these two crystalline gneisses.

Component 5.2 : Seismic monitoring, seismic hazard, multiple geophysical earthquake precursory studies and micro-zonation for NW Himalaya.

(V.M. Choubey, Ajay Paul, A.K. Mahajan, A.K. Mundepi, Naresh Kumar, Gautam Rawat, P.R.K. Gautam and Devajit Hazarika)

Component 5.2a : Real time monitoring and analysis of seismicity, earthquake source characteristics, seismotectonic and sub-surface studies, stress changes and seismic hazard of NW Himalaya

(Sushil Kumar, Ajay Paul, Naresh Kumar, Dilip Kumar Yadav, and Devajit Hazarika)

Current Seismicity scenario from the earthquakes data recorded at WIHG seismic array in the NW Himalaya

The Himalaya, world's tallest mountain range, continues to rise as plate tectonic activity drives India into Eurasia. The compression from this collision results in severe seismic activity along the facade of the range. Stress builds continually along faults in the region, until it is released through earthquakes. Tectonic earthquakes are the most common of all natural earthquakes. Each one of them is associated with faulting in rocks, a fault being a shear fracture in which rocks on its two sides undergo relative slip parallel to the discontinuity surface. Although some of them may be associated with formation of fresh faults in rocks, most tectonic earthquakes occur due to renewed slip on pre-existing faults. The understanding of earthquake source processes and the medium characteristics provides the basic tools for the assessment, mitigation and reduction of seismic hazards. To obtain these objectives WIHG is operating a regional seismic network in the NW Himalaya to address seismotectonics, and the evolution of stress pattern of the region in better way. Accurate assessment of the earthquake hazard is critical step for earthquake risk mitigation.

Observations noted from the analyses of local earthquakes

WIHG is operating a seismic array consisting 30 seismographs (Fig. 37). Eleven broadband seismographs are connected through VSAT and getting data at Dehra Dun in real time mode. In the last year during April 1, 2010 until March 30, 2011, we have recorded about 600 local earthquakes. The focal depths of these local events range between 0.0 and 40.0 km, but large number confined to upper 20 km. The local magnitude ranged between 1.0 and 4.3. The earthquakes define a relatively narrow belt of earthquake epicenters, which straddles the Main Central Thrust (MCT), named Himalayan Seismic Belt. The longitudinally seismic activity in this belt is not uniform. This current epicentral belt located from locally recorded earthquakes coincides with the broadly existing Seismic records of moderate and small magnitude earthquakes.

About the earthquakes Data used in the analysis of various Seismological parameters

With the growth of populated centers and high storage dams with their associated power plants in the NW Himalayan region, the risk due to seismicity has increased manifolds in the recent years. In view of these facts we have studied the b-value and fractal dimension of seismicity in this highly seismically prone region to obtain a realistic hazard evaluation of North-Western Himalaya and adjoining regions. We have analyzed 1221 Earthquakes from the

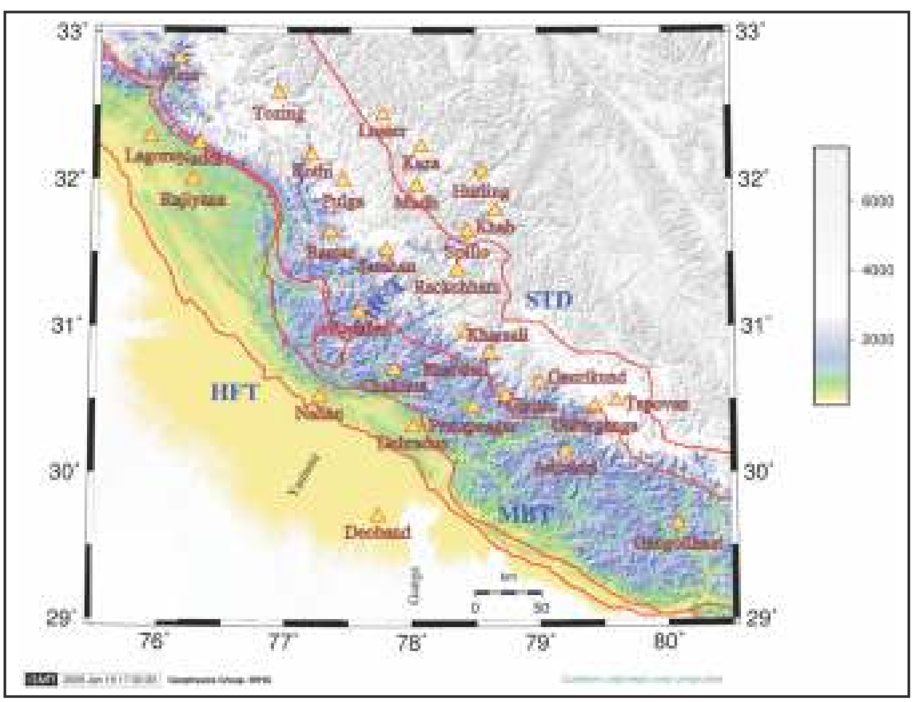


Fig. 37: Broad-band and short period seismographs are in operation in the NW Himalaya shown with the triangles.

northwest Himalayan region triggered during 2004-2010.

Mapping and correlation of the b-value and the fractal dimension from the earthquakes triggered in the NW Himalaya, India

The changes in b value and fractal dimension D of hypocenter distribution in the NW Himalaya and adjoining regions have been analyzed in this study (Fig. 38). The resulting Characteristics found by this analysis are shown in figures. 39 & 40 and their interpretation is as follows: The contour of b value mapping of the region lying between 28.5°-33.5°N and 75.5-81.5°E indicate that b value is inconsistent in the NW Himalayan region. Low b value observed around the Chamoli region (30.5°N, 79.5°E). The low value of b in this zone indicates the presence of fluid in the sub-surface as suggested by Monsalve et al. 2008. We have

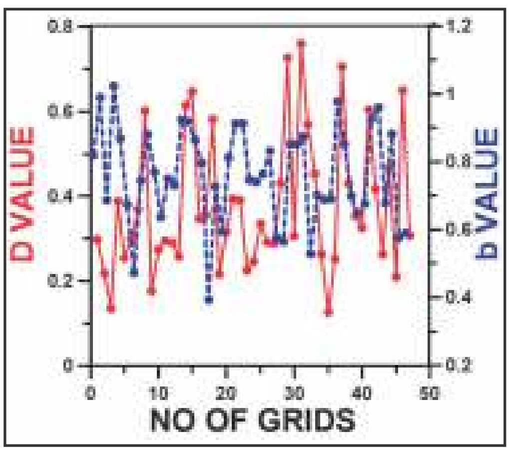


Fig. 38: Variations of D with b value with the different grids in the study area.

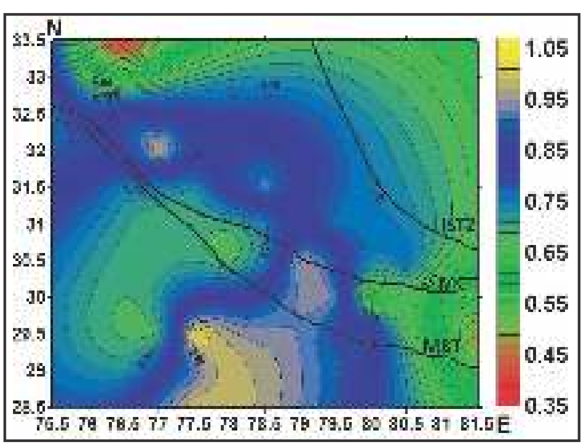


Fig. 39: b value contour map for total 1221 earthquakes (M⩾3.0).

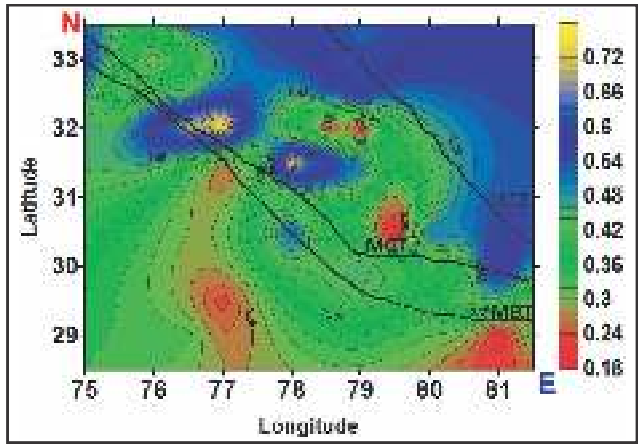


Fig. 40: Fractal Dimension contour map (D) for total 1221 earthquakes (M⩾3.0).

also observed low D value around this region. The low value of D in this zone indicates the presence of fluid in the sub-surface as suggested by Monsalve *et al.,* 2008. The presence of fluid in this zone may contribute to reducing the effective stresses and show relatively lower value of D as observed by Barton *et al., 1999* in Long Valley, California, and Singh et al., 2008 in Koyna region. The Low fractal value around the chamoli region strength the evidence of presence of fluid filled rock matrix in the upper crust of this region. Mukhopadhyay and Kayal, 2003 studied the aftershocks of Chamoli earthquake (1999) and their tomographic interpretations obtained low-velocity zone (high V_P/V_S ratio) that extends from the surface down to 15 km depth, and explained this anomaly as may be due to fluid-filled fractured rock matrix. The liquid-filled source area might have contributed to the nucleation of the mainshock. Delineation of such characteristic seismic images may be useful for seismic hazard/risk evaluation in active tectonic zones.

In the present analysis, the calculated value of Fractal correlation dimension D varies from 0.18 to 0.75, which shows that this region has low D value. The average value of D in the region is very low (0.38). The obtained value of D is low along the passage of MCT and north of the MCT trend indicating strong heterogeneity in this part (Fig. 40).

The low D value is observed in the NE-SW trending zone in the western Himalaya. Arora and Singh, 1992 have also reported a conductive zone in this region using magnetotelluric survey.

We found a positive correlation between b and D values (Fig. 38).

The average spatial correlation in this region is 0.7, which indicates the events are not randomly distributed, but more or less clustered. The b value ranges from 0.35-1.05 using MLM. The b value is estimated 0.66 using LSM. The error estimate of b-value lying under reasonable limits 0.001-0.002. b~1, from both the methods suggests that the area is seismically active.

A sharp rise in the b value is observed in the north of the MCT along the MCT trend indicates strong heterogeneity in this part.

From the slop of the plot C(r) and it is found that fractal dimension D is 0.78 (D<1), which shows that the faults are distributed in a line and is indicative of more clustered events in the region. Similar results have been obtained in the eastern Himalaya and southern Tibet region by Singh et al., 2008.

About the uplift erosion and microseismicity in the Dhauladhar range of 1905 Kangra earthquake meizoseismal region, Western Himachal, NW Himalaya: response between climate and Seismicity

(this study is based on local earthquake data collected in the NW Himalaya during 2004-2011; during 2004-2011 about 2600 local earthquakes and more than 3000 regional and teleseismic data base is prepared and analyzed as per research objectives)

Dhauladhar range (D range) lies in physiographic and strike continuity of the Pir Panjal range that flanks the southern boundary of the Kashmir basin. It is located in the frontal part of the Lesser Himalaya framing the Sub Himalayan foreland basin in the Kangra reentrant. The D range has a characteristic tectono-geomorphic setting. The elevation of the range rises between 4000 m and 5000 m in the eastern segment and decreases between 3500 m and 2500 m in the western segment. Kangra and Palampur fans lies in an intramontane basin, called Kangra Dun, between the D range front and the Southern Siwalik range at elevation between 1500m and 800m. The Kangra Dun is of restricted extent in the eastern segment and does not extend to the western segment. The D range was glaciated during Pliestocene glaciation, and the glaciers occurred at much lower level (2800m) than the present ice- margin in the Himalaya. On the northern side of the water divide of the range, Ravi river flows Northwest in Chamba region on the northern flank of the D range. There are valley filled terraces in the Ravi River. Both the Kangra Dun sediments and the Ravi river terraces are derived from the D range with dominant source of Dhauladhar granite. Seismicity monitored in the recent years through local network of digital seismographs indicates that seismicity is concentrated in the eastern segment and characterized by seismicity quiescence in the western segment. Coincidently the rupture zone of 1905 Kangra earthquake of magnitude Mw=7.8 also lies in the eastern segment of the D range. There is also focused precipitation in the western segment with mean annual precipitation greater than 3000 mm. It is proposed that the uplift of the D range is attributed to faster erosion rate as a result of focused and heavy precipitation and compensated by isostatic uplift due to erosion of the large volume of debris and deglaciation in the D range. It appears the seismicity in the western segment is linked to removal of the load that resulted into increased shortening rate and concentration of seismicity, implying that there may be a linkage between uplift-erosion, climate and seismicity.

Focal mechanism solutions stress distribution studies in the NW Himalaya

Digital uniform data collected for the period of 2008-2010 was analysed through the seismic networks of Kangra and Kinnaur regions of Himachal Himalaya. More than 300 earthquakes have been recorded in the Himachal Himalaya in the magnitude range of 1.0 to 4.5. This seismic activity show high concentration of seismicity around Main Boundary Thrust (MBT), Main Central Thrust (MCT) and Kinnaur region.

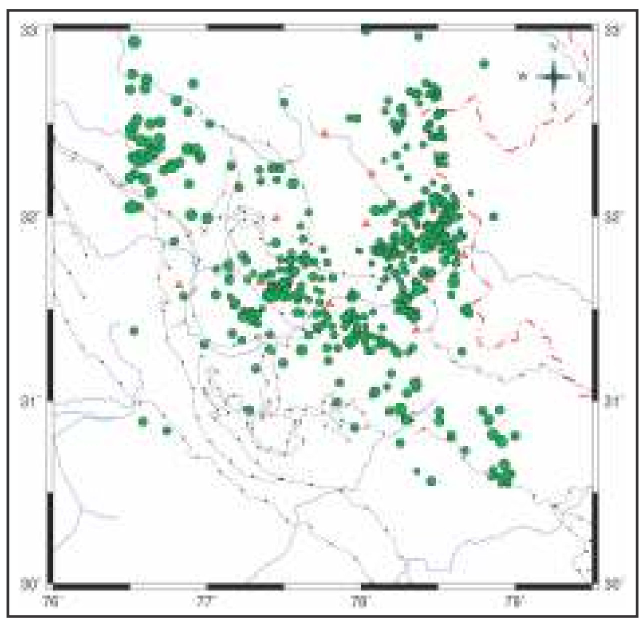


Fig. 41: Microearthquake activity observed during 2008-2010 in NW Himalaya using data of Kinaur seismic network.

Digital waveform data of earthquake for the period 2008-2010 of NW Himalaya is processed to obtain the earthquake location source parameters and its further analysis. The recent epicenter plot of Kinnaur and adjoining region is shown in figure 41. It highlights that high microearthquake (1.0<M<4.0) is occurring in the epicentre zone of M6.5 Kinnaur earthquake of 1975. The seismic activity is nearly aligned to N-S which is perpendicular to the general trend of Himalayan seismicity and tectonic discontinuities. Therefore this region is controlled by seismic activation of regional tectonic faults other than general trend of Himalayan tectonics.

Rest of seismicity of for the same period of 2008-2010 is plotted in figure 42. In this data set, the events in the magnitude range of 2.5<M<5.0 of Garhwal-Himalaya region for the period of 2007-2010 are used for Fault Plane solution (FPS) determination, with clear P-wave first motion Polarities. Depth section profiles are prepared across the trend (NE-SW direction) of major tectonics of the region. In the Garhwal-Kumaun region USGS determined Fault plane solutions of earthquake events lying around main central thrust (MCT) are also taken in to consideration. It is observed that almost all the events of this region

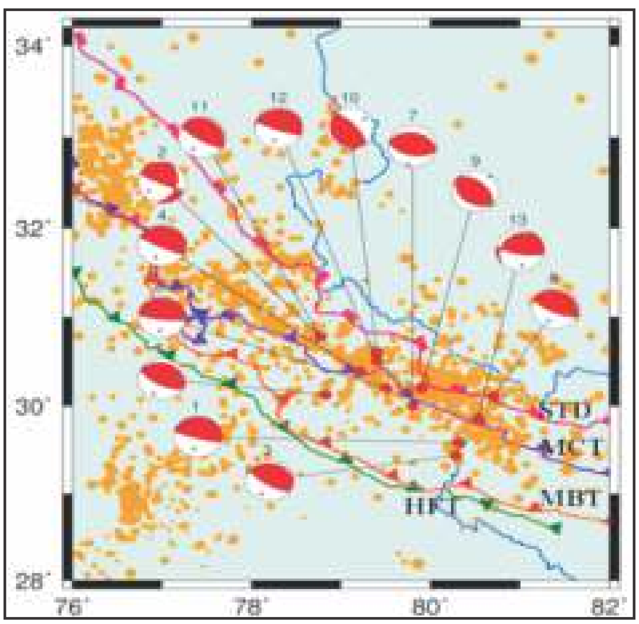


Fig. 42: Fault plane solutions of earthquakes for the events of Garhwal-Kumaun region (USGS events), with the background seismicity (yellow circles) in the range 1.0-5.0 magnitude. The FPS are of events above 5.0-6.0 magnitude. The dark quadrants (red) are compressional and the white part in the FPS are dilatational quadrants.

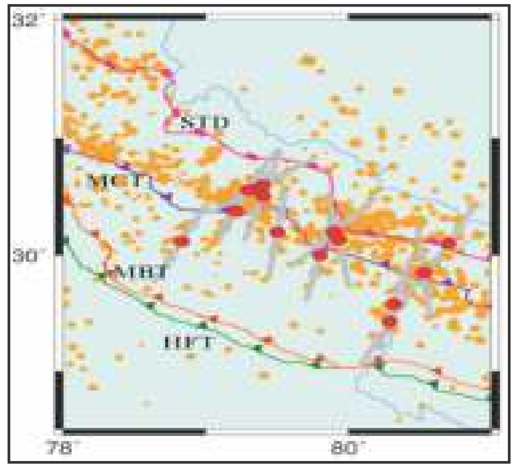


Fig. 43: P-axis projection for the earthquakes on the tectonic map of Garhwal-Kumaon region. Thick grey arrows pointing at the red dots (epicenters) represent the direction of P-axes Orientation for the respective Fault Plane Solutions.

shows Thrust type of faulting with their nodal plane trending in NW-SE direction, with one events (S.No.13) having small component of strike-slip motion. The projection of P-T axes of the focal mechanism solutions on a focal sphere shows the distribution of P-T axes on a focal sphere, it is seen that all the P-axes are concentrated near periphery showing the low plunges of the fault planes and thrust nature of faulting and the T-axes are near centre. The P-axes trends (Fig. 43) and the stress tensor inversion results show that the maximum compressional axes is directed towards NE, similar to the Indian plate motion. The stress field condition in this Garhwal-Kumaun region is of compresssional stress regime.

Component 5.2b:
Multi-parametric Geophysical Observations for earthquake precursory research

(Naresh Kumar, Gautam Rawat, Ajay Paul, P.R.K. Gautam, Devajit Hazarika, V.M. Choubey)

Complementing the observations at Multi Parameter Geophysical Observatory (MPGO) Ghuttu, a network of two stations for total magnetic field measurements at Bhatwari and Adibadri is established at the end of year 2006. Ghuttu observations served as a reference to these observations to remove magnetospheric and ionospheric effect, in order to isolate tectonomagnetic effect in total magnetic field. ULF Band magnetic field variations are also started from January 2007 at Bhatwari. Beside these magnetic observations, seismological data is also utilized from Garhwal

Kumaun Board Band Seismic (BBS) network for studying earthquake precursory signatures.

Geomagnetic Studies

Principal component analysis (PCA) of three simultaneous observation of total magnetic field is employed, to explore the time variability. PCA of total magnetic field for three station has been completed up to year 2009. Figure 44 shows PCA of complete year 2009. Variation in square root of eigen values are plotted.

Observing seismic index (a parameter given by Molchanaov, 2003 characterising seismic influence at observation point) at Ghuttu for entire year, it is evident that earthquake occurred on 21.09.09 of magnitude 4.8 may be significant earthquake for earthquake precursor point of view (Fig. 45). This earthquake occurred at (30.878N, 79.049E) around 09:43:52.03 GMT on 21.09.09. There is increased fluctuations in second eigen value starting from second week of august-2009. This anomalous variation remains few days after the earthquake. Occurrence of this anomalous feature in second eigen value indicates source of this variation is not magnetospheric. Further analysis is in progress.

ULF Band EM emissions

Magnetic field variations in the frequency band of 0.01 Hz to 32 Hz are continuously being registered at Bhatwari, Ghuttu and Adibadri through highly sensitive LEMI30i ULF band induction coil magnetometers. This network measurement will allow us to use polarization ellipse method for locating seismo-EM signals in Garhwal-Kumaun area. Comparison of polarization ellipse parameters

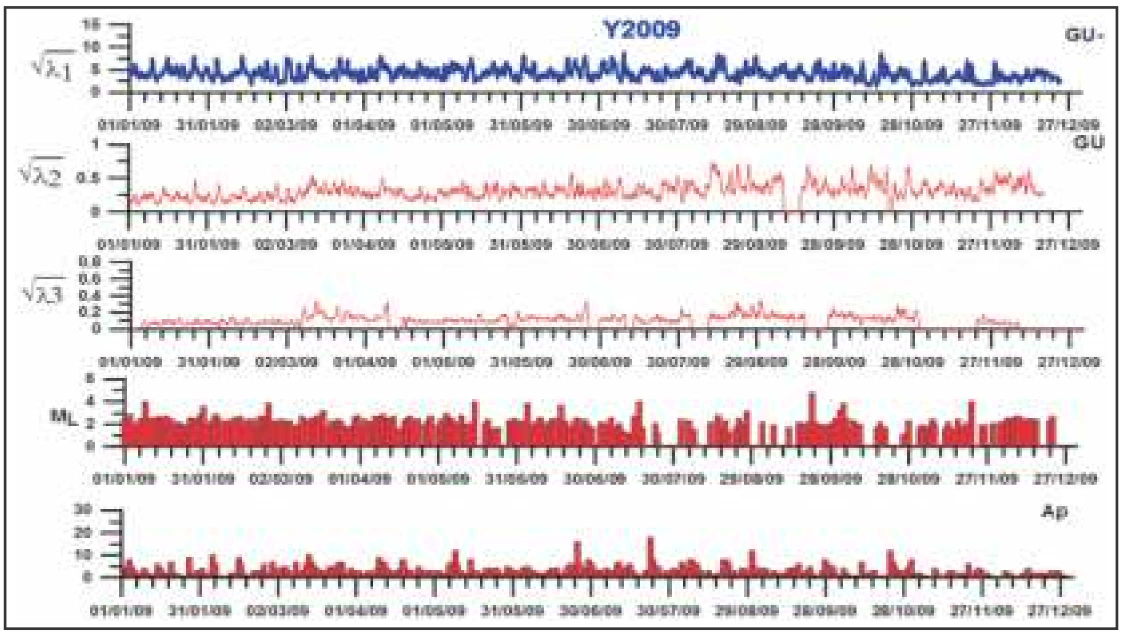


Fig. 44: Principal component analysis of Total Magnetic field data for year 2009.

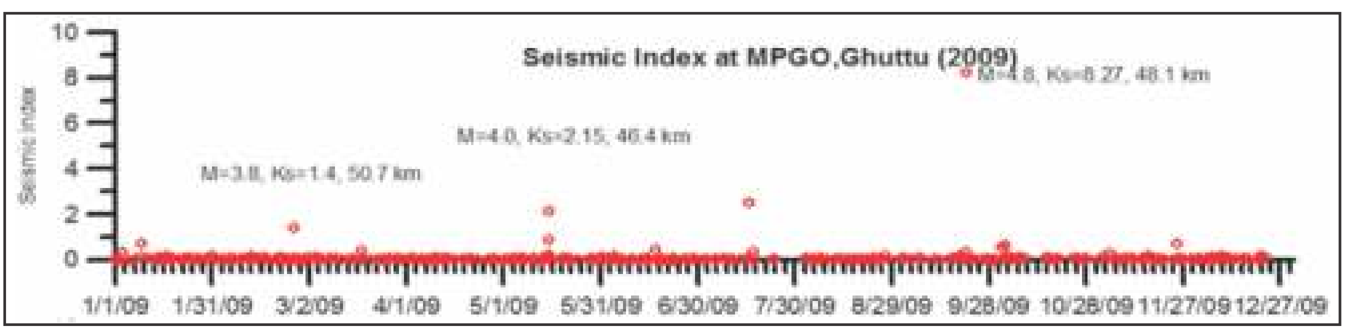


Fig. 45: Plot of seismic Index at Ghuttu for year 2009.

in selected frequency band, formed by the magnetic field components at the measurement stations allows discrimination of seismo-EM signals from the natural background signals of magnetospheric/ ionospheric origin. We have deployed one ULF induction coil magnetometer in Koyna during Year 2006. The data from this unit along with data from Kolhapur University is utilized for locating source zone of EM signals based on method of polarization ellipse developed by Dudkin et al., at LVIV Ukraine. Test application of this method in the Koyna region using two station data sets revealed that intersection line of PE planes suggest that azimuth of the EM source align in the NNW-SSE direction, well coinciding with the nodal plane of normal fault of two largest earthquake occurred during observation period (Fig. 46).

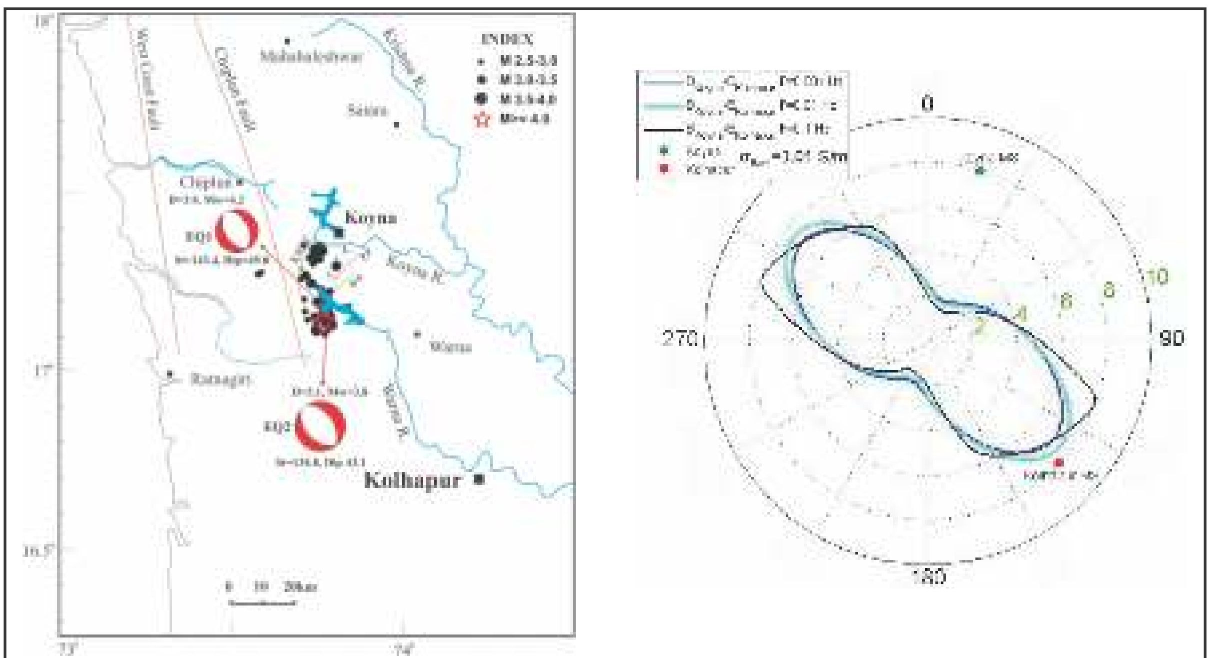
Seismic Precursors

The change in the velocity ratio Vp/Vs is one of the precursor phenomenon. This ratio decreases and then recovers shortly before an earthquake. Aggarwal et al. (1975) have reported a successful prediction of an earthquake in the Blue Mountain Lake area in US. On the basis of an observed drop of the Vp/Vs ratio from 1.73 on July 30 1973 to about 1.5 over the next two days, a prediction was made on August 1 that an earthquake of magnitude 2.5 3 would occur in a few days. An earthquake of magnitude 2.6 did occur on August 3.

Similar precursory studies have been carried out from the data acquired in the VSAT linked Broad Band Seismic Network in NW Himalaya and the following graph (Fig. 47) shows the variation of Vp/Vs from July 07 to March 11. It shows that the value of Vp/Vs is uniform around 1.73 and the phenomenon of drop of Vp/Vs (by about 10-15%) and its recovery has not been observed till date.

Superconducting Gravimeter

Continuous gravity measurements are being carried out through Superconducting Gravimeter (SG) at MPGO Ghuttu, for observing the gravity variation due to ongoing regional tectonic processes. The only SG station in the Himalayan region is highly sensitive that can record gravity changes to μGal level. It is observed that the gravity measurement to μGal level is influenced by many factors such as tidal forces, atmospheric pressure, rainfall, moisture etc. The usefulness of data adoptive techniques like wavelet and singular spectrum analysis developed to de-noise



(i) (ii)

Fig. 46 : (**i**) Map of western India showing ULF station and seismicity during March-June,2006, EQ1 is the earthquake occured on 17 April 2006 (ML=4.7, h=3.9 km, 17.13 N,73.78 E, 16.39.59.4 UT) and EQ2 is the earthquake occured on 21 May 2006 (ML=4.2,h=5.1 km, 17.17 N, 73.77 E, 20.29.01.2 UT). (**ii**) Koyna/Kolhapur PE major axis ration against direction of the magnetic dipole.

and estimate the time varying amplitude of tidal effects, atmospheric pressure and hydrological influence on high resolution gravity field measured to a sensitivity of µGal by SG.

As shown in figure 48, the gravity data of SG has gaps, high frequency noise produced due to surface vibration during strong earthquake and co-seismic changes produced by nearby large magnitude earthquake and admittance of atmospheric pressure. The gaps in the recording of gravity data is produced due to power failure which is very difficult to maintain in this remote site of higher Himalaya. The SG sensor is so sensitive to gravity change that whenever any

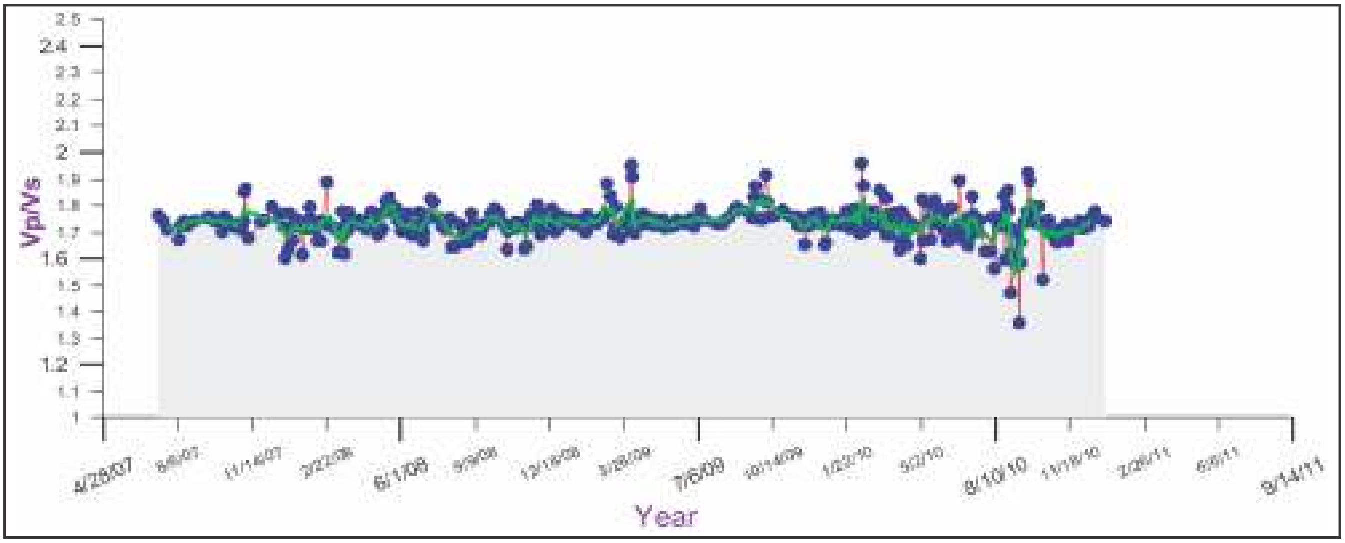


Fig. 47: Plot showing the change in Vp/Vs ratio for the period July 07 to March 11.

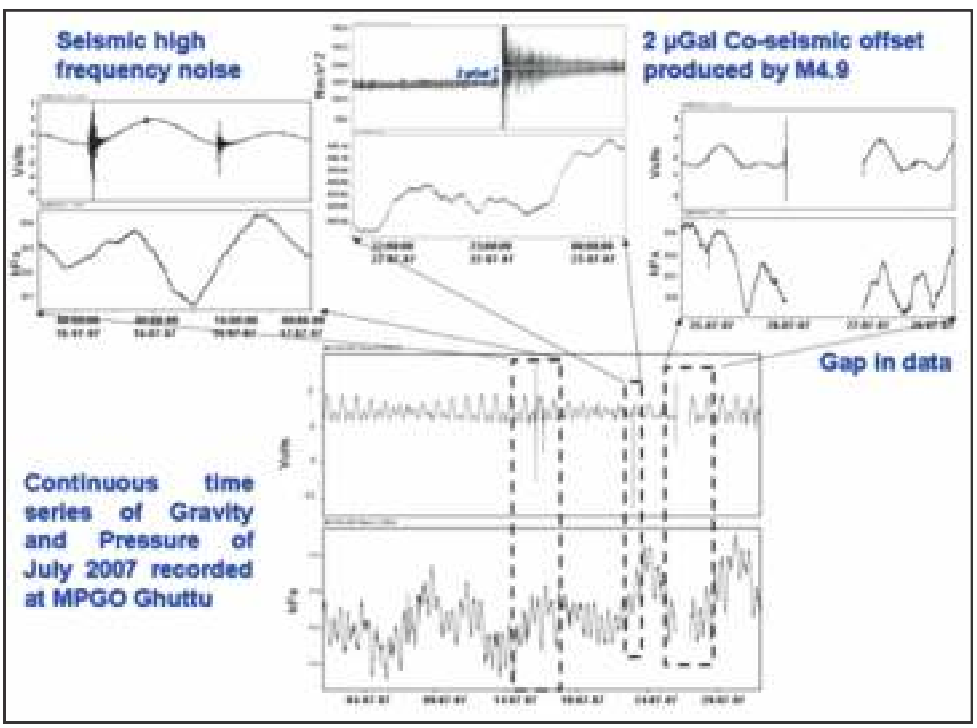


Fig. 48: Processing of SG data to remove the effects of influential parameter.

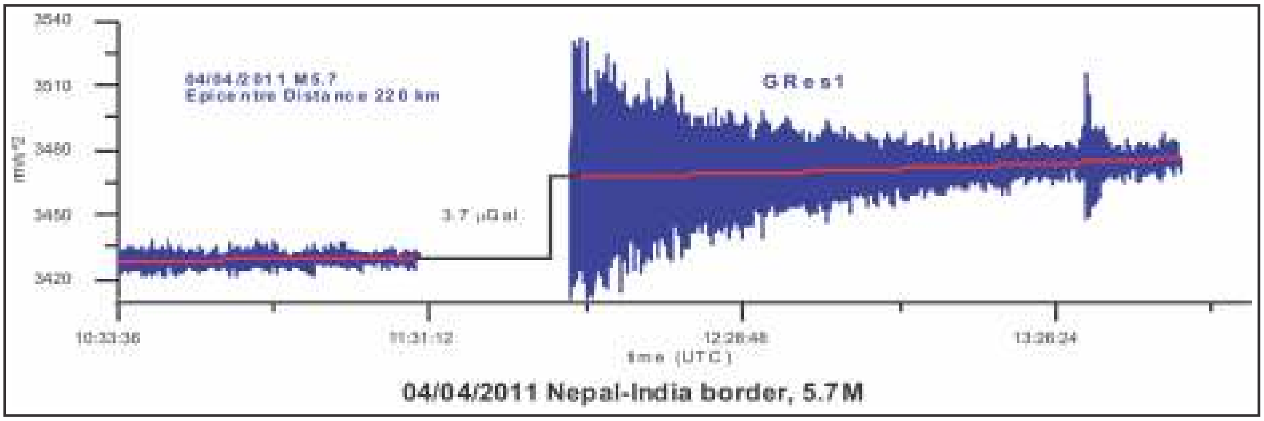


Fig. 49: Co-Seismic change observed in the gravity data during M5.7 earthquake of 04/04/2011 occurred about 200 km from MPGO in Darchula region.

earthquake of more 6.0 magnitudes occurs in any part of the earth then high frequency perturbations are recorded due to vibrations of earth's surface. These high frequency vibrations are also observed during occurrence of nearby large magnitude earthquake of M>4.0. The gaps are filled and high frequency vibrations are separated from the recording data to unable it for observing gravity variations due to regional tectonic stress changes.

The main objective of MPGO and continuous recording of minute variation in gravity using SG is to detect the precursory signatures. We are recording local seismic activity through BBS network as discussed in the previous section. So far we are successful to detect the Co- and post-seismic changes through this time series of gravity. A well preserved co-seismic change of 2 µGal (Fig. 48) has been observed during the occurrence of M4.9 Kharsali earthquake of July 22, 2007 that occurred at a distance of 60 km towards NW from MPGO station. Based on this analysis it has been observed that co-seismic change in gravity is identified whenever any earthquake of M>4.5 occurred within a distance of 100 km. Recently an earthquake of M5.7 occurred in the Dharchula region (India-Nepal Border) on April 4, 2011 and the co-seismic change (Fig. 49) also observed during its occurrence having epicenter distance of 200 km.

Radon studies

Mostly accepted and widely reported radon (Rn222) measurements, a tool for earthquake precursor research, is a part of multi-parametric geophysical observation in the Garhwal Lesser Himalaya for earthquake related studies. Radon is being recorded continuously at an interval of 15 min at 10 m depth in a

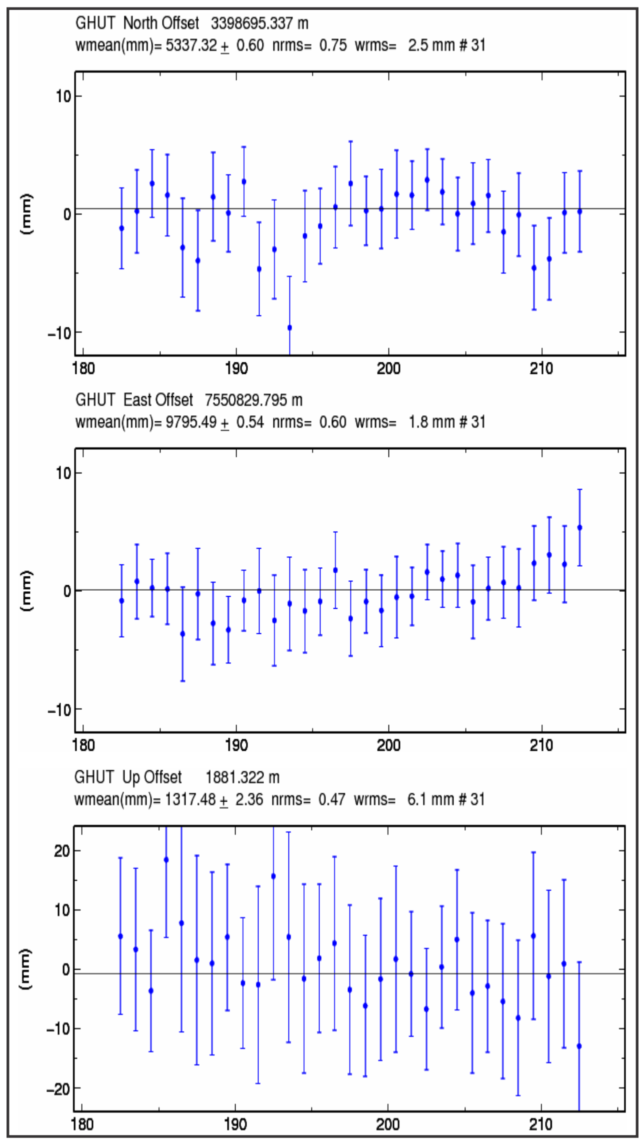


Fig. 50: Time series of July 2007.

68 m deep borehole. Three years high resolution 15 min data at 10 m depth shows a complex trend and has a strong seasonal effect along with some diurnal, semi-diurnal and multi-day recurring trends. A well-defined seasonal pattern is prominent with a high emanation in summer and low values in winter accounting for about a 30% decrease in count values in winter when the atmospheric temperature is very low at this station located 1.90km above mean sea level. Diurnal, semi-diurnal and multi-day trends in this time-series are mainly observed during April-May and October-November. This is the period of spring and autumn when there is a high contrast in daynight atmospheric temperature. Hence the high fluctuation in Rn concentration is mainly caused by the temperature contrast between the air-column

Fig. 51: Local GPS bench marks around the Tehri Reservoir**.**

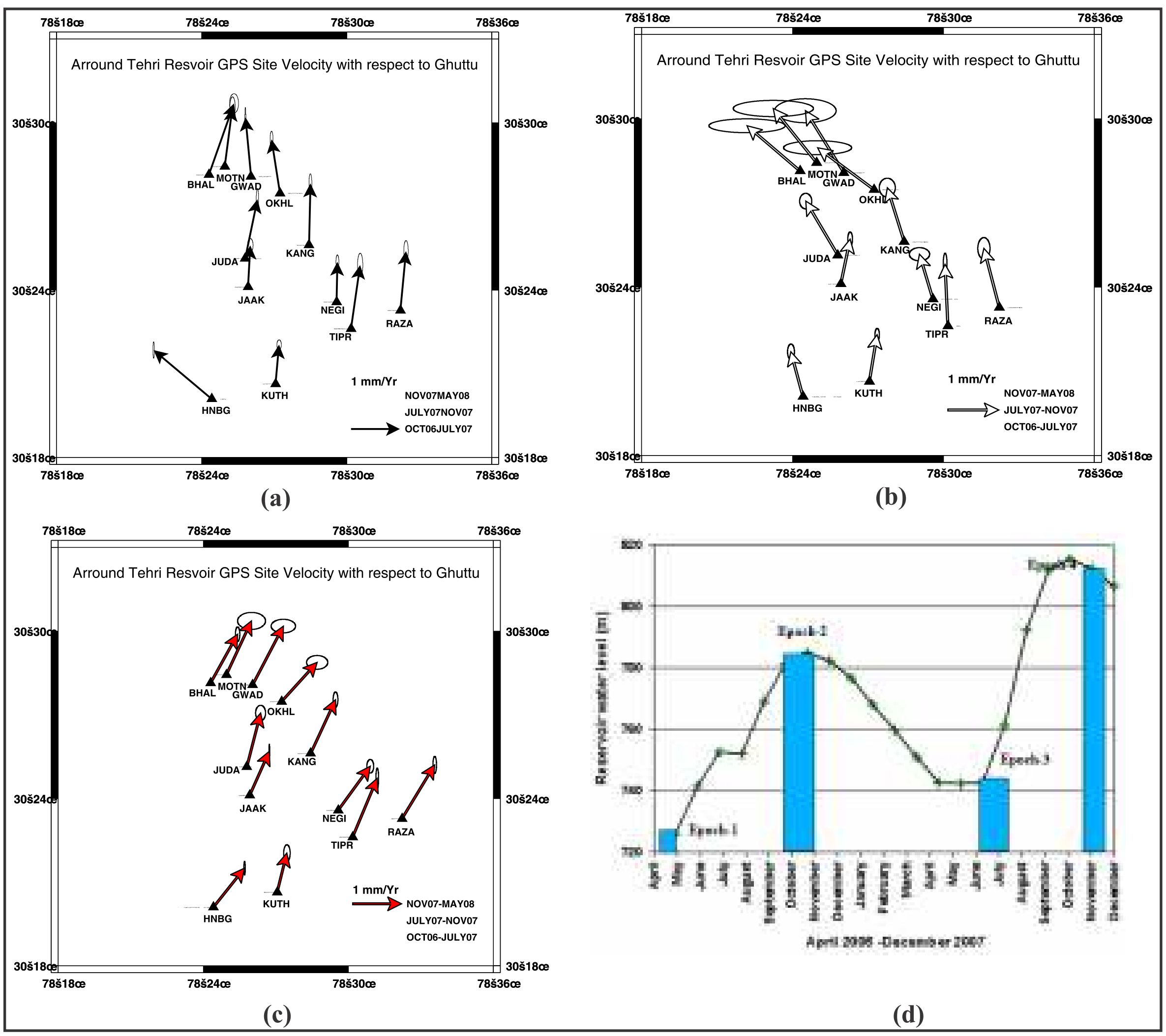


Fig. 52 (**a**) Velocity vectors for period Oct 06- July 07. (**b**) Velocity vectors for period July 07 Nov 07. (**c**) Velocity vectors for the period Nov 07-May08. (d) Reservoir water level from April 2006 to Dec. 2008. Velocity vectors with reference to Ghuttu.

inside the borehole and the atmosphere above the earth's surface.

GPS Studies

GPS Data is continuously monitored with the help of TOPCON receiver of permanent GPS station at Ghuttu with sampling interval of 15 sec and 30 sec. Preprocessing of raw GPS data utilizing utility software TEQC / TPS2RIN has been completed and data is now available in the usable (rinex) format. Our main focus is now on processing of the data to evaluate the stability of the station. To examine the behavior of the station, we have processed one month data of July 2007 and calculated GPS time series (Fig. 50) within the error range of 10mm. Apart from continuous observations at Ghuttu, campaign mode GPS data has been collected four times (Oct. 06, July 07, Nov. 07 and May 08) at fifteen bench marks established around Tehri reservoir (Fig. 51). The data has been collected alternatively pre monsoon and after monsoon continuously for five days at each bench mark. To observe the effect of pore pressure due to the reservoir water loading/unloading on local seismicity of the study region, initially the data has been processed with respect to the ITRF05 reference frame using the 10.32 version of GMIT/GLOBK Linux based software. Further processing has been carried out with the advance version 10.35 of GAMIT software. In the processing we take care for all assumptions and norms which are designed for the precise processing and produce velocity vectors (Fig. 52) around the reservoir with reference to MPGO Ghuttu. It has been observed that velocity vector with reference to Ghuttu are having different orientation at different stage of reservoir loading/unloading.

Component 5.2c :
Seismic microzonation, site response and shallow sub-surface studies in NW Himalaya and adjoining areas

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

Shallow Sub surface investigations in Dun valley

As an endavour to study subsurface of the Dun fan deposits, we try to evaluate the utility of surface seismic time-lapse travel time tomography; we monitor a site through time along a single 2-D profile in Donga Fan. The objective is to attribute decrease in S-wave velocity with the development of perched water bodies in the upper 30-40 m of the subsurface. The site is located near Bahadarpur area of Donga Fan which shows a decrease in shear wave velocity below station location 120 from its surroundings like a funnel shaped feature with contrasting color from light blue (Vs ~400m/s) at a depth of 20 m to light/dark green at a depth of 80 m (Vs ~500-600m/s; Fig. 53). The decrease in velocity in funnel shaped feature is attributed to the presence of water which decreases the velocity of shear wave in comparison to its surrounding material.

Second attempt in this direction was calculating the thickness of sediments under Dehra Dun Fan sediments. Earlier information on the thickness of Dun gravels under the Dehra Dun fan was based on tectonics and stratigraphic investigations and estimated to be 600 m. Later, based on tube-well boring and field observations, the thickness of the Dun gravels has been revised to 100-300 m. In the present investigations, shear wave velocity (*V*s) field has been

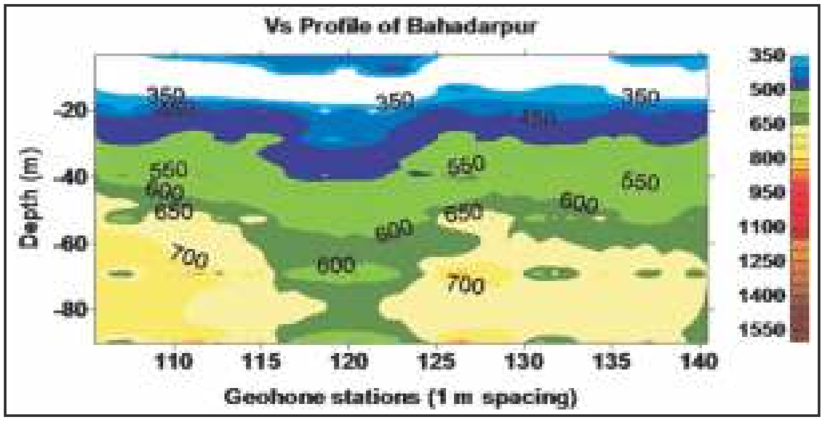


Fig. 53: Identification of water bodies using subsurface seismic method. Shear wave velocity profile of Bahadarpur area, Donga Fan showing decrease in Vs below station 120 in funnel shaped features may indicate the presence of water body.

PROGRESS IN MISSION MODE PROJECTS

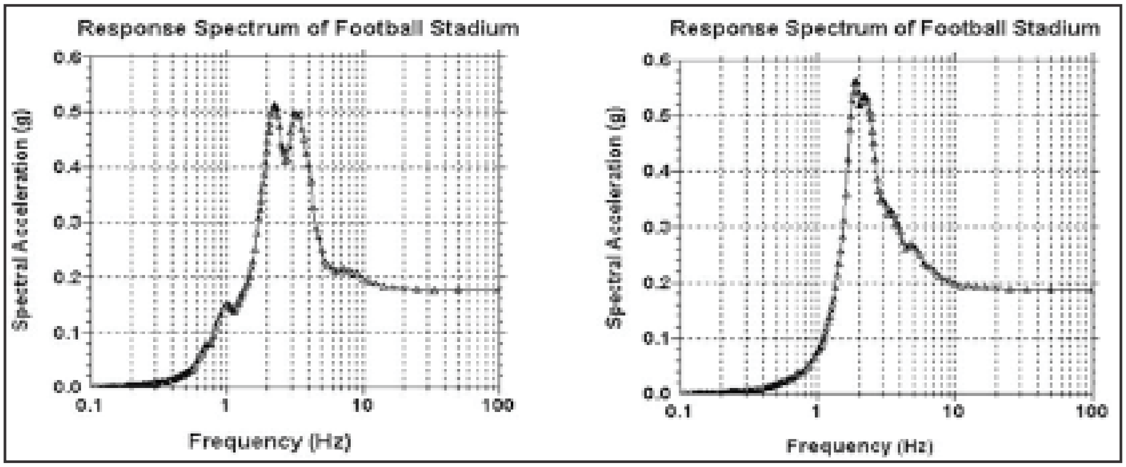


Fig. 54: Shows response spectrum of Football stadium located in the center part of the city. The comparison of response spectrum using actual thickness of sediments (140m) (left) and 30m soil column (right) has been shown.

calculated using multichannel analysis of surface waves (MASW), surveyed using 4.5 Hz frequency geophones with Elastometer-aided weight drop hammer as a source. This enabled us to map the thickness of the Dun gravels and the depth to bedrock underneath the Dehra Dun fan deposits and has been estimated to be 35 m in the northern flank of the syncline, 140 m in the centre of the broad syncline and 90 m in the southern flank of the syncline below the ground surface.

Another effort in this direction is site characterisation using 30 m soil column as per NEHRP recommendation and actual thickness (140 m) of the soil column. All along the Himalaya we have a thick fan deposit, which has great potential of site amplification due to high seismic hazard and presence of large population shows high risk involvement.

In lieu of this we compared the site response derived using 30 m soil column and actual thickness (140 m) of the soil column. The comparison of the results of response analysis using 6.8 mb magnitude earthquake considering its epicenter 100 km away from the site of investigation, it is observed that the fundamental frequency of the site changes from 1.88 Hz to 3.22 Hz for a soil column at depth of 30 m to 140 m respectively. The analysis also suggests that there is no difference in the response of the soil column of 30m or 140 m depth for a single storey building having natural frequency of 10Hz. However, there is sharp change in the response of 1Hz natural frequency soil column which vary from 0.084 g to 0.208g for a soil column at depth of 30m to 140m respectively (Fig. 54).

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Component 5.3
Crustal deformation and geo-hazard studies in Himalayan region

(S. Rajesh, Swapnamita Choudhury and P.R.K Gautam)

Component 5.3a :
Dynamics of Crustal shortening and Lithospheric Structure of Garhwal-Kumaun Himalaya

(S. Rajesh and P.R.K. Gautam)

Crustal shortening in the Himalayan Foreland

Two permanent GPS stations have been established and made operational first time by WIHG in Sub-Himalaya, a lithologically challenging area to establish permanent GPS stations, close to the HFT at Biharigarh and Shambuwala/Nahan (Fig. 55). These two stations are landmark GPS permanent

Fig. 55: A sample picture of permanent GPS station set up at south of Nahan, in Himachal.

stations that can plausibly answer the ongoing debate on present day crustal accommodation processes in the Himalayan Foreland, what! Plays what? Tectonics or Climate. Prevailing interpretations on surface displacements or slip rates in the frontal part are based on conjectures rather than substantiated by accurate measurements. Added to the difficulty is the dynamicity of pore space fluid in determining the solid earth deformation in the foreland.

On the failure of fault propagation above 14° N followed by the M_w=9.1 Sumatra Andaman earthquake of 26th Dec. 2004

The 26th December 2004 Sumatra-Andaman earthquake (Mw = 9.1 to 9.3) occurred along the convergent plate boundary of the Indo-Australian and Southeastern Eurasian plates caused the devastating Tsunami along the rim of eastern Indian Ocean states. Many investigations including the work by Banerjee et al., (2005, Science) reported abrupt cessation of the fault rupture up to 14° N along the frontal arc of the Sumatra-Andaman oblique convergence zone, and the same has been shown in figure 56a. Reasons behind such a cessation or failure in the propagation of fault rupture were not known and had been investigated through a new methodology called Geoid to Topography ratio using satellite altimeter derived geoid and gravity over the region. It has been inferred and shown in figure 56 (b), that the mantle plume

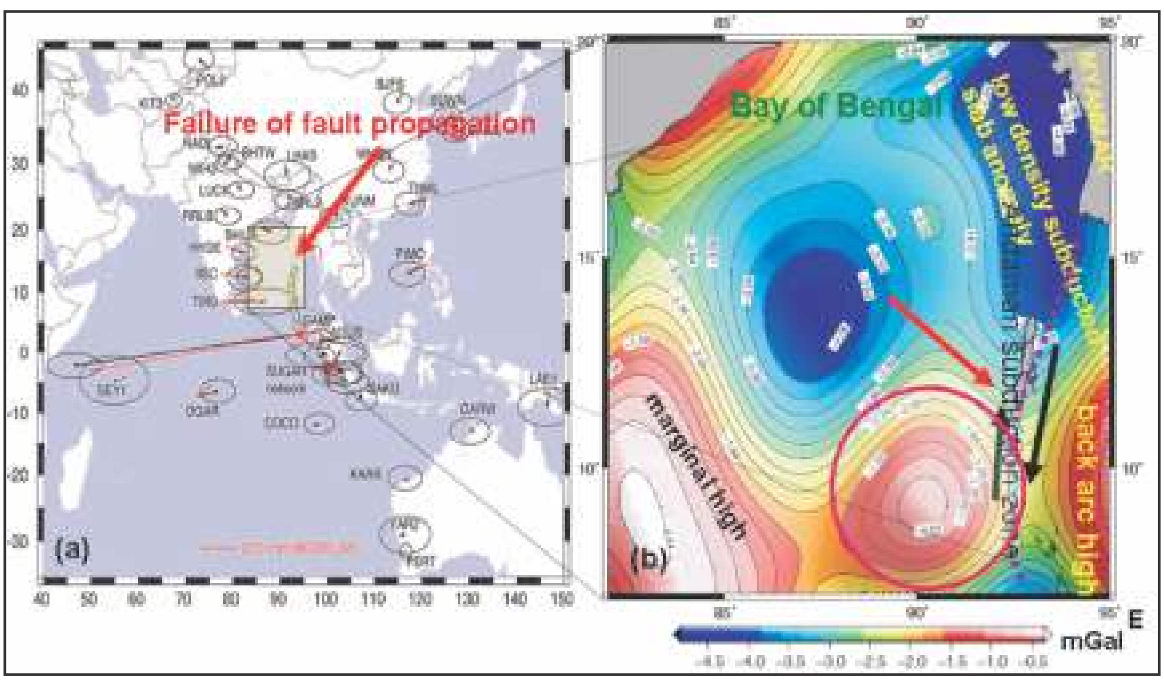

Fig. 56 : (a) shows the GPS observed far field static offset followed by the 26th December 2004 Sumatra-Andaman earthquake (Banerjee et al., science, 2005). Bold red arrow shows the region at 14° N, where the fault propagation was ceased along the Sumatra-Andaman trench. **(b)** Shows the gravity anomaly over the shaded rectangular area that covers the fault propagation zone (Rajesh and Majumdar., MGR, 2010). The purple colored encircled area represents how the under-plated, dense and viscous ridge-compensating body affected the ridge-trench collision zone (shown as black dual arrows) and hence the fault propagation**.**

related under plated compensating body of the southern Ninetyeast Ridge is relatively dense and viscous which affected the density driven gradient flow between the ridge and the subducted lithospheric slab. The regional gravity shows Andaman convergent area between 7° to 14° N experienced greater crustal shortening as a result of Ninetyeast Ridge-Trench collision. Details are given in Rajesh and Majumdar (2010, MGR and 2011, AES) Publications.

On the dynamics of pore space fluid in the Doon Valley

One of the intriguing aspects of solid earth deformation in the Doon valley is the role of fluids that preserved inside pore spaces of Doon gravel. In general, pore space fluid dynamics in alluvium becomes very critical to determine whether liquefaction processes should happen or not. So far we have little knowledge on what would be the dynamical behaviour of fluids that present in the Doon gravel in the wake of an earthquake, although we are sitting very close to the zones of different levels of seismicity. Numerous hydrological and geological investigations carried out in the Dehra Dun Valley by many scholars confirmed the presence and nature of Doon aquifer and mapped the thickness of the weathered zone. But we do not know how the dynamicity of pore space fluids presented in the Doon weathered layer is detrimental for the occurrences of secondary effects of earthquake such as liquefaction and fluid extrusions.

A novel method has been developed to understand the dynamics of pore space fluids presented in the Doon alluvium when it subjected to periodic and a-periodic forces. Initial results suggest the existence of two distinct characteristic gravitational energy decay response of the Doon alluvium. At shorter periods of a-periodic excitation the alluvium response is mainly controlled by the dynamicity of fluids, especially water present in the pore spaces. However, the response of the Doon alluvium to periodic excitations are dominant only at larger periods, where pore space fluids like water have little role in controlling the gravitational energy decay. Since this is a medium property, a tool has been developed to understand the momentum diffusivity of pore space fluids which has wide ranging applications from liquefaction to exploration Geophysics. More work in this direction is currently under progress.

Component 5.3b :
Crustal Deformation, Strain Accumulation and Geohazard Study in the Himalayan Region using SAR Interferometric Techniques

(Swapnamita Choudhury)

Field work

Field work was carried out in Kangra-Dharamshala-Chamba region for reconnaissance survey for the study of active tectonics of the region. Another field work was carried out in Tehri-Bhagirathipuram-Raulakot region for mapping of tectonic discontinuities around the dam.

Work Done

Correlation of seismicity after the filling of the 42 km^2 Tehri Dam reservoir in the state of Uttarakhand, India was carried out. Several thrust systems, faults and shear zones mark the dam site. This intra-plate convergent zone has been seismo-tectonically very active. The study of any induced seismicity and ground motion activity with the loading of the dam was initiated using seismological data and SAR Interferometry. InSAR data processing suffered from extreme layover conditions. Beyond a month no coherence in the data used could be retained. Due to very few acquisitions in this region by ESA the data was insufficient for a persistent scatterer method. With the launch of India's RISAT programme, availability of data should improve. Data from the WIHG seismic network from eleven stations around the dam for the years 2007-10 was used to study the seismicity conditions around the dam. Seismic data of the years 2000-10 from ISC (along with our data) was also used for correlation of water level fluctuations of the reservoir with seismicity. Since impounding started in 2005 it has been observed that seismicity presents an unusual pattern in the initial filling cycle with renewed seismicity in the later filling cycles. Lesser number of earthquakes occurred in the filling season (March to September) and the drawdown period was acompanined with enhanced seismicity. Occurrence of higher magnitude earthquakes after peak water levels in the reservoir can be attributed to time lag for pore pressure to increase considerably with permeability to trigger the earthquakes. The Himalayan tectonic regime, being in a compressive regime, should experience stability rather than instability induced due to loading of the reservior

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PROJECT

Multi-Parametric Geophysical observatory for Earthquake Precursory Research at Ghuttu, Garhwal Himalaya

(V.M. Choubey, Ajay Paul, Gautam Rawat and Naresh Kumar)

In a quest to document and understand the nature of earthquake precursors in a Himalaya, Wadia Institute established first Multi-Parametric Geophysical Observatory (MPGO) in Indian at Ghuttu, Central Himalaya. In a region of active geodynamics and high seismic activity, the MPGO (Fig. 57) is located to the south and very close to the Main Central Thrust (MCT). Located in a narrow belt of high seismicity, this segment has not witnessed any great earthquake at least in last two centuries, but has been a seat of number of large earthquakes such as the 1991- Uttarkashi of M6.6 and 1999- Chamoli earthquakes of M6.4. A noble feature of the observatory is that it is equipped with most modern and sophisticated equipments like superconducting gravimeter, overhauser magnetometer, tri-axial fluxgate magnetometer, ULF band search coil magnetometer, radon data logger, water level recorders, etc. and are backed up by broad band seismometers and GPS. It is believed that the earthquakes may have precursors with manifestations in various time series of geophysical processes. The MPGO was set up in the Garhwal Himalaya keeping in view the previous earthquake history in the form of seismicity, earthquake hazard and seismic gaps for strong earthquake.

Seismicity

The MPGO is the central part of active seismic zone, corroborated by a close network of BB seismic stations as shown in figure 57. Some stations of this network are linked through VSAT to monitor the seismicity in real mode at Central Recording Station (CRS) Dehra Dun. In addition Wadia Institute is operating more than 25 BB seismic stations in the adjoining regions of Himachal Pradesh and Jammu & Kahsmir. After the installation of MPGO, as a part of independent project of Ministry of Earth Sciences (MoES), Wadia Instiute strengthened seismic network in the Garhwal Himalaya that lowered down the earthquake detection threshold to nearly M2.0 compared to its initial level of M2.5 in 2007. The recent data of all earthquakes of

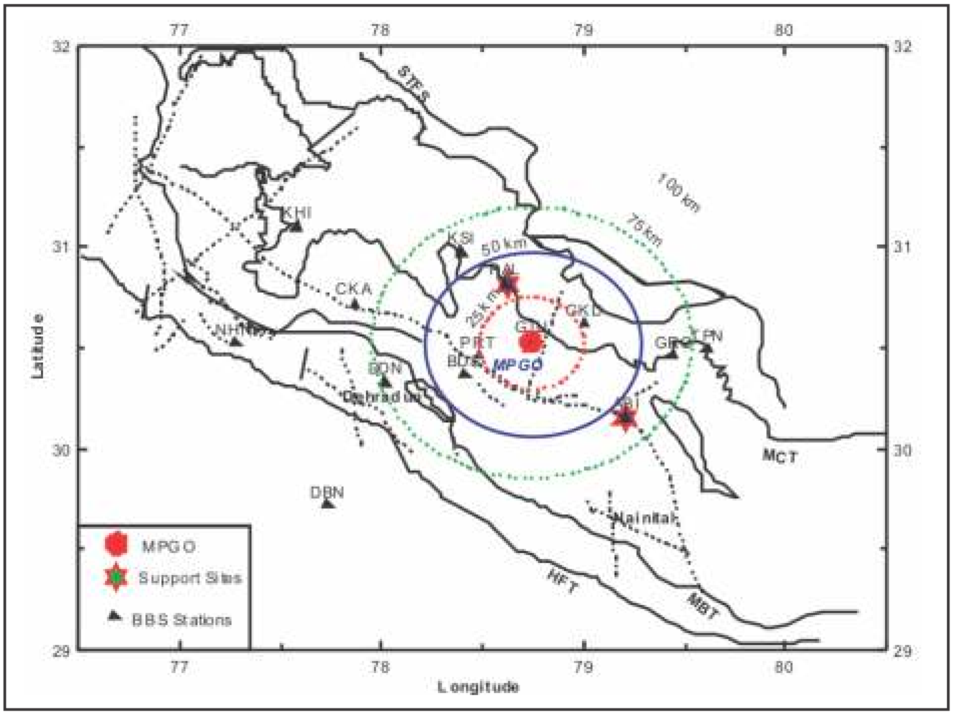

Fig. 57: Location of MPGO, Ghuttu, Support sites and BBS Network of WIHG.

M≥2.0 have highlighted a high seismic activity over MCT zone around MPGO station (Fig. 58).

The recent and past seismicity around MPGO is analysed to search earthquake precursory signatures in the time and spatial variability of earthquake occurrence. We are adopting different techniques such as seismic quiescence, enhancement of seismic activity, RTL (Region-Time-Length) algorithm for the change in the behavior of seismic activation to get any signal of zone preparing for large earthquake around MPGO and other parts of India. Using these techniques, we have detected some seismic precursory signals in the past data in Garhwal Himalaya (Lyubshin et al., 2010) and in Koyna-Warna region (Shashidhar et al., 2010). The precursory signatures observed during the occurrence of M~5 earthquakes in the Koyna-Warna region are shown in figure 59.

The epicentre location of these M~5 earthquakes and the observed spatial variation of RTL and the quiescence period (red blocks) prior to earthquake occurrence during the 2006 to 2009 is shown in figure 59a. It is clear from figure 59b that the Temporal variation of RTL, negative values in RTL (seismic quiescence) were present during (1) July to September 2007; (2) May to July 2008 and (3) July to October 2009. The earthquake time series is also shown with the quiescence (green line) period during 2009, prior to the M5 earthquakes that occurred in the months of November and December respectively.

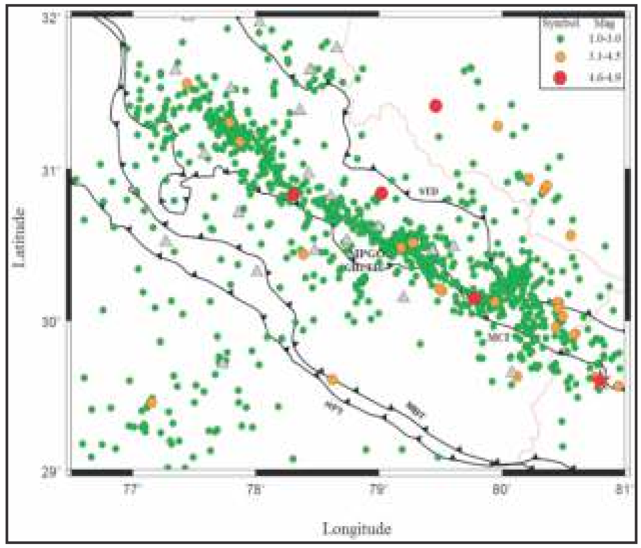

Fig. 58: The recent seismic activity in the Garhwal Himalaya.

Crustal structure beneath the broadband seismograph at MPGO Ghuttu

Teleseismic earthquake data recorded at the broadband seismological observatory installed at Multi-Parametric Geophysical Observatory (MPGO), Ghuttu are analyzed using Receiver Function (RF)

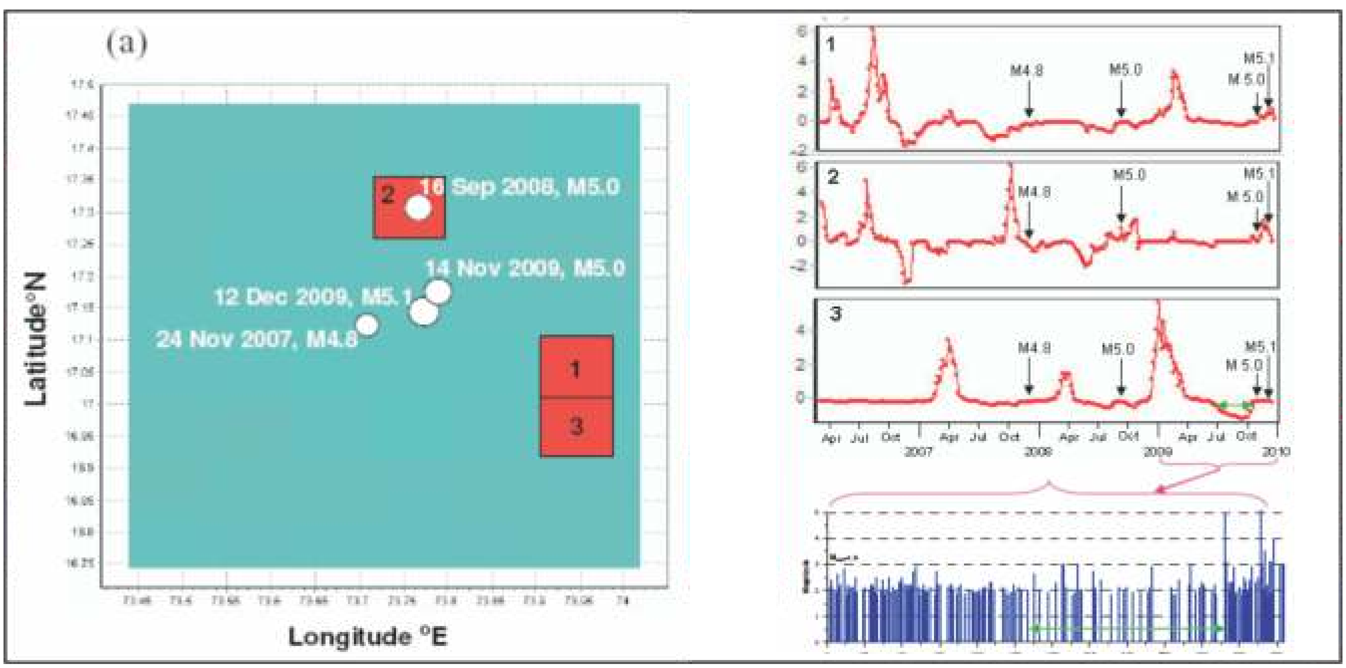

Fig. 59: Spatial variation of RTL and the quiescence period (red blocks) observed prior to the M~5 earthquke in the Koyna region (Shashidhar et al., 2010).

method to determine the seismic characteristics of the crust. The RFs calculated from the teleseismic *P* waveform for a range of back azimuths show little variation in the Moho *Ps* arrival time, indicating nearly same crustal thickness from all back azimuths. However the rays piercing from different direction shows different structure in the mid-crust. In order to study the azimuthal variation of mid-crustal layers, the RFs are grouped in narrow bins of backazimuth and epicentral distance ranges. By ray-tracing the incident *Ps* phase through the crust, using the ray parameter calculated from the focal depth and epicentral distance of the earthquake, the Moho piercing points are calculated for the *Ps* conversion. The RFs are grouped according to these Moho piercing point clusters (Fig. 60, clusters A, B, C, and D). The earthquakes for

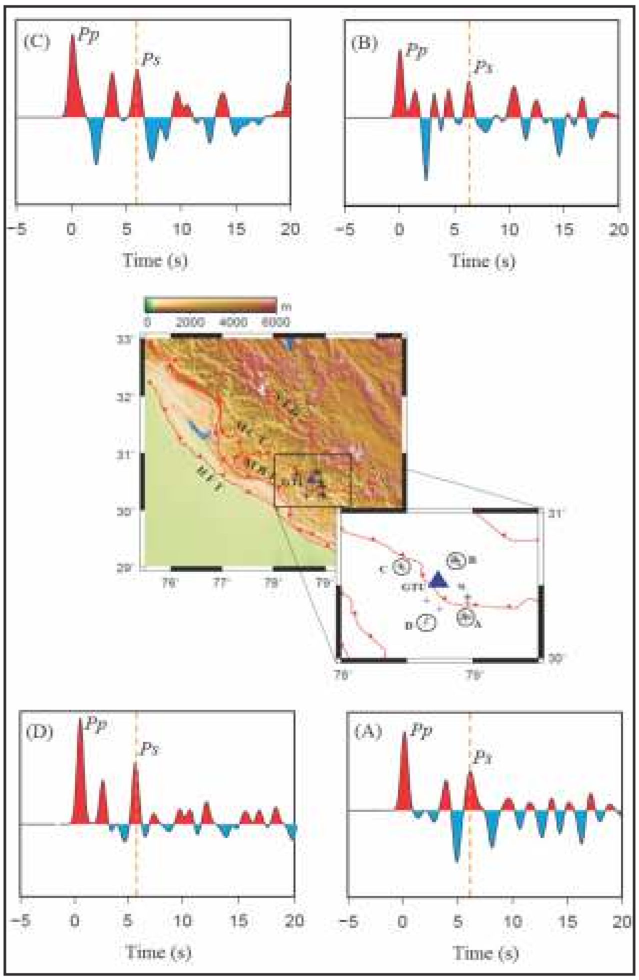

Fig. 60: Map showing the location of the Moho *Ps* piercing points around the GTU station. Stacked radial receiver functions for the four clusters are plotted as A, B, C, and D. The Moho *Ps* arrival times for each cluster are marked on the individual plots.

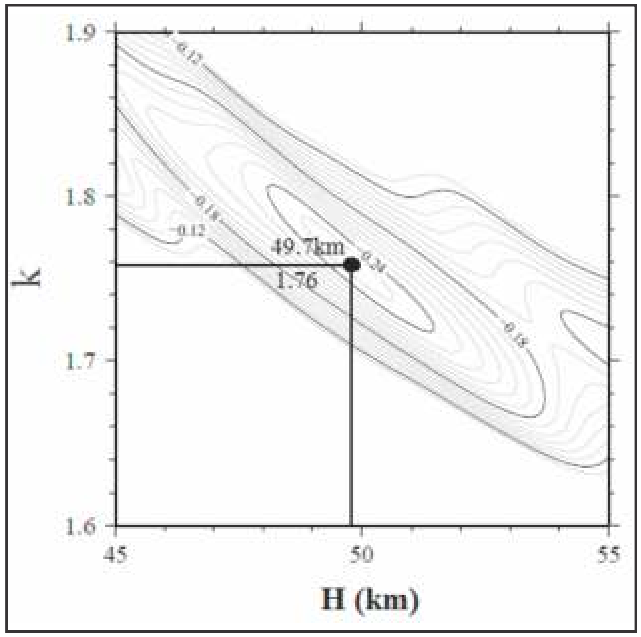

Fig. 61: The Vp/Vs versus crustal thickness (H) for GTU radial receiver functions shown in Fig.60 calculated using the stacking technique of Zhu and Kanamori (2000). The crustal thickness beneath GTU is ~49.7 km, and the average crustal Vp/Vs is 1.76 ±0.05.

clusters A, C and D pierces the region south of Main Central Thrust (MCT) and the RFs shows single mid crustal layer at 3.8s, 3.0s and 2.5s respectively. On the other hand the RFs for the teleseismic waves entering the region from northeast backazimuth pierces the region north of MCT (cluster B) and shows multiple phases corresponding to several intra-crustal discontinuities formed due to inter-stacking of Indian crust during subduction process beneath the Eurasian plate. The Moho *Ps* conversion and crustal multiples in the radial RFs are used to estimate the average Vp/Vs ratio of the crust using the H-K stacking method of Zhu & Kanamori 2000 (JGR, Vol:105, pp.2969-2980). In this method all the radial RFs are stacked irrespective of distances and directions to suppress effects of lateral structure variation and the time domain RFs are converted into the H-Vp/Vs domain to calculate the average crustal thickness (H) and Poisson's ratio of the crust. By this method a average crustal thickness of ~49.7 km and Vp/Vs of 1.76 beneath GTU station (Fig. 61) is obtained.

Superconducting Gravimeter

Continuous gravity measurements are being carried out through Superconducting Gravimeter (SG) at MPGO Ghuttu as a part of eleven geophysical parameters. The only SG station in the Himalayan region has a very high accuracy and sensitivity (μGal level) for observing minor changes in gravity that is influenced by many factors such as tidal forces, atmospheric pressure, changes in water table, moisture etc. Three years gravity observations show a heavy influence of tidal forces, atmospheric pressure and hydrological effect. Major emphasis is on to adopt an approach which allows parameterizing the influence of tides, pressure and hydrology in the gravity data.

The estimation and elimination of most dominating tidal and atmosphere pressure effects show gravity residuals ranging up to 30-35 μGal in a year, especially during the rainy periods. The correlation with recorded precipitation as well as water level changes recording in a 68 meter deep borehole show that hydrological cycle influences the gravity field in three distinct manners; namely (i) transient steep changes in all cases are associated with intense rainfall events (ii) medium-term changes on a time scale of few days correlate well with ground water level fluctuations and (iii) slow seasonal gravity changes appears to be the combined effects of degree of soil saturation as well as rate of recharge of aquifer. In the later case, the increase in slow gravity field during the onset of rainy season is controlled by the rate of water level rise with time delays from couple of days to tens of days though decrease of gravity field following the rainy season is determined by the temperature controlled evaporation of moist soil.

The residual of gravity obtained in figure 62 shows a variation of about 30-35 μGal for the observation of more than one year. These variations are high in the rainy season. The important issue of Global Geodynamics Project (GGP) of detecting changes in near surface water storage using gravity is being done by incorporating a 68 meter deep borehole at about 200 m distance from the SG station. The daily rain fall is also being observed at that point. In order to investigate the variation related to hydrological effect in the gravity residual continuous observation of water table level is recorded in the borehole. In the Himalayan region heavy rainfall of over 25 mm/h is occurred in the rainy season from June to August. We investigated the gravity variation for whole rainy season as well as for short period before and after heavy rainfall. The short period influence caused gravity changes in the order of 1 μGal after occurrence of heavy rainfall has been also observed.

Radon Studies

The time series of radon concentrations monitored at MPGO observatory over the period from January 2007 to March 2011 have been collected continuously at a time interval of 15 minutes. It is readily apparent that the temporal pattern is quite complex. The most obvious feature in the time series is the seasonal (annual) cycle in Rn variability, with high values in the summer/rainy season (July to September) and low values in the winter months (December to February) which is most prominent in the running average curve obtained through 31 days average value for each data and sliding window of one day. During 2008 the maximum radon counts 4752*100 per 15 minute were recorded on 19th June 2008 whereas the minimum counts 3790*100 per 15 minute were observed on 28th December, 2008. A similar difference was observed in the other two years data indicating an annual change in count values of the order of 22.62, 25.38, 28.17 and 27.12 percent in 2007, 2008, 2009 and 2010 respectively with the maximum value in summer and the minimum in winter.

Furthermore, the data exhibit non-constant variance, with very low background variability in the

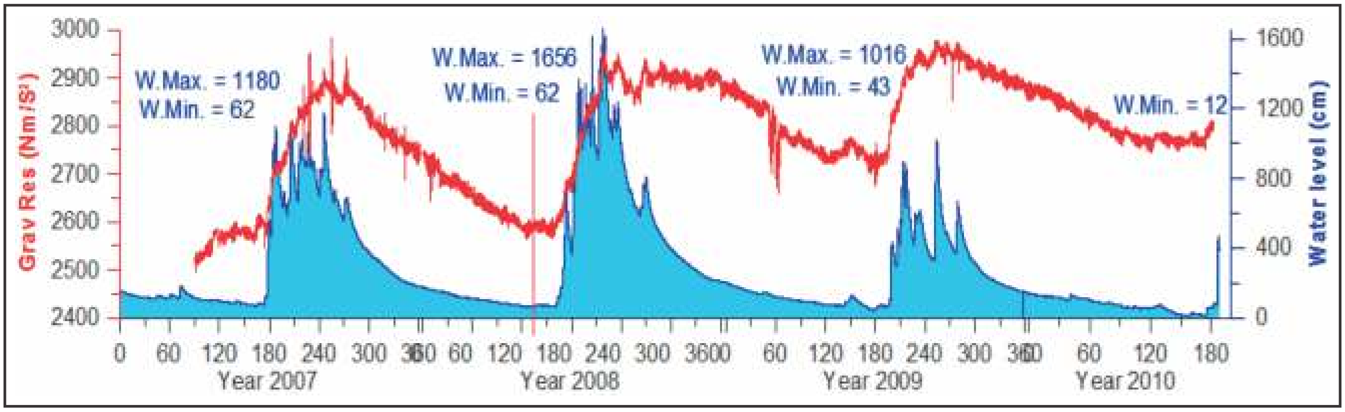

Fig. 62: Residual of gravity obtained after removing tidal and pressure effect.

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winter, moderate variance in the summer, and very high volatility in the transition seasons, both in spring and in autumn. As an example of annual variation of Rn concentration in 2007, in the beginning of the spring (mid March), the radon concentration starts increasing from a background level (average counts 3800*100 per 15 minute low level) that exhibited high variability (about 500 counts in one day), reaching a broad peak in July-August. From June to the end of September, the Rn concentration/emanation was high however the daily variation was moderate. In autumn, the radon concentration started decreasing (starting October), again with high volatility (again about 500 counts daily variation) and reached a minimum value in winter with low background level of nearly 3800 counts. This low concentration remains between December to February (winter season), the period in which the daily variation is negligible. However, a few peaks with high diurnal variations are also observed in the month of January, which are sharp peaks of diurnal excursions lasting a couple of hours in the course of the day (e.g. the few peaks with variation of about 250 counts observed in January, 2007 are shown in figure 63). A similar trend of cyclic variation of radon concentration in the borehole air column at 10 m depth was observed in 2008; 2009; 2010 and few months of 2011 establishing a well-defined pattern in radon exhalation over a calendar year.

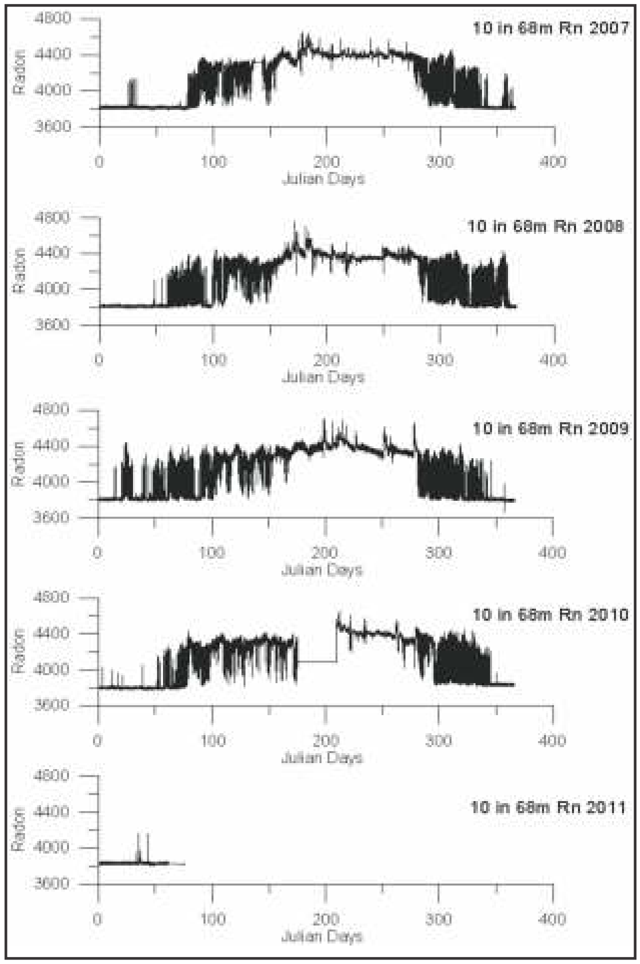

Fig. 63: Radon variation at MPGO Ghuttu.

Magnetic Studies

Continuous monitoring of geomagnetic field at Multiparametric Geophysical observatory at Ghuttu is being done toward the search of earthquake precursory research stress changes, associated with the process of earthquake generation, perturb various physical properties of subsurface rocks. These changes may cause time dependent local magnetic anomalies either due to piezomagnetic effects or due to electro kinetic effects. In order to detect these changes, all component of magnetic field is being measured continuously at MPGO Ghuttu.

Total magnetic field measurements

Total magnetic field (Fig. 64) is being observed with the help of state of the art overhauser magnetometer having higher sensitivity and resolution compare to traditionally used Proton Precision Magnetometers. Preprocessing of geomagnetic data set is using a program developed in institute to fill the gaps by linear regression considering measurements at nearby observatories. These gaps are flagged so that due care has been taken while studying temporal behaviour of geomagnetic time series. Simultaneous measurements at three places are helpful in removing magnetospheric effects. Further considering night time data only reduces ionospheric effect. Thus differential data from three nearby observatories allow removal of main field. Night time differential data from three observatories is continuously observed and any variation in these plots may indicate tectonomagnetic effect.

Figure 65 shows differential plot for the month of June, 2010. The arrow indicate the day of occurrence of 5.1 Mb earthquake (USGS event id US2010xvck) in Dharchula region (29.86N, 80.46E) at 04:14:12 IST, 23 Jun 2010. The differential plot indicates there are some changes before the earthquake and the differential baseline is not stabilized even after the earthquake. This may be noted that there is another earthquake of 5.3 Mb in the same region (29.82N, 80.40E) at 00:08:23 IST, 07 Jul, 2010. This is preliminary observations and

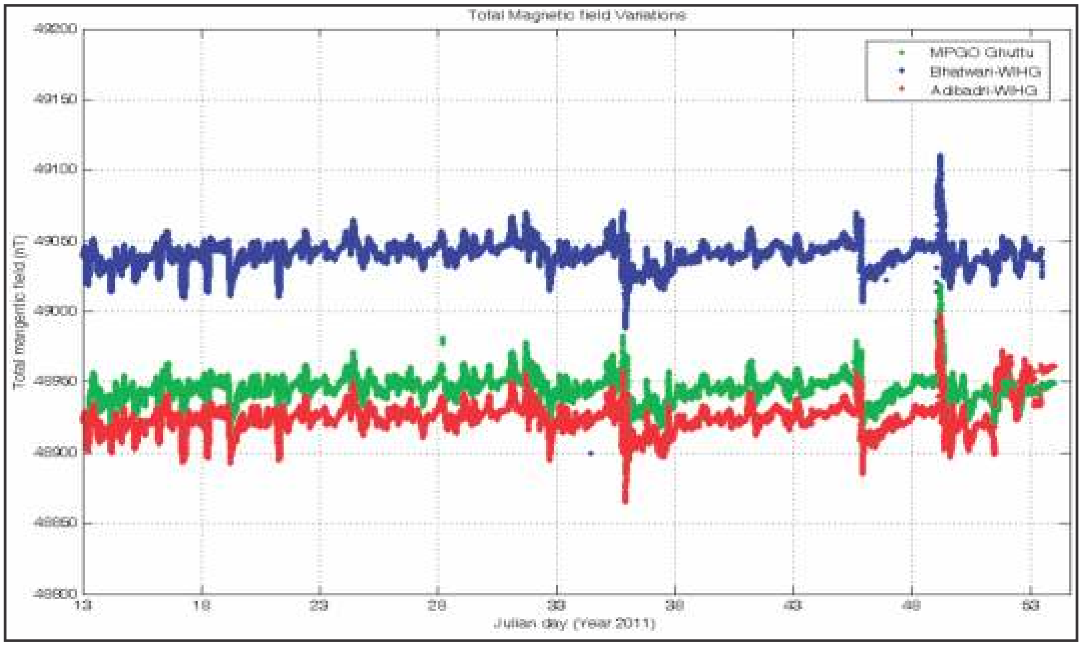

Fig. 64: Total Geomagnetic field variations from Jan 13 -2011 to Feb 22, 2011.

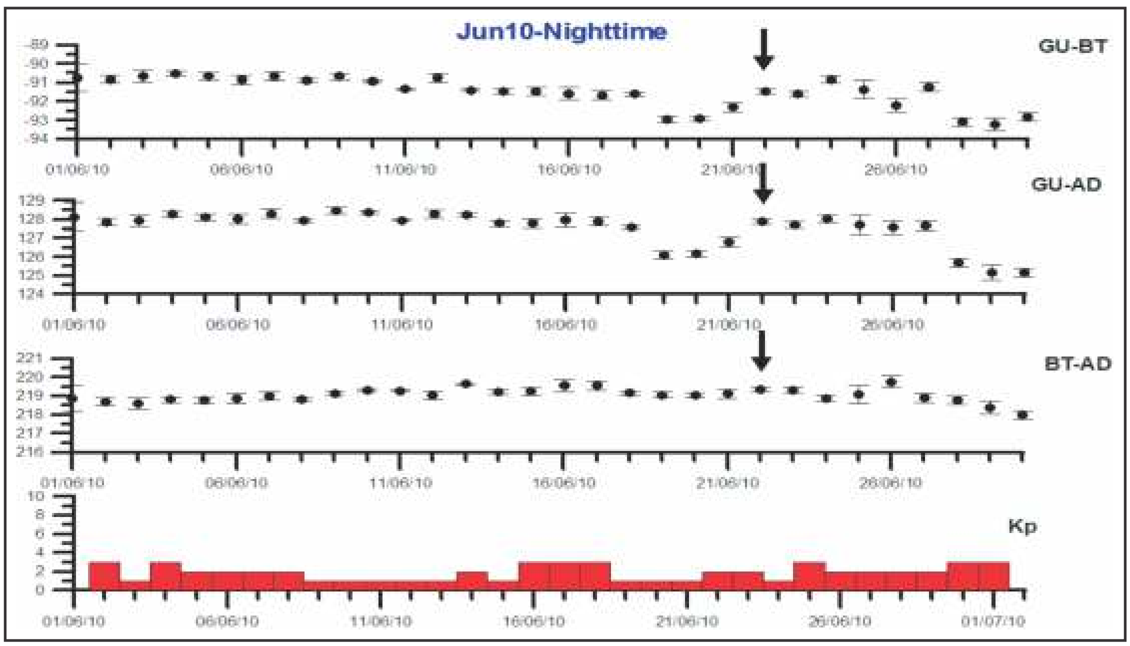

Fig. 65: Differential plot for Total geomagnetic field. (GU: MPGO Ghuttu, BT: Bhatwari, AD: Adibadri) for the month of June, 2010.

statistical techniques are being applied in order to quantify this observation.

ULF band Electromagnetic field variations

Three induction coils for a frequency range of 0.001 to 30 Hz are continuously monitoring ULF band electromagnetic field variations at MPGO Ghuttu. This frequency band is critical for earthquake precursory signatures. Following the report of anomalous behaviour in magnetic field variations in ULF band after Loma Prieta Earthquake, electromagnetic variations are continuously monitored around the globe. This band consist three mode of Schumann resonance peak frequencies. Schuman resonance frequencies are generated by electromagnetic fields generated by worldwide

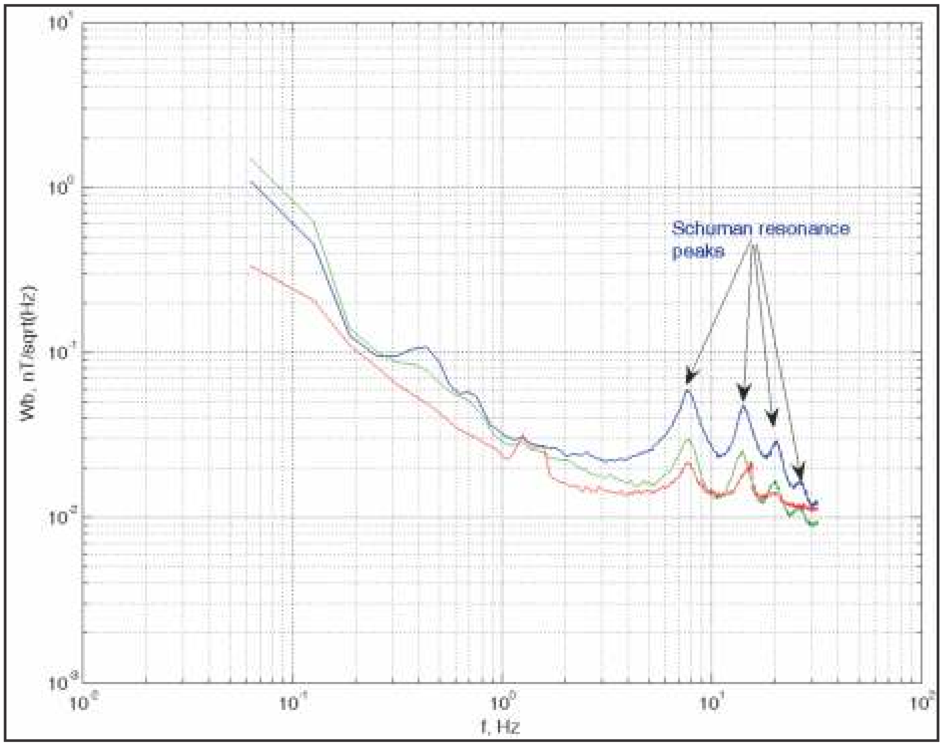

Fig. 66: Schuman Resonance Peaks as observed in Ghuttu.

lightning in a waveguide formed between ionosphere and earth. Hayakawa (2005) reported anomalous behaviour of Schuman resonance frequency variation before an earthquake. Figure 66 shows Schumann resonance peak frequency mode in power spectrum of one hour data of three component of ULF induction coil at Ghuttu.

PROJECT

Telemetric Seismic Monitoring of Garhwal for Developing Hazard Scenario in Uttaranchal

(Ajay Paul)

VSAT Linked Seismic Network for Seismic Hazard Studies in Garhwal Himalaya comprising of Broad Band Seisomograph (BBS) have been installed in the central seismic gap in July 2007 (Fig. 67). Each station is equipped with Trillium-240 (broadband) seismometer and of high dynamic range (> 138 dB) Taurus data acquisition system (DAS). High accuracy GPS synchronies the DAS clock every minute. All the stations of the network are connected to the central station at Dehra Dun by VSAT. The network is shown in figure 68 on the tectonic map of the regions. Since the seismic data is being acquired in real time it is processed immediately to monitor the local seismic activity of the region.

Important Elements of the existing installed Network

Figure 68(a) shows the epicentral locations of the earthquakes recorded since the installation of the network. Since its installation, five thousand Eight hundred thirty nine (5,839) events have been detected by the network till March 2011. Of these one thousand two hundred thirty eight (1339) events are local and located within or very near the network. As shown in Figure 68 the local seismic events in the magnitude range 1.0-5.0 are occurring south and near to the main central thrust (MCT). During this period two clusters are prominent one is in and around the epicenter of Kharsali earthquake and the second one is very near and towards NW of the epicenter of Chamoli earthquake. These clusters appeared from the commencement of installation of VSAT network and became dense with the passage of time. It is significant to note that the seismicity pattern of Garhwal-Kumaun region as recorded in the present network suggests that the region south of MCT trending NNE-SSW along thrusts and faults is seismotectonically active. The region continues to record shallow focus events with low stress drop values. Though 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 microearthquakes. This may

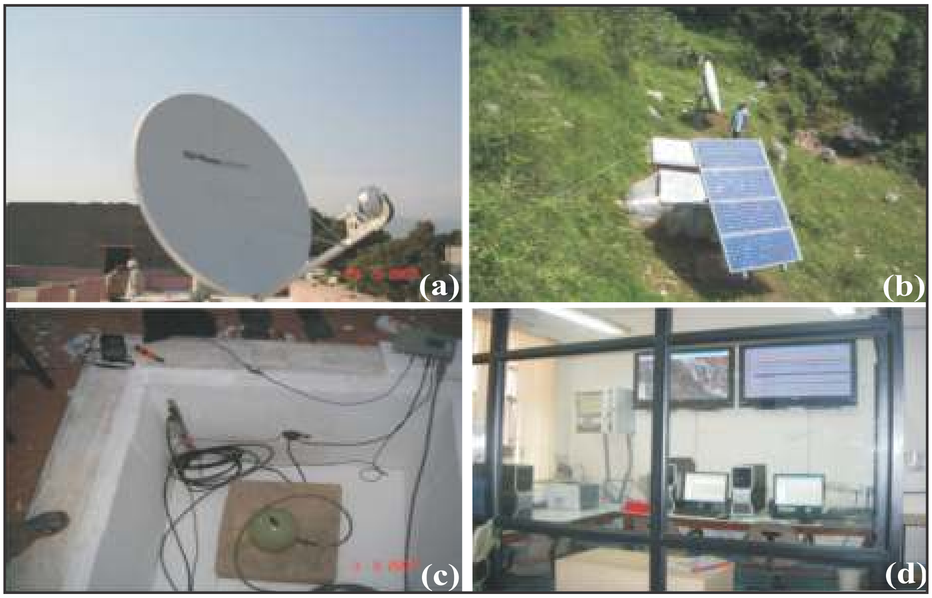

Fig. 67. **a**) Receiving at WHIG Dehra dun, **b**) View of the Remote site Chakrata, **c**) Sensor inside the pit at remote station, and **d**) Central Recording Station, WHIG, Dehra Dun.

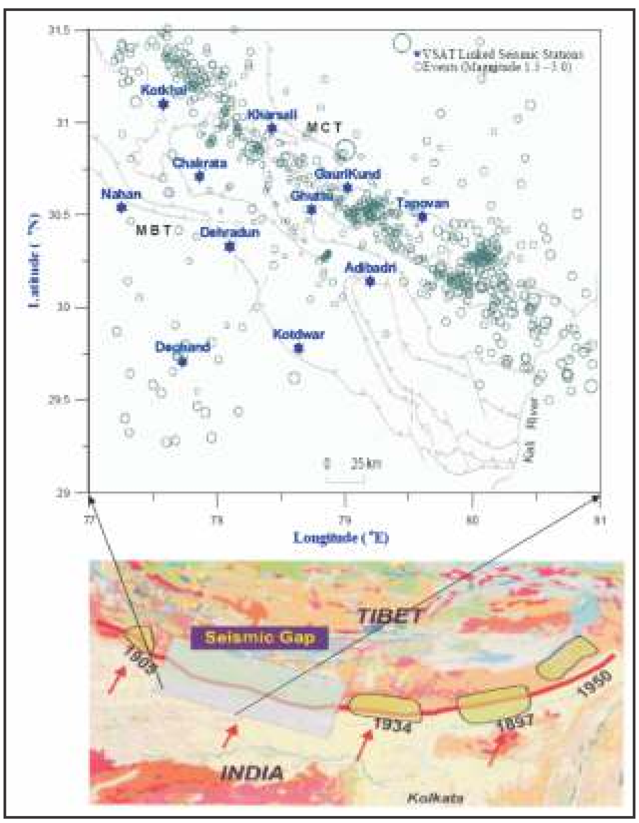

Fig. 68. (a) Seismicity of the region (july 2007 to March 2011) on the Tectonic map (after Valdiya 1980). **(b)** Seismic gap and great earthquakes in Himalaya in India: Shillong 1897, Kangra 1905, Bihar- Nepal 1934 and Assam 1950: MBT Main Boundary Thrust, MCT Main Central Thrust.

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 such a scenario where the accumulated strain energy is large and crust of the region is unable to sustain the released there is a strong possibility of a great earthquake in near future. For the same regular monitoring is being carried out to demarcate space time patterns of enhanced seismicity/ quiescence that invariably precede the large earthquakes, but no anomalous pattern has been identified so far (Fig. 69).

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 in eastern Himachal Pradesh (AFNAH-II)

(N.S. Virdi and G. Philip)

(DST Seismology Programme)

Google Earth, IRS satellite images and Survey of India toposheets (available with the WIHG) have been examined and target areas for field work were designated in the Outer and Lesser Himalaya along the Gambhar rivers and its major tributaries in the western parts of the project area and along the Tons, Pabar and the Satluj rivers and their major tributaries in the eastern segment. Field work was carried out in the following areas of Himachal Pradesh and Uttarakhand:

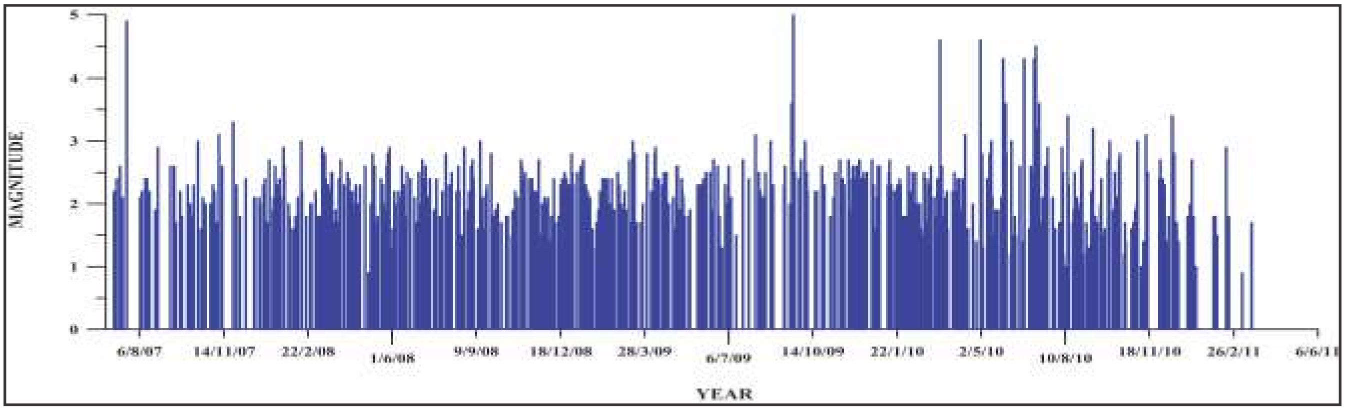

Fig. 69: Chronological sequence of earthquakes (M.2.5) from July 07 to Feb 2011

a) Talon ki nadi in its upper reaches around Dhon and the Jalmuse ka khala in the upper reaches of the Bata river and also along the MBF and pull-apart basin around Dhon.

b) Tons and Pabar valleys including their major tributaries for delineation and field checks of active faults identified on satellite images.

c) Satluj valley between Rampur and Luhri along the H.T. road (NH-22) for study of past blockades and lacustrine deposits and effects of active faults around Nogli, Dattnagar, Bithal , Kepu and Luhri.

d) Karsog Quaternary Basin for mapping of debris flows and other fluvial deposits and effects of some active faults.

For field work, base geological maps published by Auden (1934), Bhargava (1977), Virdi (1979) and Raiverman et al. (1983) have been used. The aim of the field work was to map the Quaternary cover and collect evidences of neotectonic activity as well as identification of some active faults affecting the Quaternary cover as well as the country rocks. Attempts were also made to identify and demarcate evidences of past slope failures leading to landslides, rock falls and debris flows which at places have blocked the stream channels to produce temporary lakes. These lakes sometimes have sequences of lacustrine and fluvial deposits which are indicative of past neotectonic activity and sometimes past seismic shaking.

Following base maps were prepared using 1:50,000 scale S.O.I. toposheets for use in the project work

- Drainage and topography
- Regional geology and structural features, major and minor lineaments.
- For some selected areas detailed geological maps were prepared showing the country rocks, main tectonic features e.g. faults, folds etc. and the Quaternary cover such as alluvial fans, river terraces, lacustrine deposits and colluvial cover due to past slope failures and landslides as well as debris flows.
- Some abnormal geomorphic features such as past evidences of channel diversion and river piracy, basin asymmetry and tectonic tilting of the drainage channels were demarcated on the maps. Some of these sites were verified during the field work.
- A number of faults affecting the Quaternary cover including alluvial fans and terraces and also controlling the drainage channels of major tributaries of the Pabar, the Tons, Gambhar, Giri , Ashni and the Satluj rivers were identified using the Google Earth and IRS satellite images. These faults traverse through the Quaternary cover over the Chail and the Jutogh metamorpics and the Lesser Himalayan sediments belonging to the Simla-Jaunsar , the Shali and the Rampur groups. Some of these faults and other geomorphic and neotectonic features were verified in the field. Remaining faults will be studied and verified during the field work at a later date.

Evidences of River Piracy

Some more examples of channel diversion have been observed on the satellite images in the Satluj and the Pabar rivers. These will be analysed further by detailed mapping and field checks. River capture at these localities further substantiates that neotectonic activity as a result of the current tectonic regime is affecting the Lesser Himalayan region also.

Active faults

We have scanned the IRS satellite images as well as the Google Earth for locating some faults which have affected the Quaternary cover as well as the country rocks. Field studies have shown that these faults have controlled the topographic features as well as drainage channels. Some of these faults lie parallel to major thrusts and seem to be showing activity sympathetic to the activity along major faults.

Main Boundary Fault (MBF)or the Bilaspur Thrust

The MBF has been studied by us over a stretch of about 200km between Chewag in the NW (along the lower reaches of Katal ki nadi and the Beja ki khad upstream of their confluence at Pata to Balad nadi) through Taksal near Kalka , Morni south of the Ghagar river, Nahan, Dhon, Jalmuse ka khala, Baila, Sataun , Rajpur and Kalawar in the Tons valley. At many locations we have collected evidences of strike slip along the trace of the MBF, formation of sag- ponds and pull-apart basins with lacustrine deposits.

The following major faults have been identified and verified in the field in the Lesser Himalaya. Analysis of the data collected is in progress. Detailed geological and geomorphological maps of the fault zones and the surroundings are being finalized.

a) Dharmi gad fault in the Tons valley.

b) Faults mapped in the Pabar valley around Rohru

c) Nogli and related faults in the Satluj valley

d) Faults mapped near Luhri in the Satluj valley affecting the parautochthon and the thrust sheets and the tectonic windows.

e) Karsog Quaternary basin and the effects of Kau khad and the Bithali khad faults.

PROJECT

Earthquake risk reduction in the Himalaya as a part of Indo-Norwegian collaboration with NORSAR

A.K. Mahajan and A.K. Mundepi

Suitability of seismic refraction equipments for seismic noise array measurements and f-k analysis

In recent years, seismic noise array measurements have emerged as a promising way for estimating Vs profiles and characterizing the corresponding soil structure. Although methods based on analysis of seismic noise are simpler, cheaper and faster than other soil penetrating techniques. Array deployment requires the use of several stations which are not always available for all the research groups. Broadband stations are expensive, but even short-period sensors can require a significant economical effort as it is necessary to use several.geophones. In this work, the results from broadband stations and vertical geophones using the f-k method have been compared. Circular arrays with both types of instruments were installed north and south of the Himalayan Frontal Thrust (HFT) also known as Mohand Thrust, with different soil characteristics. Figure 70 shows the array configuration and its theoretical response.

In order to carry out a preliminary analysis of the maximum diameter of the array that would be needed to reach the natural frequency of the geophones (4.5 Hz), we have graphically compared the dispersion curves obtained through the circular arrays of 25m of diameter (using the 9-broadband stations and the 24 geophones configurations) with the theoretical kmin/2 and kmax limits corresponding to the 9-broadband stations array, with 25, 50 and 100 meters of diameter (Fig. 71). It is important to observe that the strict comparison between the dispersion curves and the theoretical wave number limits can be done only for the diameter of 25m, as no measurements were taken for arrays with higher diameter. Obviously, the expected dispersion curves that we would obtain for arrays of 50 or 100 meters would be slightly different than the dispersion curves obtained with the arrays of 25 meters, at least at the frequencies out of the validity frequency range estimated for the 25m array. Nevertheless, this comparison can provide a rough estimate of the diameter of the array that would be needed to reach the frequency of 4.5 Hz. In the analyzed cases, by visual inspection of Fig. 71, we may conclude that the diameter of the arrays deployed at NGA and Roshnabad could be extended approximately to 100 and 50 meters, respectively, which would imply an inspection depth around 100 and 50 meters for NGA and Roshnabad. The comparison carried out in terms of dispersion curves shows an excellent agreement between broadband stations and geophones recordings in the frequency range of applicability of the arrays used. These results indicate the possibility of using seismic refraction equipments for the f-k analysis in the frequency band of geotechnical engineering interest. This has potentially great importance since the same equipment is indicated to be applicable for both seismic noise measurements as well as for active

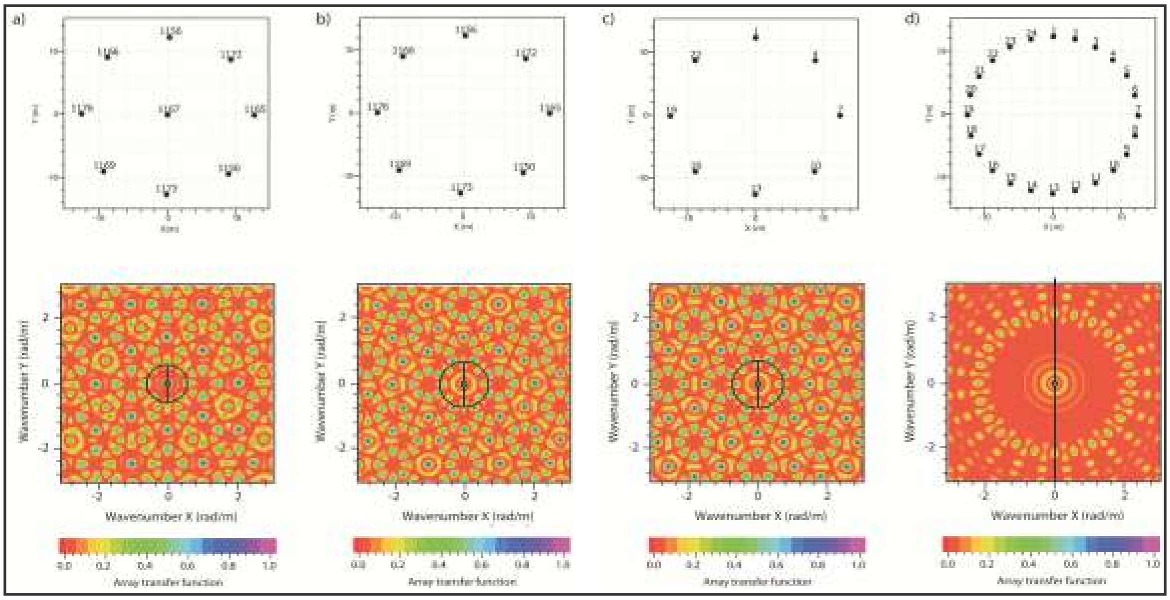

Fig. 70: Array configurations and theoretical response.

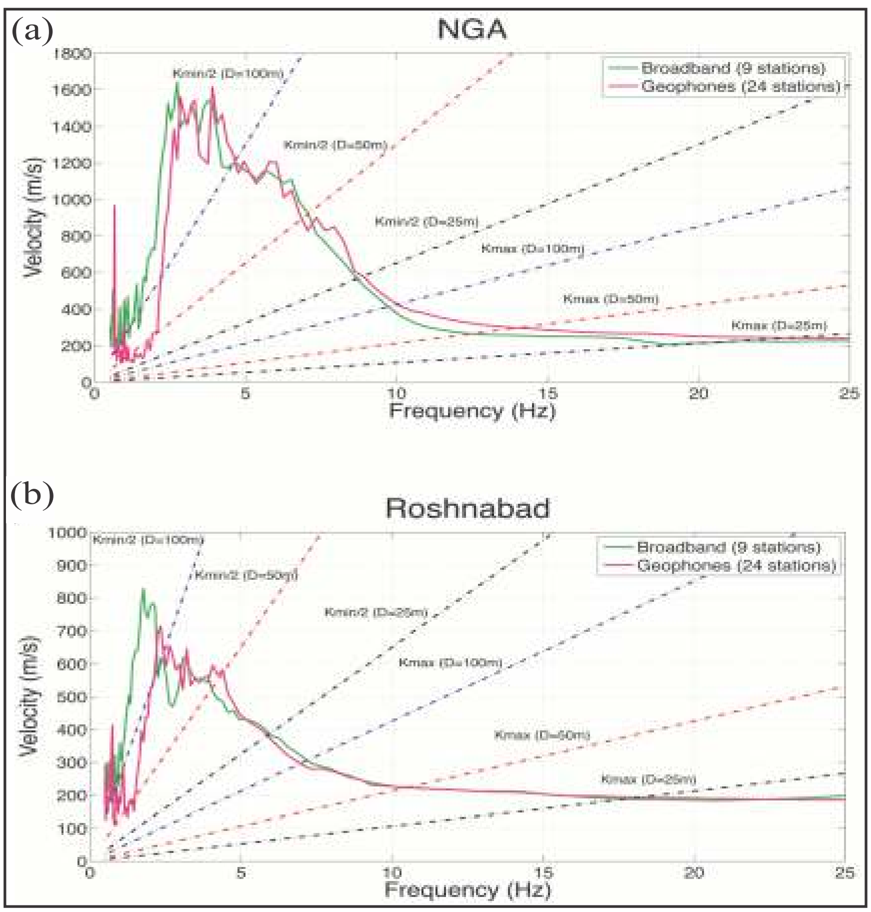

Fig. 71: Dispersion curves obtained through the circular arrays of 25m of diameter, using the 9 broadband stations and 24 geophones configurations. The theoretical kmin/2 and kmax limits corresponding to the 9-broadband stations array, with 25, 50 and 100 meters of diameter are also included.

reflection seismic surveys.

PROJECT

Mineralization and petrogenesis of mantle sequence and cumulates of the Manipur Ophiolite Complex, Indo-Myanmar Orogenic Belt, NE India

(A. Krishnakanta Singh)

Although, a number of research work have been carried out on geology of North East India, still the Indo-Myanmar Orogenic Belt remains as one of the least explored part of the country. Besides, till date no detail mineralogical and geochemical including geochronological studies of these rocks has been carried out. Thus this project will be useful to understand the petrogenetic aspects and emplacement mechanism of ophiolitic suite of Indo-Myanmar Orogenic Belt. The project will lead to deciphering better understanding the metallogenic significance of the geochemical characteristics of various types of mineral deposits associated with the mafic and ultramafic rocks within ophiolites. The results obtained through this study may provide the framework for new advances in our understanding of mafic and ultramafics intraplate magmatism and associated metellogeny. It may also help in *localization of mineral deposits* (Ni-Cu-PGE-Au, Fe-Ti-V, chromite and limestone deposits etc.) *and ultra-high pressure (UHP) minerals, native elements and alloys within the ophiolite belt.* Results of this integrated study combining field geology, multifaceted high precision geochemical and isotopic analysis, REE, HFSE and trace element modeling in the light of current theories will give new insights for an understanding and evolving a conceptual model for the development of the Indo-Myanmar Orogenic Belt.

PROJECT

Geomorphology and Sedimentation History of Alaknanda valley between Saknidhar Thrust and the Alaknanda Fault, Lesser Central Himalaya, Uttarakhand

(Pradeep Srivasatava)

This year the work under the DST sponsored program was carried out into two heads

1. Ms. Shipra Chaudhary who was SRF in the project submitted her Ph.D. thesis. Therefore focus was on summarizing the work done sofar and finalizing the thesis draft. Additionally, a palaeoflood sequence was studied and dated using OSL. The results indicate increase in frequency and magnitude of floods in Alaknanda Valley since last 850 years. A total of 11 flood events of increasing magnitude are observed in which the 1907 Alaknanda flood was of the highest magnitude.

2. One palaeolake section in Dhauli Ganga valley at the confluence of Girthi gad and Dhauli Ganga River was studied where 48 samples for sedimentaological, mineral magnetics and geochemical analysis were collected and sedimentary litholog was made. Six samples for Luminescence dating were collected as well. The samples for dating are completed and yielded ages from 12±1 ka to 8±1 ka. Sedimentological and mineral magnetic studies are underway. Apart from this 12 paleolandslides in Alaknanda-Dhauli Ganga valley were sampled for luminescence dating and out of these 7 samples are completed and rests are under processes. The completed samples yielded ages between 43±1 ka to 7±1 ka. Part of this data has been submitted as M.Sc. dissertation of Mr. Tanuj Shukla.

PROJECT

Role of tectonic-climate interaction in the morphogenic evolution of Dhauladhar range during late Quaternary in Kangra and Chamba regions of western Himachal Pradesh.

(V.C. Thakur)

The Dhauladhar range (D-range) , lying between the Beas and Ravi rivers in Himachal of northwest Himalaya, has a unique tectonogeomorphic setting in the Lesser Himalaya with highest peaks rising to 5000m elevation in the western segment and decreasing to 2700m in the eastern segment. The D-range frames the northern margin of the Sub Himalayan Siwalik foreland basin in the Kangra reentrant. The main body of the D-range is composed of lower Paleozoic granites with predominance of porphyritic granite. An intramontane basin, Kangra dun, is located between the range front of the western segment of the Dhauladhar range to the north and the Siwalik range to the south. The dun is filled by the post-Siwalik sediments of the Kangra and Palampur fans largely derived from the north. The high altitude segment with Dharamsala and Palampur towns located at its base receive much higher precipitation, >3000 mm/yr as compared to the adjoining areas to the east, west and south. There are glacial lakes and small glaciers on the crestal part of the D-range at elevation between 4500 m and 5000 m. Morain deposits, indicating extent of past glaciations, have been reported from much lower elevation at ~ 3000m in Garhwal and neighbouring Rohtang and Lahaul. This imples that the glaciers were occurring in the past at similar lower elevations in the D-range. The Kangra and Palampur fans represent repository-sinks for the materials eroded from the D-range. The fan sediments largely consist of erratics, boulders in debris and gravels made of Dhauladhar granites. The granite borne debris were brought down from the D-range through glacial-deglacial events in the past major climatic episodes. The Kangra dun, a synformal depression, is developed in front of the rising D-range.

Kangra dun

The study area, Kangra valley, lies between the high mountains of Dhauladhar range and the low lying Siwalik ranges. The valley constitutes an intramontane basin comprising the post-Siwalik sediments of the Kangra and Palampur fans overlying the Upper Siwalik Boulder Conglomerate formation. It is designated as the Kangra dun, a terminology used for intramontane basins in the frontal parts of Sub Himalaya, like Pinjor dun and Dehra dun in India and Rapti dun and Dang dun in Nepal. The Kangra dun forms a broad and open synformal depression, corresponding to northwestern part of the Lambagaon syncline mapped by the Oil and Natural Gas Commission (Karunakaran and Rao 1979, Powers et al. 1998). In the study area, the southern Siwalik range demarcates a physiographic break against the southern margin of the dun flat surface.

Kangra and Palampur are the two major adjoining fans occupying the Kangra dun between the Dhauladhar range front and the southern Siwalik range. Both the fans together have an areal extent of 35 km length (E W) and 10-15 km width (N S). The fans are essentially drained by feeder streams which originate on the southern flank of the D-rang. There are isolated ridges trending north-northeast separated by broad valleys. The ridge surfaces slope both to north and south. The main fan surface occupying the intervening valleys constitutes the main part of the south-sloping Kangra fan. Towards the terminal parts, the south-sloping fans and ridges merge with the flat and horizontal-sub horizontal dun surface. Large granite boulders with average size distribution of 2-5m diameter with some exceptionally large out-size with 8m diameter occur on the exits of the main streams at the mountain front and are distributed in stream channels. The boulders lie on the surface and in clusters, subangular to subrounded, clasts supported or occur independently. The boulders occurring near mountain streams exits, interpreted as erratics, represent part of the glacier lobes descending down the valley gorges. The large granite boulders, decreasing in size, occur from proximal to terminal parts of the fans. The granite debris has been transported from the D range through narrow gorges and exits of streams in high energy environment. The fabric and distribution of large boulders upto the distal parts of the fans suggest catastrophic floods. The orange-red silt- clay with a few granite boulders also contain in the top part diamicton bed consisting angular to subangular clasts, poorly sorted in sand matrix. The orange-red silt is a paleosole. In an excavated trench at a locality Yol golf course, orange-red silt horizon, ~ 5m thick, is underlain and overlain by granite boulders bearing unit comprising granite boulders in quartz and feldspar laths bearing sand matrix. ng:

Optical Simulation Luminiscence (OSL) dating of the samples was carried out at the Wadia Institute of Himalayan Geology, Dehra Dun. We have estimated the OSL ages of the samples from the fan sediments. The samples were extracted from sand-silt lenses in the gravels. There are two clusters of OSL ages. OSL dates 32-40 Ka and OSL dates 12-18 Ka, the former is correlated with the marine oxygen isotope stage (MIS-3) and the latter with the marine oxygen isotope stage (MIS-2). These ages indicate two glacial episodes corresponding to the last glacial cycle and the Last Glacial Maximum (LGM). The orange red paleosoles, 3-10m thick, occur on the surface and intercalated within the granite debris of the fan at different localities in the Kangra fan. These have been described as the pedogenised loess by the earlier workers. The pedogenisation of loess indicate warm wet cimate that followed the cold arid phase.

An early Pliocene-Pliestocene uplift was proposed for the Pir Panjal range bordering the southern boundary of the Kashmir basin, based on the oldest dated, 4.5 Ma, fluvio-locustrine Karewas sediments marking the initiation of the Pir Panjal range uplift and formation of the Kashmir basin (Burbank 1982). As D-range lies in southeastern continuity to the Pir Panjal range of the Kashmir basin with similar tectonostratigraphic-cum-physiographic setting, the D-range may have been also uplifted during early Pliocene-Pliestocene time. An early Pliocene uplift phase is also indicated by the Fission track (AFT) ages of Zircons, 3.9-4.9 Ma, of Mandi granite (Walia et al. 2009) which is a part of the eastern extension of the Dhauladhar granite.

Temperature time plot derived from the mineral ages of the Mandi granite indicate cooling rate 3.4º/Ma during early Miocene (Mehta, 1977) increased to ~ 77ºC/Ma during Pliocene (Walia et al, 2009). The sharp increase in cooling rate is attributed to exhumation and uplift of the Dhauladhar range during early Pliocene. The Upper Siwalik Boulder Conglomerate, 1500m thick, is widely exposed south of the Kangra dun and is also observed underlying the Kangra and Palampur fans sediments in the Kangra dun. The Boulder conglomerate is marked by increased sedimentation rate and grain and clast sizes in the Siwalik foreland basin (Burbank 1996, Raiverman 2002, Kumar et al. 2003). Based on a regional-global synthesis, Peizhan et al. 2001 have found increased grain sizes and sedimentation rates during 2-4 Ma period due to influence of climate change and erosion rates. The Boulder Conglomerate is magneto-stratigraphically dated, giving a 5.9 Ma age at the base (Sangode et al. 2003) and 0.2 Ma age toward the top (Rao et al. 1988). These ages suggest that coarsening of clasts size corresponds to the Pliocene uplift in the Himalaya.

Glaciation in Dhauladhar

In northwest Himalaya, the Dhauladhar, the Beas valley, the Lahaul and the Garhwal are affected by the same climate system. The regions receive South Asian summer monsoon during summer and mid-latitude westerlies during winter. In the Bhagirathi valley of Garhwal, during Pliestocene, the Bhagirathi glacial stage, an extensive valley glacier advanced down the valley to a locality Jhala at an altitude 2300 m lying ~40 km from the present glacial margin (Sharma and Owen 1996). In upper Tons valley, two main glaciers joined and descended down to the valley with lowermost morains occurring at an ~2700m elevation of during ~ 15 Ka (Scherler et al., 2010). In upper Beas valley south of Rohtang pass, an area close to the D-range, the morains have been reported from Solang and Palchan at the lowest altitude of 2500m (Owen et al., 1996). These occurrences suggest that the Dhauladhar range was covered by glaciers with their maximum extent reaching down to ~ 3000 m during the last glacial cycle and the LGM. The Kangra and Palampur fans are spread within the altitude ranging from 1800 m in the proximal part to 800 m in the distal part. Large granite boulders, 3-7m diameter, occur on the surface clustered around the proximal part of the fan at localites near Bhagsunath water fall, near the exits of Gaj, Churan Manji, Manuni, Baner and Neogal khads (streams). The boulders are interpreted as erratics, suggesting that the glacial lobes advanced to these levels.

Uplift-erosion and Seismicity

The Kangra region was affected by the devastating 1905 Kangra earthquake (Middlemiss 1910) of magnitude Mw 7.8 (Ambreys and Bilham 2000). Based on surface deformation study in the epicenter region, a NE dipping rupture ~ 100km long, striking 155º ± 5 with total reverse slip of 2-8 m has been estimated for the Kangra earthquake (Wallace et al. 2005). The estimated rupture lies in the eastern segment of the D-range. Based on upgraded network including three components digital instruments of 21 stations, Kumar et al. (2009) have shown concentration of seismicity in the eastern segment and relative quiescence in the western segment of the D-range. The seismicity is clustered underneath the eastern segment and further north, and characterized by seismicity quiescence in the western segment of the D-range. The eastern segment receives much higher snow during winter through midwesterlies and also higher rain during summer monsoon than the eastern segment. Intensification of erosion in the western part, altering the gravitational stresses, may result into increasing the convergence rate and elastic strain accumulation.

Chamba Region

The Chamba region lies on the northern and northwestern side of the Dhauladhar range water-divide. The Ravi river originates from near Bara Banghal glacier basin. The river flows largely northwest from its origin along a narrow valley and takes a sharp east-west course in some segments. The river flows in a narrow valley with confined channel in larger part of its journey However, in some places the river carves out broad valley segments at localities Gehra, Chamba, Kiyani, Rajnagar, showing well developed terraces and the fans. Four levels of terraces are recognized along the Ravi in Chamba. The terraces are of both the valley fill and strath types (Fig. 72). The terraces T4, T3, T2 are the valley fill while T1 is the strath terraces. The T1 terrace is the youngest and attains a height 6-10 m from the present day river bed and distributed all along the river valley. The terraces T2 and T3 are very well preserved at along the river valley but the T4 is preserved at some places. The height of the T2, T3 and T4 terraces from the river bed are 54 , 89 and 188 m respectively. Compositionally all the terraces contain pebbles to boulders sized clasts of granite, quartzite, sandstone and volcanic with different amount in different terraces. The volcanic clasts are present in the terrace deposits after joining the Saho river with the Ravi river. It is because the Saho river brought the volcanic clasts from its catchments area where volcanic rocks are expozited. The granite boulders of size, 3-5 m across length, are observed along the tributaries coming from the granitic terrain and joining the Ravi river. The four terraces of Ravi river are described below.

T4 terrace: These are the oldest terraces and found at 186 m from the present river bed. The terraces are preserved near the Chamba and the Kiyani area and not preserved all along the river valley. The terrace T4 is unpaired. At places, bed rock exposed at the base while in some places complete fluvial deposit observed form the base and no bed rock exposed. This uneven thickness of the gravel column is due to the original bed rock topography. The terrace deposits are mainly granite, quartzite and phyllite clasts amounting 45%, 30% and 25% respectively. At the basal part of terrace T4, the quartzite, sandstone and some amount volcanic present and granite is present with a very less proportion, while the amount and size of granite boulder increasing toward top. The clasts are subangular to subround in shape and size of the clasts varies from cobble to boulder. The matrix is sand of granitic composition. The deposit is mainly clasts supported which indicates a high energy depositional environment. At the top, the terrace deposit is overlain by a thick local debris flow deposits and at some places, local debris flow attain same height as T4. This suggests that during the time of formation of T4 the debris flow activity were common. A thick muddy deposit is observed near top of terrace T4, which indicated a damming situation and formation of a local lake. The lake records are well preserved at Bhariya and the Cheema terraces. The lake deposits are underlain and overlain by a fluvial deposit.

T3 terraces: This terrace attains an elevation of 89 m from the present day river bed and is widely distributed along the river valley. The terraces are paired and observed on both banks of the river. The terrace deposits are composed of pebbles to boulders size clasts of quartzite, sandstone, and granite amounting 50%, 30% and 20% respectively. The deposits show well imbrications and at places associated with sand lenses. The matrix is coarse sand. The deposits are matrix to clasts supported, indicating variation in the sediment water ratio as well as the variation in the stream power. The size of the clasts generally vary 2 cm-1 m in diameter. In some places the terrace material is overlain by local fan deposits, which indicate a later climatic event.

T2 terrace: The terraces occur at 54 m above from the present day river bed. The clasts are mainly of granite and quartzite present in equal amount. The clasts are sub rounded and are embedded in sandy matrix. The clasts show stratification and imbrications indicating a fluvial environment.

T1 terrace: The T1 terraces are youngest and are distributed all along the river valley and are unpaired. They are observed at elevation of 6-10 m above the present day river bed. The boulders, cobbles and pebbles sized clasts are predominantly of granite constituting 40%, quartzite 25%, sandstone 20%, and phyllite 15%. The clasts are subrounded to rounded showing imbrications and grading. The average size of the clasts is 2-5 cm and some out size clasts are also present. The deposits are matrix supported indicating a low energy environment during the deposition of T1. The OSL dating suggests that these terraces are formed around 6 ka. The clasts are embedded in sandy matrix. In some places the sand lenses are also observed.

Saho river is a large tributary of river Ravi that flows in SW direction and joins the main river near Chamba. At present, the Saho river is much smaller in terms of channel width and water discharge as compared to the Ravi, but it has terraces similar in size to those of Ravi river. This may suggest a common climatic episode of similar magnitude. Like the Ravi, the terrace in the Saho, at places, overlie the bed rock , while in some places valley-fill deposit is observed. The varying thickness of the gravel column is due to the uneven bed rock topography. There are three levels i.e. T1, T2, T3 terraces preserved in the Saho. The T3 is the oldest and attain a height 125 m from the river bed. This terrace is preserved all along the Saho river. The Saho and Jadera villages are located on the terrrcae T3. The clasts of Saho terrace are angular indicating a local debris deposit, while the Jadera is a fluvial deposit. Both the terraces attain the same elevation. The terrace T2 is observed at an elevation of 70 m and preserved at some places. The youngest terraces T1 is a strath terrace and well preserved near the confluence of the Saho river with the Ravi river. The main component of all the three terrace are mainly quartize, phyllite, slate and volcanic The Saho terraces are devoid of granite clasts, as there is no granite body in the Saho river catchment. In the upstream, the clasts are subangular to subrounded, whereas in down stream, the clasts are subrounded to rounded. Grading and imbrication are also observed, and the clasts are embedded in sand and silt matrix.

The OSL dating of some terrace deposits has been undertaken. The OSL dates suggest that aggradations phase of the oldest Saho river terrace was initiated around 34 ka and continued till 22 ka. While the youngest terrace of the Ravi river gives age of 6.152±0.561 ka. A thick, 3m, sandy deposit dated 9.875±1.421 ka occur on the top of Mangla T3 terrace suggesting out of sequence age. This is interpreted as reworking of an older terrace.

Fig. 72: Mosaic view showing four level of terraces along the Ravi river in Chamba area. Regional trend of terraces NW-SE, view from NE. T1 terrace, T2 terrace, T3 terrace, T4 terrace.

RESEARCH PUBLICATIONS

Papers Published

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Mehta, M., Dobhal, D.P. Srivastava, P. : Geomorphological Evidences of post LGM Glacial advancements in Himalaya: study from Chorabari Glacier, Garhwal Himalaya, India. Journal of Earth Science System (Springer) (Comm.).

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Tripathi, K., Sen, K. &d Dubey, A.K. 2011. Modification of fabric in pre-Himalayan granitic rocks by post-emplacement ductile deformation: insights from microstructures, AMS and U-Pb geochronology of the Paleozoic Kinnaur Kailash Granite and associated Cenozoic leucogranites of the South Tibetan Detachment zone, Himachal High Himalaya. International Journal of Earth Sciences (In-press).

Upadhyay, Rajeev & Parcha, S.K. : Early Cambrian trilobite traces fossils from the Jadhganga (Nelang) Valley, Uttarakashi District, Garhwal, Tethys Himalaya, India (Comm.).

Book Edited

Sushil, Rama & Kumar, Sushil (Eds) 2011. Artificial Intelligence: Problem solving with knowledge, Pragya Publication Pvt. Ltd., 280p.

Tewari, V.C. & Seckbach, Joseph (Eds): STROMATOLITES: Interaction of Microbes with Sediments, Cellular Origin, Life in Extreme Habitats and Astrobiology, 18 (Book, COLE Series, Springer - Verlag in press to be released in 2011).

Technical Reports

Kumar, Rohtash, Ghosh, S.K. & Gupta, Vikram : Geological report on Mapping of the Kolodyne Stage II, HEP (4 x 115 MW), Distt. Lawngtlai, Mizoram, January, 2011.

Kumar, Sushil : Report on International training program for “Seismic design of structures & Hazard mitigation” sponsored by the Taiwan's National Science Council (NSC) and organised by the National Centre for Research on Earthquake Engineering (NCREE), Taipei Taiwan from November 22 to 26, 2010.

Kumar, Sushil : Seismic Bulletin Report on Regional & Teleseismic Earthquakes for the months of May-October, 2010.

Mahajan A.K. : Report on Microzonal stress map of Doon valley and submitted to the Secretary “Supreme Court Monitoring Committee”.

Phadtare, N.R. : Final report of the DST project 'Quaternary climate change in Ladakh and Karakoram Himalaya', Concluded on Jan. 31, 2011.

Rajesh, S. : IUGG report: Contributed and compiled a report on research contributions of WIHG in the field of geodesy and gravimetry. The same has been submitted to the Additional Surveyor General of India towards the preparation of a national report under India Chapter being presented at XXV General Assembly of IUGG Melbourne, Australia, 2011.

Rajesh, S. : Project-1: Compiled and sent a project report to ISRO on SARAL/ALTIKA on the topic “Geodynamics evolution of the Indian Plate through High resolution geoid from SARAL/ALTIKA altimeter.

Rajesh, S. : Project-2: Compiled and sent a project report on “Establishment of two continuously operating Permanent GPS stations at Panamik, in J&K and Pithoragarh in Uttarkhand for the approval from MoES, Govt. of India.

Rawat, B.R.S., Bhomik, S., Sinha, P., Sah, M.P., Nautiyal, S., Lal, G. & Bhatt, R. : Report of the multidisciplinary committee to cover the work of 99MW Singoli Bhatwari Hydroelectric Project (HEP) under construction by M/s L&T Uttaranchal Hydropower Ltd. submitted to MoEF, Govt of India, New Delhi, 2011.

Sah, M.P. & Gupta, Vikram : Landslide investigation on Tachla Naur Motor Marg (NH-94, Kmstone-39), Tehri district, Garhwal Uttarakhand. Page 9 with 6 Figs., September, 2010.

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Sastry, P.G., Kumar, R., Bhomik, S., Gupta, A.K., Sah, M.P., Sathykumar, S., Nautiyal, S., Romala, U. & Bapu P.V.P. : Environmental monitoring of multidisciplinary committee (MCD) for 76 MW Phata Byung HEP' under excavation by M/s Lanco Mandakani Hydro Energy Pvt. Ltd. (LMHEPL) submitted to MoEF, Govt. of India, N. Delhi, 2010.

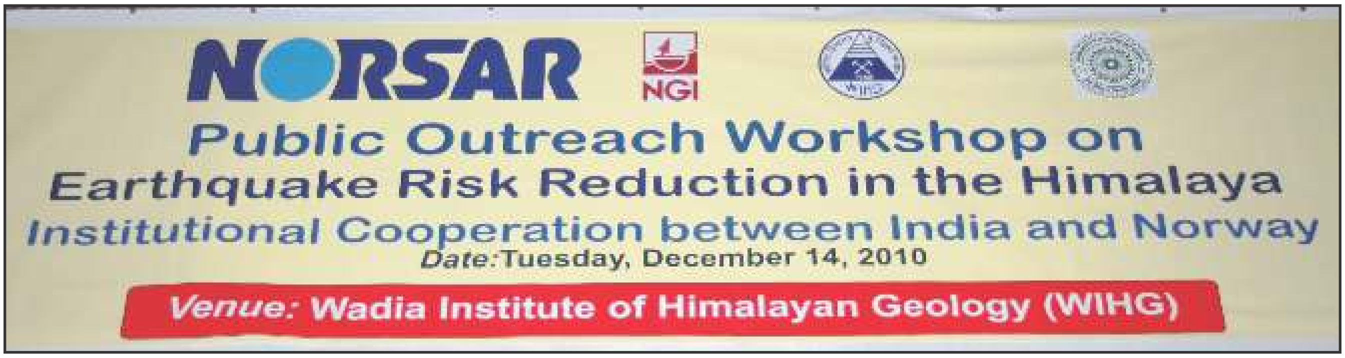
SEMINAR/SYMPOSIA/WORKSHOP ORGANISED

Wadia Institute of Himalayan Geology, Dehra Dun has organized one day workshop on "Earthquake Risk Reduction in Himalaya with special reference to Dehra Dun" 14th December, 2010 on to disseminate the results of earthquake risk reduction efforts made by WIHG, IIT Roorkee and Norwegian Research Institutes NORSAR and NGI, Norway under joint collaborative project with funding support from the Norwegian Ministry of Foreign Affairs through Norwegian Embassy to India (New Delhi) among the stake holders. The workshop was intended to pave way for further initiatives towards building up of an earthquake-safer environment in northern India. Keeping in view the long-term impact, it focused on two main themes: i) The seismic hazard risk in the Himalaya with special reference to Dehra Dun, with target audience of Architects and Engineers, and ii) The seismic vulnerability of hospitals and schools, with target audience of health authorities and school teachers.

Prof. A.K. Gupta welcomed the delegates, and introduced the participants with the theme of the workshop and efforts made by the Institute in this regard.. Prof. S.K. Singh, Vice Chancellor of Hemvati Nanadan Bahuguna University, Garhwal inaugurated the workshop followed by a brief note on the progress and theme of the workshop by Dr Conrad Lindholm, Principal investigator of the collaborative project.

Dr A.K. Mahajan gave a brief report on seismic hazard status of Uttarakhand, with a special emphasis on seismic microzonation of Dehra Dun city. Dr D.H. Lang discussed on various issues related to building vulnerability assessment of Dehra Dun city, while Dr D.K. Paul talked on how to strengthen these buildings using retrofitting strategies.

The workshop received great response wherein more than 90 participants from Mussoorrie-Dehra Dun Development Authority (MDDA), Town and Country Planning, Public Works Department (PWD), Jal Nigam, Jal Sansthan, Director Education, Disaster management and Mitigation Centre, Dehra Dun (DMMC), doctors from Government Hospital (Health departments), schools teachers, architects, and engineers from different districts of Uttarakhand participated in the workshop.



SEMINAR/SYMPOSIA/WORKSHOP ORGANISED

AWARDS AND HONOURS

- Prof. Anil K Gupta, Director has been selected for the *Third World Academy of Science (TWAS) Prize, 2010* for his fundamental contribution to the study of Indian monsoon variability.
- The Geological Society of India awarded Dr. Pradeep Srivastava with the '*S.S. Merh Award2010*' for his significant contributions in the field of Quaternary Geology.
- Dr. R.J. Perumal was awarded as *"Professur Invitee -2010"* to University of Savoie, LGCA, CNRS Laboratory, Chambery, France.
- Dr. R.J. Perumal was awarded "*BOYSCAST*" Fellowship by DST Govt. of India for the year 2010-11 to work in Centre for Neotectonic studies, University of Nevada, Reno with Prof. S.G. Wesnsouky.
- Dr. Ansuya Bhandari wins *"Young Scientist Award 2010"* for best oral presentation under the Earth Sciences discipline in the 5th Uttarakhand State Science & Technology Congress held in Dehra Dun.
- Ms. Leena Kamra received the 'Best Poster Award' in the 7th International Conference on High Levels of Natural Radiation and Radon Areas (HLNRRA7) held in BARC, Mumbai.

VISITS ABROAD

- Dr. D. Hazarika participated in the 14th International workshop on Seismic Anisotropy (IWSA-2010) held at Perth, Australia during April 2010.
- Dr. N. K. Saini and Sh. Chandra Shekhar visited Germany for XRF training provided by M/s Bruker, Germany from May 2-15, 2010.
- Dr. R.J. Perumal visited University de Savoie, Chambery, France for learning CNR dating and to formulate a collaborative project under the "Professor invite" Scheme from May 1, 2010 to June 4,2010.
- Dr. A.K. Dubey, Dr. A.K. Singh and Mr. Yogesh Ray have participated and presented their work in the Himalayan-Karakoram-Tibet 25 Workshops held at San Francisco State University, US from June 8-10, 2010. Dr. A.K. Dubey also participated in NSF Workshop held at San Francisco, US from June 11-12, 2010.
- Dr. Rajesh Sharma visited France for Laser Raman Micro Probe training provided by M/s Horiba Jobin Yvon, France from June 12-20, 2010.
- Dr. D. Hazarika visited Institute of Physics of Earth (IPE), Russian Academy of Sciences (RAS), Moscow, to participate in Indo-Russian collaborative project from 19th July to10th Aug., 2010.
- Dr. A.K. Mahajan visited to NORSAR, Norway under the joint collaborative project between India and Norway on "Earthquake Risk Reduction in Himalaya" during Aug. 21, 2010 and Sept. 6, 2010.
- Dr. D.P. Dobhal visited China to participate in the Indo-China joint workshop 'Mountain Eco-Systems and Climate Change' on Sept. 29, 2010.
- Dr. P.K. Mukharjee visited USGS, Resten, Virginia, USA under interactive and collaborative program with Mr. Andrew Gorsz for a month during Sept.-Oct., 2010.
- Dr. M.P. Sah visited Nepal to participate in the '2nd Third Pole Environment (TPC) Workshop' and Regional Workshop on 'Glacial Lake Mapping GLOF Risk Assessment and Mitigation Measure in the HKH Region held at Kathmandu, on Oct. 26-29, 2010.
- Dr. Naresh Kumar visited Veitnam to participate in the '8th General Assembly of Asia Seismological Commission (ASC2010)' held at Hanoi, on Nov. 7-10, 2010.
- Dr. Sushil Kumar visited Taipei, Taiwan 'National Center for Research on Earthquake Engineering' to participate in the 'International training program for Seismic Design of Structures' on Nov. 21- 26, 2010.
- Dr. D.P. Dobhal participated in the "Inception Workshop on Cryoscope studies and capacity building", organized by ICIMOD in Katmandu on Jan. 24-28, 2011.

Ph.D. THESES

Name of Student	Supervisor	Title of the Theses	University	Awarded/ Submitted
Anusuya Bhandari	Dr. B.N. Tiwari Dr. M.N. Joshi	Systematic study on fossil assemblage of the Dharmsala Group of Himachal Pradesh India, and its significance in understanding early Miocene phase of the Himalayan evolution.	HNB Garhwal University, Srinagar, Garhwal	Awarded
R.K. Bikramaditya Singh	Dr. N.S. Gururajan Prof. G.S. Rawat	Deformation and metamorphism of Bomdila and Se La Groups of crystalline rocks and geochemistry of the associated granitoids in parts of Kameng district of Arunachal Pradesh, Eastern Himalaya	HNB Garhwal University, Srinagar, Garhwal	Awarded
P.R.K. Gautam	Dr. M.N. Viladkar Dr. Sri Niwas Pandey Dr. Rambhatla G Sastry	Geotechnical mile characterization through geotechnical imaging	IIT, Roorkee	Awarded
Naresh Kumar	Prof. B.R. Arora Prof. S Mukhopadhyay Prof. V.N. Singh	Quantification of Seismic regimes in Knagra-Chamba region of Himachal Himalaya	IIT, Roorkee	Awarded
Shipra Choudhary	Dr. Pradeep Srivastava Dr. Y.P. Sundriyal	Late Quaternary evolution of Alaknanda valley in the vicinity of North Almora Thrust, Garhwal Himalaya, India	HNB Garhwal University, Srinagar, Garhwal	Submitted
Rakesh Bhambri	R.K. Chaujar	An Analysis of Glaciers Changes in Garhwal Himalaya using Remote Sensing and GIS Techniques	CCS University, Meerut	Submitted
Kanchan Deoli Bahukhandi	Dr. S.K Bartarya Dr. N.A. Siddiqui	A study of surface and groundwaters of Dehra Dun and Haridwar districts of Uttarakhand: Impact assessment of Urbanization and Industrialization	University of Petroleum and Energy Studies, Dehra Dun	Submitted

MEMBERSHIP OF NATIONAL/INTERNATIONAL COMMITTEES

Name of the Scientist	Status	Prestigious Committee/s outside WIHG
Prof. Anil K. Gupta	Vice President	Indian Geophysical Union
Dr. A.K. Dubey	Fellow Fellow	Geological Society of India, Bangalore Indian Geological Congress, Roorkee
Dr. V.C. Tewari	Vice President Member Member	Indian Geological Congress, Roorkee Editorial Board International Journal Astrobiology, New York, USA Editorial Board Indian Geological congress, Roorkee
Dr. V.M. Coubey	Member	IGCP - 571
Dr. Rohtash Kumar	Member	IGCP-581
Dr. M.P. Sah	Member Member	Phata-Byung 76 MW HEP of Lanco Hydro Energy Pvt. Ltd. Phata district Rudraprayag Singoli-Bhatwari 99 MW HEP of L&T Uttaranchal hydropower Ltd. Bedubagar (Augustmuni) district Rudraprayag
Dr. S.K. Ghosh	Astt .Editor Member	Himalayan Geology Indian Association of Sedimentologists
Dr. N. R. Phadtare	Advisor Executive Member Working Member	Uttarakhand Centre of Climate Change (UCCC), Kumaun University, Nainital International Committee on Global Geological and Environmental Change (IC GGEC) International Commission of Peatland Research (ICPR), Sweden
Dr. Kishor Kumar	Life Member	Palaeontological Society of India, Lucknow
Dr. Rajesh Sharma	Member Scientific Committee	International Applied Geological Congress, April 2010, Mashad, Iran
Dr. G. Philip	Vice Chairman	Indian Society of Remote Sensing (Dehra Dun Chapter)
Dr. B.N. Tiwari	Life Member	Palaeontological Society of India, Lucknow
Dr. T.N. Jowhar	Executive Member Member	Computer Society of India, Dehra Dun Earth System Sciences of the Indian Science Congress Association
Dr. S.K. Bartarya	Member	Groundwater in Bureau of Indian Standard, New Delhi
Dr. Sushil Kumar	Member	Bureau of Indian Standards technical committee "Earthquake Engineering Sectional Committee-CED 39", New Delhi, India

	Member	American Geophysical Union
Dr. D.P. Dobhal	Member of the expert committee Member of Expert committee	Integrated Programme on Dynamics of Glacier in Himalaya. (PAMC_HG) , DST 2nd Rashtriya Yuva Vaigyanik Sammelan -2010, organised by, UCOST, Dehra Dun
Dr. Vikram Gupta	Member	Working Committee of Experts (WCE) for Upgradation of Landslide Hazard Map in India, Committee constituted by the National Disaster Management Authority (NDMA), Govt of India, New Delhi
Dr. P.S.Negi	Member, executive council Member	APT (Association of Plant Taxonomy), India Group to deal Mountain Environment and Global Change Issue, Italy.
Dr. S. Rajesh	Member	Indian Society of Photogrammetry and Remote Sensing
Dr. Naresh Kumar	Junior Associateship	Abdus Salam International Centre of Theoretical Physics (AS-ICTP), Trieste, Italy
Dr. D. Hazarika	Life member Life member	Indian Geophysical Union Assam Science Society
Dr. S.K. Rai	Member	Geochemical Society, America

PARTICIPATION IN SEMINAR/SYMPOSIA/ WORKSHOP/ MEETINGS/ TRAINING COURSES

- 3rd Meeting of CSIR and DST Librarians at Jawaharlal Nehru Centre for advance scientific research, Bangalore on May 10-12, 2010.
  Participant : Saheed Ahmad
- Meeting at National Centre for Ocean Information Services (INCOIS), Hyderabad on June 10-11, 2010.
  Participant : P.K.R. Gautam
- 7th Annual Meeting-2010 of Asian Oceanic Geosciences Society Seminar (AOGS) Hyderabad, July 5-9, 2010,
  Participant (s) : Sushil Kumar, D.P. Dobhal, D. Hazarika and Naresh Kumar
- Conference on 'Nonconventioan Energy Resources of Uttarakhand',University of Petroleum and Energy Studies , Dehra Dun on July 16, 2010.
  Participant : V.C. Tewari
- National Workshop on "Archaeological Science" organized by Archaeological Survey of India, New Delhi on July 17-18, 2010
  Participant : N.K. Saini
- Workshop on 'Integrated Research Techniques' Sponsored by Uttarakhand State Council for Science and Technology, Dehra Dun on July 17-18, 2010.
  Participant : Rajesh Sharma
- Eighth Annual NIAS DST Training Programme for Senior Scientists, National Institute of Advanced Studies, Bangalore, July 26, 2010 to Aug. 7, 2010.
  Participant : V.C. Tewari
- Meeting of NTPC consultancy programme, Noida on Sept. 1, 2010.
  Participant (s) : Rohtash Kumar, S.K. Ghosh and Vikram Gupta
- Meeting of IGCP -571, New Delhi on Sept. 9, 2010.
  Participant : V.M. Choubey
- Brainstorming Session on the development of 'National Geotechnical Facility' at Poonch House, Dehra Dun on Sept. 17, 2010
  Participant : V. Gupta
- Meeting of 2nd PAC, IIG, Mumbai on Sept. 23-24, 2010.
  Participant (s) : Ajay Paul and P.K.R. Gautam
- Meeting on 'Snow and Glacier project: Phase-II', Ahmedabad on Sept. 29, 2010.
  Participant : G. Philip
- Indo-China joint workshop on "Mountains Ecosystem and Climate Change", Organised by China Meteorological Department, Beijing, China, Sept. 29, 2010
  Participant : D.P. Dobhal
- National Seminar on 'Rock Deformation & Structures', Jadavpur University, Kolkata, on Oct. 29-30, 2010
  Participant (s) : A.K. Dubey, Koushik Sen, Kavita Tripati, Souvik Das and Kaushik Sen
- 'Pravin' Hindi training, Delhi for a period of one month during Oct. - Nov., 2010.
  Participant : Devajit Hazarika
- Meeting of IGCP 581, GSI, Hyderabad on Nov. 2, 2010.
  Participant : Rohtas Kumar
- 5th Uttarakhand State Science and Technology Congress, Nov. 10-12, 2010 at Doon University, Dehra Dun
  Participant (s) : V.C. Tewari, B.N. Tiwari and Ansuya Bhandari
- Meeting of the Group Monitoring of DST sponsored projects, H.N.B. Garhwal University, Srinagar on Nov. 10-11, 2010.
  Participant (s) : Anil Kumar Gupta and H.K. Sachan
- 33rd Conference of Indian Botanical Society, Shivaji University, Kolhapur on Nov. 11-12, 2010.
  Participant : N.R. Phadtare
- International workshop on "Seismo-electro-magnetic and Atmospheric Science", Agra University, Agra on Nov. 17-18, 2010.
  Participant : P.K.R. Gautam
- 7th International Conference on 'High Levels of Natural Radiation & Radon areas', BARC Mumbai on Nov. 22-25, 2010.
  Participant : Leena Kamra
- South Asia Media Briefing workshop on "Climate Change" organised by Centre for Science and Environment (CSE), New Delhi

Nov. 24-25, 2010.
Participant : D. P. Dobhal

- Workshop on 'Earthquake Precursors-Scenario and Future directions", NGRI, Hyderabad on Nov. 25-26, 2010.
  Participant (s) : B.R. Arora, V.M. Choubey and Naresh Kumar
- National Seminar on 'Global Warming and its effects on Water Resource', organised by Graphic Era University, Dehra Dun on Dec. 3-4, 2010
  Participant : D. P. Dobhal
- 14th Symposium on 'Earthquake Engineering' & Golden Jubilee Celebrations, Department of Earthquake Engineering, IIT Roorkee on Dec. 17-19, 2010
  Participant (s) : Sushil Kumar, A.K. Mahajan, Ajay Paul
- National Conference & 27th Convention of Indian Association of Sedimentologists (IAS 2010) organized by the University of Jammu, Jammu on Dec. 22-24, 2010
  Participant (s) : N. Siva Siddaiah and M. Shukla
- 98th Indian Science Congress, SRM University, Chennai during January 3-7, 2011
  Participant (s) : V.C. Tewari and T.N. Jowhar
- Meeting on collaboration of Iceland and WIHG on 'Earthquake Precursory Research', Chennai on Jan. 4, 2011.
  Participant : V.M. Choubey
- 36th IGCP meeting held at Kolkata on Jan. 12, 2011.
  Participant : V.C. Tewari
- National Conference on 'Science & Geopolitics of Arctic & Antarctic (SaGAA)' New Delhi, on Jan. 14-15, 2011
  Participant (s) : Anil K Gupta and S. K. Parcha
- International Symposium on '2001 Bhuj earthquake and advances in Earthquake Sciences', Gandhinagar, Gujarat on Jan. 22-24, 2011.
  Participant (s) : V.C. Thakur, B.R. Arora, Swapnamita, C.V., Naresh Kumar, D. Hazarika, D.K. Yadav and S. Rajesh
- 39th Meeting of the Executive Members of Indian Geological Congress, Delhi on Jan. 24, 2011.
  Participant : V.C. Tewari
- Meeting of the Sectional Committee for 'Ground Water and related Investigations', Delhi on Feb. 11, 2011.
  Participant : S.K. Bartarya
- Meeting of Project Advisory Committee (DST) held at Delhi on Feb. 14, 2011.
  Participant : A.K. Dubey
- Training course on 'Geochronology and Radiogenenic isotope geochemistry', NGRI, Hyderabad from Feb. 14-18, 2011.
  Participant (s) : D.R. Rao, Santosh K Rai, Brikramadithya and Megha M Daga
- National seminar on 'Late Quaternary Geology and Himalayan Orogen and Foreland Basin', Lucknow University, Lucknow on Feb. 16-17, 2011.
  Participant (s) : B.N. Tiwari, Manish Mehta and Zahid Majeed
- Workshop on 'Results Frame-work Document', Vighyan Bhavan, Delhi on Feb. 22, 2011.
  Participant (s) : K.K. Purohit, Rajesh Sharma and D.R. Rao
- National Seminar on 'Sedimentation, Tectonics and Hydrocarbon potential in Himalayan Foreland basin', Univ. of Jammu, Jammu on Feb. 22-23, 2010.
  Participant : Ajay Paul
- National Conference on 'Landscape Restoration Processes- Challenges and Opportunities' Organised by Forest Research Institute, Dehra Dun on Feb. 22-23, 2011.
  Participant : D.P. Dobhal
- Meeting of DST sponsored SSS projects, Vadorada, Gujarat on March 3-4, 2011
  Participant : Rohtash Kumar
- Meeting of Management Board of Ghyan Vihar University, Jaipur on March 5, 2011.
  Participant : Rajesh Sharma
- National Seminar on Application of Remote Sensing and GIS Technology in Water Resources Management, WIHG during March 15-16, 2011
  Participant (s) : P.P. Khanna and T.N. Jowhar
- Meeting of the DST constituted 'Fast Track Committee', Delhi on March 16, 2011.
  Participant : A.K. Dubey
- Meeting of ISRO-SARAL, Ahmedabad, Gujarat on March 16-17, 2011.
  Participant : S. Rajesh
- Workshop on National Knowledge Network, Delhi on March 25, 2011
  Participant : Tajender Ahuja

LECTURES BY VISITING SCIENTISTS

Name and address	Date	Topic
Prof. S. Sensharma, University of Lucknow, Lucknow	28.05.10	Texture and compositional evidence for Open System processes in the Dongargarh Large Igneous Province, Central India
Prof. Sri Niwas, FASc, FNA, Indian Institute of Technology Roorkee	27.10.10	Mathematical modeling of nonlinear electrical response of double phase conducting medium
Dr. P.S. Roy, Dean, Indian Institute of Remote Sensing, Dehra Dun	16.12.10	Land Use land cover change in Indian River Basins-human dimension of climate change
Padmashri Prof. Anil Prakash Joshi, Environmentalist and Chairman of "Himalayan Conservation Studies and Conservation Organization, Dehra Dun	17.01.11	Common Mistakes
Prof. D. C. Srivastava, Indian Institute of Technology Roorkee	21.01.11	New method for strain estimation from elliptical marks
Prof. Ashok K. Singhvi, Physical Research Laboratory, Ahmedabad	21.2.11	Synergistic approach between Geology and Physcis: A case from Luminescence
Prof. Ramesh Chander (Retd.), Indian Institute of Technology Roorkee	18.2.11	Using Boussinesq Theory to understand deformational behiviour of the Earth near a new reservoir
Dr. Rajesh Agnihotri, National Physical Laboratory, New Delhi	3.2.11	Role of Natural (Solar) Forcing in the Recent era of Anthropogenic Climate Change

LECTURES BY INSTITUTE SCIENTISTS

Name of Scientist	Venue	Date	Topic
G. Philip	IIRS, Dehra Dun	30.04.10	Glacier lake outburst flood
R.J. Perumal	LGCA, Chambery, France	02.05.10	Paleoseismic investigations along the Himalayan Frontal Thrust and its seismic hazard
R.J. Perumal	Universite de Savoie (US), Grenoble, France	25.05.10	Active tectonics of frontal Himalaya and its seismic hazard
G. Philip	GSI Field Camp at Kala Amb	25.05.10	Neotectonic activity in the Frontal belt of northwestern Himalaya
P.S .Negi	WIHG, Dehra Dun	04.06.10	Biodiversity and Climate in Himalayan perspective
P.S Negi	WIHG, Dehra Dun	14.06.10	High altitude Ecosystem: Treeline as a climate marker
A.K. Mahajan	IIRS, Dehrdun	24.06.10	Seismic probability modeling and microzonation
V.C. Tewari	MVDU, Katra, Jammu	24-27.06.10	INSPIRE lecture series in Geology
D.P. Dobhal	Uttarakhand State council for Science and Technology, Dehra Dun	05.07.10	Response of glacier to Climate Change bservation and Facts, Uttarakhand Scenario
N.R. Phadtare	Kumaun University, Nainital	07.07.10	Climate change in Himalaya: An overview
D.P. Dobhal	Indira Gandhi National Forest Academy, Dehra Dun	10.07.10	Glacier and glacier studies - the Himalaya perspective
N.K. Saini	Archaeological Survey of India at New Delhi	17.07.10	X-ray analytical methods in chemical characterisation of archaeological material
N. Suresh	Archaeological Survey of India New Delhi	17.07.10	Luminescence Dating
Sushil Kumar	Hope Town Girls School Selaqui, Dehra Dun	18.07.10	Earthquakes in the Himalayan region and their real time recording
A.K. Mahajan	Survey of India, Dehra Dun	25.07.10	Disaster Management: Earthquake at National level data users
V. Gupta	Lal Bahadur Sastri National Academy of Administration, Mussoorie	27.7.10	Landslide and their management in the Himalaya

A.K.L. Asthana	WIHG, Dehra Dun	30.07.10	Geomorphology and mass movement study in Mandakini basin, Garhwal Himalaya
G. Philip	IIRS, Dehra Dun	06.08.10	Glacier and GLOF studies using Earth Observation Data
N. Suresh	Archaeological Survey of India, Dehra Dun	11.08.10	Thermoluminescence Dating
C.V. Swapnamita	WIHG, Dehra Dun	13.08.10	The Tehri Dam, Uttarakhand: Concerns and Investigations
P.P. Khanna	WIHG, Dehra Dun	20.08.10	Mass Spectrometry: An overview of ICP-MS
N. K. Meena	WIHG. Dehra Dun	27.08.10	Environmental magnetic evidences of Late-Holocene climate fluctuations in vicinity of Chorabari and Gangotri glaciers, Higher Himalaya, India
D.P. Dobhal	Indian Council of Forestry Research and Education, Dehra Dun	10.09.10	Climate change impact on glaciers- observation and Facts
M.P. Sah	Hemis Monistory, Leh Ladakh	12.09.10	Impact of plantation on landslide, cloudburst in cold desert area of Ladakh
Chaujar, R.K	WIHG, Dehra Dun	14.09.10	Lichenometry
Bartarya, S.K	IIRS Dehra Dun	22.09.10	Exploring the groundwater in Hilly Terrain
G. Philip	IIRS, Dehra Dun	22.09.10	Application of Remote sensing in groundwater exploration in Himalayan Terrain
Pradeep Srivastava	WIHG, Dehra Dun	Sept.2010	An Introduction to Optically Stimulated Dating technique
P.K. Mukherjee	F.R.I., Dehra Dun	Sept.2010	Wet Chemical Laboratory: An overview of Analytical Techniques
Pradeep Srivastava	Annual convention of the Geological Society of India, Bangalore	Oct.2010	Himalayan Rivers and past climatic changes
V.C. Tewari	Instruments Research and Design Establishment, Dehra Dun	21.10.10	Laser Takniki ka Bhuvigyan mein up yog
M.P. Sah	ICIMOD, Kathmandu, Nepal	29.10.10	Status of glacial lake mapping and glacial lake outburst flood risk assessment in Indian Himalaya
A.K. Dubey	Jadavpur University, Kolkata	30.10.10	Structural evolution of the Himalaya: significant problems and a possible solution

D.P. Dobhal	Graphic Era University, Dehra Dun	03.12.10	Impact of Climate Change on Glacier Melt and Water Resources in the Himalaya
Chaujar, R.K	Graphic Era, Dehra Dun	03.12.10	Climate Change and its effect on Himalayan Glaciers
A.K. Mahajan	Regional Training Institute, GSI, Guwahati	09.12.10	Methodology of Seismic Microzonation
Sushil Kumar	University College, Yhiruvananthapuram, Kerala	13.12.10	Earthquakes in the Himalayan Seismic belt and seismographs
G. Philip	IIRS, Dehra Dun	20.12.10	Remote sensing applications in glacier and GLOF studies
V.M. Choubey	WIHG, Dehra Dun	2010	Continuous radon observations at MPGO.
Pradeep Srivastava	Academic Staff College of BHU, Varanasi	20.1.11	Himalayan Rivers: Responses to Past Climatic Changes
C.V. Swapnamita	Institute of Seismological Research (ISR), Gandhinagar, Gujarat, India	23.01.11	The Tehri Dam, Uttarakhand: Crustal Strain and Implications in case of Reservoir Induced Loading
Keser Singh	WIHG, Dehra Dun	28.01.11	Tectonic evolution of Kishtwar Window with respect to the Main Central Thrust, NW Himalaya
A.K. Gupta	Lucknow University, Lucknow	16.02.11	Abrupt changes in the Indian monsoon during the late Quaternary and the Holocene
G. Philip	IIRS, Dehra Dun	18.02.11	Surface rupture mapping and paleoseismicity analysis
A.K. Mahajan	IIRS, Dehra Dun	18.02.11	Probabilistic Seismic Hazard Assessment and Seismic Microzonation
V. Gupta	Head Quarters of Uttaranchal Sub Area, Dehra Dun	19.02.11	Landslides and Related Disasters in Uttarakhand
R. Islam	HNB Garhwal University, Srinagar, Garhwal	25.02.10 to 10.3.11	Lecture series for M.Sc (Earth Sciences) students
A.K. Gupta	Mizoram University, Aizwal	03.03.11	INSPIRE Lecture Series: 'Role of Earth Science in the evolution of Civilization and building of modern Nations'
S. Rajesh	ISRO, Space Applications Centre, Ahmedabad	15.03.11	Geodynamic evolution of the Indian Plate through high resolution geoid/gravity derived from the SARAL/ALTIKA altimeter
V.C. Tewari	Jai Narain Vyas University, Jodhpur, Rajasthan	28.3.11	Cretaceous - Paleogene sedimentation, global events and paleogeography

TECHNICAL SERVICES

Analytical Services

The instruments available in central facility laboratories are responsible for generating analytical data of very high standards. The users of these facilities are not only the scientists and scholars from the Institute, they also belong to different universities, IITs, Govt. & Private Oraganizations from various parts of the country. Three thousand nine hundred sixty one samples were analyzed for major, trace and rare earth elements during this year. The down time for all the instruments was zero during this period.

This year the Laser Ablation attached to the ICP-MS was successfully optimized for analysis of about 40 elements using pressed powder pellets of samples.

Lab. / Technique	Samples analyzed		
	WIHG Users	Outside Users	Total
XRF	643	707	1350
ICP-MS	725	517	1242
SEM-EDX	311	378	689
XRD	215	465	680
EPMA (slides)	84	62	144
Total samples analyzed	1978	2129	4105

Photography Section

During the reporting year around 5000 pictures were clicked using only digital cameras to cover the various functions, including Foundation Day, Founders day, National Science Day, National Technology Day, New Years Day, Seminars/ Symposia, and superannuation parties for institute staff etc., organized in the Institute. Apart from this around 1000 snaps were clicked for rock and fossil specimens. The colour printing of around 500 digital images was arranged from the market. During the reporting year 35 new high resolution digital cameras were procured for use by the scientific staff.

Drawing Section

The Drawing Section catered to the cartographic needs of the scientists of the Institute including the sponsored projects. During the reporting year the section has provided 48 geological/structural maps/geomorphological maps for the scientists and research scholars of the Institute. The section has also provided labels, captions during different programmes of the Institute.

Sample Processing Lab.

The sample processing laboratory provided thin/microprobe/polished sections to the requirements of the Institute scientists. During the reporting year the laboratory provided 873 thin and polished sections to various users for carrying out microscopic, fluid inclusion and EPMA studies. The section has also been under renovation for 5 months during this year. The lab also powdered 780 rock samples for carrying out major, trace and REE analysis by ICPMS, XRF and XRD.

S.P. NAUTIYAL MUSEUM

Museum is the key affiliation of education and continues to generate an axis of awareness to the students and public not only for the people from the 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, guided tours were provided to them. This year more than 3,000 people visited the Museum from different parts of country. On the National Science Day 28th February, 2011 more than 3, 000 students from various schools, colleges, paramedical as well as from the engineering colleges of the Doon Valley visited the Museum.

Museum observed Open days during National Technology Day (11th May, 2010). Foundation Day (29th June, 2010), Founders Day (23rd Oct. 2010) and on National Science Day (28th Feb., 2011). Like preceding years, enormous number of students and public visited the museum on these days. The print media gave a wide coverage of the function. Science quiz and Hindi essay competitions were organized on the eve of Science week celebrations (22nd to 28th Feb.2009). In the Science Quiz 28 students from various schools of Doon valley participated in the quiz competition, whereas in the Hindi essay competition thirty one schools participated. Prizes were distributed to the students who stood first second and third in the merit of these competitions.

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. The visitors from England, U.K, France, Japan, Norway, U.S.A., Nepal, Switzerland, Canada, Australia and Singapore also visited the Museum. Database of the rock and fossil specimens is almost complete and museum at present is actively planning for repository section of National Level. In order to give general awareness to the public and to the students regarding the Institute and museum activities, the Institute participated and displayed in following two exhibitions: in National Conference on “Science & Geopolitics of Arctic & Antarctic” (SaGAA) at New Delhi, on January 14-15, 2011, 2011, and in Science & Technology contribution of Indian Scientific Institutes Exhibition” at National Science Centre, New Delhi on October 5-10, 2010.

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 part of the country. The Library serves to the scientific, technical and administrative staff of the institute as well as to the scientist, academicians and researchers of sister organizations situated at Dehra Dun and various universities.

The Library is member of National Knowledge Resource Centre (formerly known as CSIR-DST e-Journals consortium). Library has access to various science and Technology packages of different major publishers. Through NKRC the DST has provided funds for online access to each institutional Library to Web of Science (WOS), Science and Nature weeklies with other NPG Publications depending on the requirement. The consortia is growing further in terms of number of publishers.

The Library subscribed to 84 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. Since the Elsevier is not participating in the consortia the WIHG Library has subscribed to Elsevier's *Earth & Planetary Collection* consisting of 115 titles on science direct platform.

Library has acquired two very important e-collections. The first is Elsevier's Earth and Planetary Science journals back file collection starting from Volume 1 issue 1 of each title to the last volume / issue of 1994, and have access from January 1995 to 2011 in current subscription. Now the continuous accesses for 115 titles are available from volume 1 to the current published issue. The second is Elsevier's Earth and Planetary Science **e-**books collection consisting of 463 titles published from 1996 to 2006. Both the collections are available on Sci-Verse Science- Direct platform.

During the year Library acquired a total number of 299 books. Out of these 97 books / reference books are purchased while 13 books are received as gratis. In addition to this 189 books in Hindi were purchased for Hindi collection. The Library has a good collection of Hindi books to promote the usage Hindi Language in the staff of the Institute. The Library acquired a total number of approx. 500 reprints of publications of various scientists.

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. This facility was also extended to the other organizations on payment basis. Approximately 1.31 lakhs pages were copied.

PUBLICATION & DOCUMENTATION

The Publication and Documentation Section is involved in bringing out the regular journal 'Himalayan Geology', and publishing the Annual Report, Hindi magazine 'Ashmika', publicity brochures etc. During this year, the section published 'Himalayan Geology' vols. 31(2) 2010 and 32(1) 2011, 'Annual Report' of the Institute for the year 2009-10 in Hindi and English, Hindi magazine 'Ashmika' vol.16, publicity brochures, folders, invitation cards, certificates etc. Additionally, for scanning and color printing of posters, maps, diagrams and figures etc, it also provided technical support service on A0/A3 size scanner & printer to scientists, research scholars and other staff of the Institute.

Himalayan Geology (journal) website http://www.himgeology.com, the facility provided by this section, is functioning with online enquiry, online prepaid subscription order and online 'Manuscript Submission'. The information regarding the journal including contents and abstracts are up-dated time to time on the website. During this year, Thomson Reuters, USA has also listed the 'Himalayan Geology' journal in the list of Impact Factor Journals.

National Days / World Environment Day / Foundation Day / Founder's Day / National Science Day

National Technology Day

The Institute observed the 12th 'National Technology Day' on May 11, 2010 as an Open Day. On this Day Museum and other laboratories were kept open for school and college children and for general public. A large number of students and the people visited the Institute museum and other laboratories. On this occasion, Dr. R.K. Mazari delivered the 'National Technology Day Lecture' on the topic: "Climate Change: Myth, Reality and Adaptation".

World Environment Day

World Environment Day was observed on June 4, 2010. On this occasion a Lecture on "Biodiversity and Climate in Himalayan Perspectiv" was delivered by Dr. P. S. Negi, Scientist 'C', Wadia Institute of Himalayan Geology, Dehra Dun.

Foundation Day Celebrations

The 42nd Foundation Day of the Institute was celebrated on the June 29, 2010. The Chief Guest of the function Sh. P.K. Bhowmick, Executive Director & Head, KDMIPE, ONGC, Dehra Dun, delivered the 'Foundation Day Lecture' on the topic "Hydrocarbon Exploration in Himalayan Fold-thrust Belt: A Perspective". On this occasion distribution of awards for best research papers published by the scientists in their respective fields were also distributed by the Chief Guest. The awards were given to (i) Dr. A.K. Mahajan for his paper entitled "NEHRP soil classification and estimation of 1-D site effect of Dehra Dun Fan deposits using shear wave velocity" published in Engineering Geology; (ii) Dr. B.K. Mukherjee and Dr. H.K. Sachan for their paper entitled "Fluids in coesite-bearing rocks of the Tso Morari Complex, NW Himalaya: evidence for entrapment during peak metamorphism and subsequent uplift" published in Geological Magazine; (iii) Dr. Naresh Kumar et al. paper entitled "Seismogenesis of Clustered Seismicity beneath the KangraChamba Sector of Northwest Himalaya: Constraints from 3D Local Earthquake Tomography" published in Bulletin Seismological Society of America, (iv) Dr. P. Srivastava, Dr. D.K. Misra, Dr. K. Luirei and Dr. S.S. Bhakhuni paper entitled "Morphosedimentary records at the Brahmaputra river exit, NE Himalaya: Climate tectonic interplay during the late Pleistocene-Holocene", published in Quaternary Science; and (v) Dr. R.J. Perumal, Dr. A.K. Dubey and others paper entitled "Magnetic fabrics indicating Late Quaternary seismicity in the Himalayan foothills", published in International Journal of Earth Sciences (Geol Rundsch).

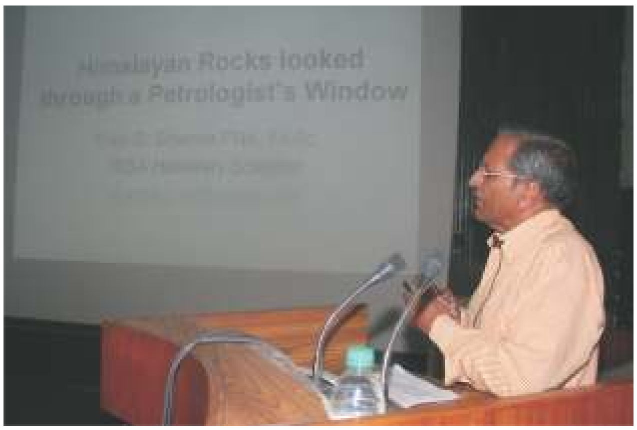
Best workers awards were also given to the Sh. Rakesh Kumar, Jr. Tech. Officer; Sh. S.S. Bhandari, Sr. Tech. Asst., Sh. Nandaram, Electric cum pump operator; Sh. Shekhranandan, Section Cutter; Sh. M.S. Rawat, Field Asst., Sh. Anand Singh Negi, UDC; Sh.

Chief Guest Sh. P.K. Bhowmick, Executive Director & Head, KDMIPE, ONGC, Dehra Dun, lecturing in the Foundation Day Celebration.

Vijay Ram Bhatt, LDC, Sh. Ramesh, Safaiwala, Sh. Chandra Pal Singh, Driver, and Late Sh. Shyam Lal, bearer for the good work carried out by them during the year 2010-11.

Founder's Day Celebrations

The Institute celebrated its Founders Day on 23rd October, 2010 in the honor of Prof. D. N. Wadia. On this occasion 'Founders Day Lecture' was delivered by Prof. R.S. Sharma, INSA Honorary Scientist at Jaipur University, Jaipur on 'The Himalayan Rock looked through a petrologist's window'.



National Science Day Celebrations

The National Science Day - 2011 was celebrated in Institute by weeklong activities, beginning with a Science Quiz Competition. The various educational institutions of the Dehra Dun participated in the Science Quiz and Hindi Essay Competition. In total 30 educational institutions participated in the quiz competition and 32, in the Hindi Essay competition. Besides this Hindi & English Slogan competition was also held on third day in which scientists, Institute staff, research scholars participated.

February 28th was observed as open day and all the laboratories and Museum were kept open to students and general public. The day started with the coming of students from the far off places such as Haridwar and Rishikesh. In total 42 educational institutions with more than 3,000 school children and a large number of public visited the Institute Museum and laboratories. Scientists, research scholars as well as the technical staff explained the functioning of the various scientific instruments and their uses to the students and other visitors.

An invited National Science Day Lecture on "Physical Chemistry in life and Indian Philosophy" was delivered by Prof. R. D. Kaushik, Dean, Faculty of Ayurveda and Medical Sciences, and Faculty of Engineering & Technology, Gurukul Kangri University, Haridwar. The lecture was attended by scientists, students as well as by visitors from different organizations from Dehra Dun.

Museum remained open throughout the day in which various exhibits on the Uttaranchal Himalaya, Impacts of Human activities on Environment, Himalayan Glaciers, Earthquakes, Landslides, Origin of Life, Volcanoes, Rocks Minerals, etc. were displayed and guided tours were provided. Like previous year this year, a joint exhibition along with Indian Society of Remote Sensing Dehra Dun was organized and the documentary on the Chandrayan was shown to public and students.

In order to give awareness to the public to save environment, the Museum also organized a special exhibition this year on the waste products and material.

DISTINGUISHED VISITORS TO THE INSTITUTE

- Padma Vibhushan Sh. Sunder Lal Bahuguna
- Padma Sri Sh. Anil Prakash Joshi
- Shri Devinder Singh , DIG, ITBP Mussoorie
- Dr. A. M. Michael, Chairman, Research Advisory committee, CSWCRII
- Prof. Masuad Ahmad CHT Affairs Govt. of. Bangladesh
- Mr. Auolas Sduled, ICIMOD, Nepal
- Prof. R.D. Kaushik, Gurukul Kangri University Haridwar
- Dr. Conrad Lindholm, Norway
- Prof. S.K. Singh Vice Chancellor, HNB Garhwal University

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.

Hindi pakhwara was celebrated in the Institute from September 14-28, 2010, during which essay competition and debate for school children and Institute employees was organized on topics "Aapda Prabandhan Mein Hamari Apexayein", "Swachha Doon : Sundar Doon", "Uttarakhand Devbhoomi : Meri Nazar Mein", and "Vartman Shikshit Pidhi Parvarik Mulyon Tatha Desh Ki Pragati Ke Prati Samvedanshil Hai". A nara competition and Swarachit Kavita Path was also organized for Institute employees on this occasion. During Hindi pakhwara also one day Hindi workshop was organized, wherein Dr. D.P.Semwal Income Tax Commissinor, Dehradun gave an invited talk on the topic "Srot par Katauti " followed by a talk on " Bharat Sarkar Ki Rajbhasha Neeti" by Dr. Muni Ram Saklani, Member Secretary Narakas, Dehra dun.

On the occasion of the Foundation Day of the Institute on June 29, 2010, the Hindi Magazine *'Ashmika'* volume 16 was released. The Annual Report of the Institute for the year 2009-10 was published in bilingual form.

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 is 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 Sr. 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 2010-11.

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, 2010-11.

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 2009-2010.

The details of information on the RTI cases during the year 2010-11 are as under :

Details	Opening balance as on 1.4.2010	Received during the year 2010 -2011	Number of cases transferred to other public authorities	Decisions where requests/ appeals were rejected	Decisions where requests/ appeals accepted
1	2	3	4	5	6
Requests for information	Nil	14	Nil	Nil	14
First appeals	Nil	1	Nil	1	Nil

No application or appeal under the Right to Information Act, 2005 was carried forward to the next financial year 2011-12.

8. Sanctioned Staff strength (category wise)

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

9. Sanctioned and released budget grant for the year 2010-2011

Plan : Rs. 2,303.58 lakhs
Non-Plan : Rs. 90.00 lakhs
Total : Rs. 2,303.58+90.00 =2,393.58 lakhs

10. XI[th] Plan approved outlay

The details of XI[th] Plan approved outlay are yet to be received by the Institute.

STAFF OF THE INSTITUTE AS ON 31.03.2011

A) SCIENTIFIC STAFF

1.	Prof. Anil Kumar Gupta	Director
2.	Dr. A.K. Dubey	Scientit 'G'
3.	Dr. V.C. Tiwari	Scientist 'F'
4	Dr. B.K. Choudhary	Scientist 'F'
5.	Dr. V.M. Choubey	Scientist 'F'
6.	Dr. Rohtash Kumar	Scientist 'F'
7.	Dr. P.P. Khanna	Scientist 'F'
8.	Dr. (Mrs.)Meera Tiwari	Scientist 'F'
9.	Dr. S.K. Ghosh	Scientist 'F'
10.	Dr. N.R. Phadtare	Scientist 'F'
11.	Dr. D.K. Misra	Scientist 'F'
12.	Dr. N.K. Saini	Scientist 'F'
13.	Dr. K.K. Purohit	Scientist 'F'
14.	Dr. Kishor Kumar	Scientist 'F'
15.	Dr. M.P. Sah	Scientist 'F'
16.	Dr. N.Siva Siddaiah	Scientist 'F'
17.	Dr. Rajesh Sharma	Scientist 'F'
18.	Dr. G. Philip	Scientist 'F'
19.	Dr. Rafikul Islam	Scientist 'F'
20.	Dr. B.N. Tiwari	Scientist 'F'
21.	Dr. D.Rameshwar Rao	Scientist 'F'
22.	Dr. R.S. Rawat	Scientist 'E'
23.	Dr. R.K. Choujar	Scientist 'E'
24.	Dr. Keser Singh	Scientist 'E'
25.	Dr. S.K. Paul	Scientist 'E'
26.	Dr. T.N. Jowhar	Scientist 'E'
27.	Dr. S.K. Bartarya	Scientist 'E'
28.	Dr. P.K. Mukharjee	Scientist 'E'
29.	Dr. S.K. Parcha	Scientist 'E'
30.	Dr. H.K. Sachan	Scientist 'E'
31.	Dr. Sushil Kumar	Scientist 'D'
32.	Dr. A.K. Mahajan	Scientist 'D
33.	Dr. D.P. Dobhal	Scientist 'D'
34.	Dr. Vikram Gupta	Scientist 'D'
35.	Shri B.S. Rawat	Scientist 'C' (on deputation)
36.	Dr. S.S. Bhakuni	Scientist 'C'
37.	Dr. Suresh N.	Scientist 'C'
38.	Dr. Pradeep Srivastava	Scientist 'C'
39.	Dr. A.K. Mundepi	Scientist 'C'
40.	Shri V. Sriram	Scientist 'C'
41.	Dr. Ajay Paul	Scientist 'C'
42.	Dr. P.S. Negi	Scientist 'C'
43.	Dr. A.K.L. Asthana	Scientist 'C'
44.	Dr. R.J. Perumal	Scientist 'C'
45.	Dr. A.K. Singh	Scientist 'C'
46.	Dr.(Mrs.) Kapesa Lokho	Scientist 'C'
47.	Dr. B.P. Sharma	Scientist 'B'
48.	Dr. K.S. Luirei	Scientist 'B'
49.	Dr. Rajesh S.	Scientist 'B'
50.	Shri Gautam Rawat	Scientist 'B'
51.	Shri Naresh Kumar	Scientist 'B'
52.	Dr. B.K. Mukherjee	Scientist 'B'
53.	Dr. Swapnamita Choudhuri	Scientist 'B'
54.	Shri N. K. Meena	Scientist 'B'
55.	Shri P.K. Rao Gautam	Scientist 'B'
56.	Dr. Dilip Kumar Yadav	Scientist 'B'
57.	Dr. Santosh Kumar Rai	Scientist 'B'
58.	Dr. Devajit Hazarika	Scientist 'B'
59.	Dr. Kaushik Sen	Scientist 'B'
60.	Dr. S.S. Thakur	Scientist 'B'

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

35.	Shri C.P. Dabral	S.L.T. Gr.II(3)
36.	Shri Satish Pd.Bahuguna	Sr. Lab. Assistant Gr. II(5)
37.	Shri S.K. Thapliyal	Sr. Lab. Assistant Gr.II(5)
38.	Shri Shiv Pd. Bahuguna	Sr. Lab. Assistant Gr.II(5)
39.	Shri S.P. Balodi	Sr. Lab. Assistant Gr.II(5)
40.	Shri Rajendra Prakash	Lab. Assistant Gr.II(3)
41.	Shri A.K. Gupta	Lab. Assistant Gr.II(3)
42.	Shri Tirath Raj	Lab. Asstt. (Photography) Gr.II (3)
43.	Shri Balram Singh	Elect.cum Pump Opt.Gr.II(3)
44.	Shri Pratap Singh	F.C.L.A.Gr. I(4)
45.	Shri Ram Kishor	F.C.L.A.Gr. I(4)
46.	Shri Ansuya Prasad	F.C.L.A.Gr. I(4)
47.	Shri Puran Singh	F.C.L.A.Gr. I(4)
48.	Shri Ram Khilawan	F.C.L.A.Gr. I(4)
49.	Shri Madhu Sudan	F.C.L.A.Gr. I(4)
50.	Shri Hari Singh	F.C.L.A.Gr. I(3)
51.	Shri Ravi Lal	F.C.L.A.Gr. I(3)
52.	Shri Preetam Singh	F.C.L.A.Gr. I(3)
53.	Shri V. Khanduri	F.C.L.A.Gr.I(1)
54.	Shri Nain Das	Lab.Assistant Gr. I(3)
55.	Mrs.Rama Pant	Field Attendant Gr.I(3)
56.	Shri R.S.Negi	Field Attendant Gr.I(3)
57.	Shri Ramesh Chandra	Field Attendant Gr.I(3)
58.	Shri Khusi Ram	Field Attendant Gr.I(3)
59.	Shri Tikam Singh	Field Attendant Gr.I(3)
60.	Shri Bharosa Nand	Field Attendant Gr.I(3)
61.	Shri B.B.Panthri	Field Attendant Gr.I(3)
62.	Shri M.S.Rawat	Field Attendant Gr.I(3)

C) ADMINISTRATIVE STAFF

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

ANCILLARY STAFF

1.	Shri Dewan Singh	Driver
2.	Shri Sohan Singh	Driver
3.	Shri Ganga Ram	Driver
4.	Shri Chander Pal	Driver
5.	Shri Naresh Kumar	Driver
6.	Shri Shyam Singh	Driver
7.	Shri R.S. Yadav	Driver
8.	Shri Surjan Singh	Driver
9.	Shri Girish Chander	Guest House Attendt.-cum-Cook
10.	Sh. D.P. Saklani	Guest House Attendt.-cum-Cook
11.	Shri Bhagat Singh	Bearer
12.	Mrs. Kamla Devi	Bearer
13.	Mrs. Deveshawari Rawat	Bearer
14.	Shri S.K. Gupta	Bearer
15.	Shri Chait Ram	Bearer
16.	Mrs. Omwati	Bearer
17.	Shri Jeevan Lal	Bearer
18.	Shri Surendra Singh	Bearer
19.	Shri Har Prasad	Chowkidar
20.	Shri Mahendra Singh	Chowkidar
21.	Shri Rohlu Ram	Chowkidar
22.	Shri H.S. Manral	Chowkidar
23.	Shri G.D. Sharma	Chowkidar
24.	Shri Ashok Kumar	Mali
25.	Shri Satya Narayan	Mali
26.	Shri Ramesh	Safaiwala
27.	Shri Hari Kishan	Safaiwala

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

Governing Body
(w.e.f. 1.12.2006)

Sl.	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	INSA - Senior 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.	Dr. M. Ramakrishnan	Flat No.8, Mani Pallavam 29, Balakrishna Road Valmiki Nagar, Thiruvanmiyur Chennai - 600 041	Member
9.	Dr. A.K. Dubey (Upto 29.08.2010)	Acting Director Wadia Institute of Himalayan Geology Dehra Dun - 248 001	Member Secretary

10.	Prof. Anil K. Gupta (w.e.f. 30.08.2010 onwards)	Director Wadia Institute of Himalayan Geology Dehra Dun - 248 001	Member Secretary
11.	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.	Name	Address	Status
1.	Dr. 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.	Shri V.K. Raina	(Ex-Deputy, D.G., GSI) 258, Sector 17 Panchkula - 134 109 (Haryana)	Member
7.	Dr. Rasik Ravindra	Director Antarctic Research Institute Goa - 403 804	Member
8.	Dr. R.K. Chadha	Scientist 'F' National Geophysical Research Institute Uppal Road, Hyderabad - 500 007	Member
9.	Dr. M. Prithviraj	Karnataka State Council for Science and Technology Indian Institute of Science Bangalore - 560 012	Member

10.	Dr. A.K. Dubey (Upto 29.08.2010)	Acting Director Wadia Institute of Himalayan Geology Dehra Dun - 248 001	Member
11.	Prof. Anil K. Gupta (w.e.f. 30.08.2010 onwards)	Director Wadia Institute of Himalayan Geology Dehra Dun - 248 001	Member

Finance Committee
(w.e.f. 01.12.2006)

Sl.	Name	Address	Status
1.	Prof. M.P. Singh	Dean, Faculty of Science and Head, Geology Department Lucknow University 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. A.K. Dubey (Upto 29.08.2010)	Acting Director Wadia Institute of Himalayan Geology Dehra Dun - 248 001	Member
	Prof. Anil K. Gupta (w.e.f. 30.08.2010 onwards)	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. 01.12.2006)

Sl.	Name	Address	Status
1.	Dr. A.K. Dubey (Upto 29.08.2010)	Acting Director Wadia Institute of Himalayan Geology Dehra Dun - 248 001	Chairman
	Prof. Anil K. Gupta (w.e.f. 30.08.2010 onwards)	Director Wadia Institute of Himalayan Geology Dehra Dun - 248 001	Chairman

2.	Joint Secretary & Financial Adviser or his authorized nominee	Department of Science & Technology Technology Bhavan, New Mehrauli Road New Delhi - 110016	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.R. 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	Secretary Member

STATEMENT OF ACCOUNTS

Goyal Bhanot & Co.

Chartered Accountants

H.O. : 1, Turner Road, Clement Town
Dehra Dun - 248 002 Uttarakhand
Phone : 0135-6543358 (O)
Mobile : 9837383358, 9219606467, 9897243712
E-mail : info@goyalbhanotco.com
B.O. : 23, E.C. Road, Opp. CJM School
Back gate, Dehra Dun

AUDITOR'S REPORT

The Members of Governing Body,
Wadia Institute of Himalayan Geology,
33, GMS Road,
Dehradun.

We have examined the attached Balance Sheet of **Wadia Institute of Himalayan Geology, 33, GMS Road, Dehradun,** as on 31st March, 2011 and the annexed Income and Expenditure Account and Receipt and Payment Account for the period 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 auditing standards generally accepted in India. Those Standards require that we plan and perform the audit to obtain reasonable assurance about whether the financial statements are free of material misstatement. An audit includes examining on a test basis, evidence supporting the amounts and disclosures in the financial statements. An audit also includes assessing the accounting principles used and significant estimates made by management, as well as evaluating the overall financial statement presentation. We believe that our audit provides a reasonable basis for our opinion.

We report that:

(i) We have obtained all the information and explanation, which to the best of our knowledge and belief were necessary for the purposes of our audit;
(ii) In our opinion, proper books of accounts have been kept by the Institute so far as appear from our examination of those books;
(iii) The statements of account dealt with in this report are in agreement with the books of account.
(iv) In our opinion and to the best of our information and according to the explanations given to us, the said accounts, *subject to our comments and observations as mentioned in the "Annexure 1 to the Audit Report"*, gives the information in the manner so required and give a true and fair view:
   - In the case of the Balance Sheet, of the state of affairs as on 31st March, 2011.
   - In the case of the Income and Expenditure Account of the Surplus for the period ended on that date.

FOR **GOYAL BHANOT & CO**
CHARTERED ACCOUNTANTS

Sd/-
CA RAJNISH BHANOT
[FCA, Partner]

Date: July 15th , 2011
Place: Dehra Dun

Goyal Bhanot & Co.

Chartered Accountants

H.O. : 1, Turner Road, Clement Town Dehra Dun - 248 002 Uttarakhand
Phone : 0135-6543358 (O)
Mobile : 9837383358, 9219606467, 9897243712
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Annexure 1 to the Main Audit Report

The following observations were noted during the course of audit for the financial year 2010-11. The same have been discussed with management and comments and explanations of the management thereon have also been obtained.

1. The institute is maintaining accounts on cash basis except interest accrued on investments, which is not in conformity with the generally accepted accounting policies adopted in India and as per the Accounting Standard 1 "Disclosure of Accounting Policies" issued by the Institute of Chartered Accountants of India. The "Uniform Accounting Format" of financial statements for the Central autonomous bodies as has been made compulsory by the Ministry of Finance w.e.f. 01.04.2001, and adopted by the Institute also, recommends accrual method of accounting.
2. The total funds which remained un-utilized as on 31.03.2011 could not be bifurcated into Plan and Non-Plan funds as separate bank account and books of accounts are not maintained. Hence it is not possible to verify how much of the funds have been utilized from Plan or Non-Plan Funds separately. However, as informed, the Institute is preparing a separate statement to bifurcate the amount utilized to respective funds in the form of utilization certificate.
3. The Recurring fund of the Corpus fund of the Institute is negative by Rs 33,38,036.00 as per Schedule 1 which shows that the institute has utilized non-recurring fund to the tune of the said amount for recurring purposes.
4. The Institute has not booked the current liability for the retirement benefit of the employees as per Accounting Standard 15 "Employees Benefits" as issued by the Institute of Chartered Accountants of India.
5. The financial statements of the institute and the projects sponsored by the other agencies and the CPF, GPF and the new pension scheme are not consolidated as per Accounting Standard 21 "Consolidation of financial Statement" as issued by the Institute of Chartered Accountants of India. The CPF and GPF are also part of the Institute as they do not have a separate legal identity.
6. The internal control regarding fixed assets needed to be strengthened. The following observations are made:
   a) The fixed asset register is not maintained by the Institute.
   b) The additions to fixed assets are not numbered properly.
   c) The verification of the fixed asset is not done periodically by the management of the Institute. The last verification report produced for verification was against letter dated 26/11/2008.
   d) The assets of the nature of Plant, Machinery and Equipments are not bifurcated into computer systems and other plant and Machinery in the books of accounts.
7. The institute is adopting the policy of charging depreciation on fixed assets on the basis of written down value method as per the rates specified in the Income Tax Act, 1961, however, the following observations are made:

Goyal Bhanot & Co.

Chartered Accountants

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Back gate, Dehra Dun

a) Full year depreciation is charged instead of six months, on assets purchased for the half year ending 31st March, 2011. As per the management the same policy had been adopted in the previous financial years also.

b) The books are depreciated @ 15% p.a. instead of 60% p.a. on W.D.V basis as applicable to research institutes. Depreciation amounting to Rs.15,39,399/- has been charged by the institute on additions made during the F.Y.2010-11, but if the same has been depreciated as per the rate and method prescribed by the Income Tax Act 1961,then surplus would have been understated by Rs.20,46,588/- (35,85,988-15,39,399)

c) The fixed assets are being accounted for on payment basis. In case the payment is made in parts then the depreciation is wrongly charged on only the amount that has been paid as against the full value of the invoice.

8. The Institute has not bifurcated the advances indicating the period of outstanding given to staff and Parties. The Party Debtors amounting to Rs. 126,921/- and Staff Debtors amounting to Rs 27,339/- are outstanding since more than 4 years. The advance which could not be realized in due course should be written off with the approval of the competent authority.

9. The Institute has transferred fixed assets of 7 projects sponsored by other agencies as per procedural guidelines, as informed. However, the guideline for any specific project for transfer of assets was not found on record. Further, there are no transactions in 22 other sponsored projects in the F.Y. under Audit. The research activities under the said projects have also been completed; however, fixed assets have not been transferred to WIHG.

10. The balances in the earmarked funds of Annual Conventuin IGU 2009 & ULF/VLF Equipments have been shown negatively by Rs. 1,99,156.00 which means, the amount had been expended from other funds specific for other purposes. The loan from WIHG should have been shown when the amount was utilized from other funds and the same should have been shown as current liability in the Institute accounts.

We are thankful to the staff and the management for the co-operation extended to us during the course of audit.

FOR **GOYAL BHANOT & CO**
CHARTERED ACCOUNTANTS

Sd/-
CA RAJNISH BHANOT
[FCA, Partner]

Date: July 15th , 2011
Place: Dehra Dun

WADIA INSTITUTE OF HIMALAYAN GEOLOGY, DEHRADUN

BALANCE SHEET
(AS AT 31ST MARCH 2011)

(Amt in Rs…)

Particulars	Schedule	Current Year	Previous Year
LIABILITIES			
Corpus/ Capital Fund	1	418,337,566	359,970,780
Reserves and Surplus	2	-	-
Earmaked/ Endowment Fund	3	1,446,535	1,463,326
Secured Loans & Borrowings	4	-	-
Unsecured Loans & Borrowings	5	-	-
Deferred Credit Liabilities	6	-	-
Current Liabilities & Provisions	7	2,622,518	3,125,835
TOTAL		**422,406,619**	**364,559,941**
ASSETS			
Fixed Assets	8	314,531,599	276,253,872
Investments from Earmaked/ Endowment Funds	9	29,024	26,809
Investment- Others	10	-	-
Current Assets, Loans & Advances	11	107,845,996	88,279,260
TOTAL		**422,406,619**	**364,559,941**
Significant Accounting Policies	37		
Contingent Liabilities and Notes on Accounts	38		

"As per our separate report of even date"

FOR **GOYAL BHANOT & CO**
CHARTERED ACCOUNTANTS

Sd/-	**Sd/-**	**Sd/-**	**Sd/-**
CA RAJNISH BHANOT	**HARISH CHANDRA**	**DINESH CHANDRA**	**PROF. ANIL K. GUPTA**
(FCA, Partner)	(Finance & Accounts Officer)	(Registrar)	(Director)

Date : 15th July, 2011
Place : Dehra Dun

WADIA INSTITUTE OF HIMALAYAN GEOLOGY, DEHRADUN

INCOME & EXPENDITURE ACCOUNT
(FOR THE YEAR ENDED 31ST MARCH 2011)

(Amt in Rs...)

Particulars	Schedule	Current Year	Previous Year
A INCOME			
Income from sales/ services	12	-	-
Grants/ Subsidies	13	239,358,200	214,966,364
Fees/Subscription	14	73,000	20,000
Income from Investments (Income on Invest from Earmarked/ Endowment - Fund)	15	869,934	801,972
Income from Royalty, Publication etc.	16	55,711	93,499
Interest earned	17	2,815,147	4,045,154
Other Income	18	2,033,868	1,481,952
Adjustment for Rounding Off		-	-
TOTAL (A)		**245,205,860**	**221,408,941**
B EXPENDITURE			
Establishment Expenses	20	125,426,769	144,312,747
Other Research & Administrative Expenses	21	25,713,666	29,361,294
Expenditure on Grant/ Subsidies etc.	22	-	-
Interest/ Bank Charges	23	5,004	2,198
Depreciation Account	8	48,471,150	43,242,978
Increase/ Decrease in stock of Finished goods, WIP& Stock of Publication	A-2	126,122	96,105
Loss on sale of vehicle	A-19	97,700	-
TOTAL (B)		**199,840,411**	**217,015,322**
Surplus/ (Deficit) being excess of Income over Expenditure (A - B)		45,365,449	4,393,619
Transfer to Special Reserve (Specify each)		-	-
Transfer to / from General Reserve		-	-
BALANCE BEING SURPLUS /(DEFICIT) CARRIED TO CORPUS FUND		**45,365,449**	**4,393,619**
Significant Accounting Policies	37		
Contingent Liabilities and Notes on Accounts	38		

"As per our separate report of even date"

FOR **GOYAL BHANOT & CO**
CHARTERED ACCOUNTANTS

Sd/-	Sd/-	Sd/-	Sd/-
CA RAJNISH BHANOT	**HARISH CHANDRA**	**DINESH CHANDRA**	**PROF. ANIL K. GUPTA**
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Date : 15th July, 2011
Place : Dehra Dun

WADIA INSTITUTE OF HIMALAYAN GEOLOGY, DEHRADUN

RECEIPTS & PAYMENTS ACCOUNT
(FOR THE YEAR ENDED 31ST MARCH 2011)

(Amt in Rs...)

Particulars	Schedule	Current Year	Previous Year
RECEIPTS			
Opening Balance	24	28,345,663	6,499,487
Grants - in - Aids	26	239,358,200	265,750,000
Grants - in - Aids/Other Receipts (Ear Marked)	27	507,215	1,398,860
Loan & Advances	28	61,454,954	75,689,250
Loan & Advances (Ear Marked)	31	-	-
Fees/Subscription	14	73,000	20,000
Income from Investments	15	869,934	801,972
Income from Royalty, Publication etc.	16	55,711	93,499
Interest earned on Loan to Staff	17	2,815,147	4,045,154
Other Income	18	2,200,668	1,481,952
Investment (L/C Margin Money)	34	53,100,000	17,500,000
		388,780,492	**373,280,174**
PAYMENTS			
Establishment Expenses	20	125,472,259	144,312,747
Other Administrative Expenses	21	25,713,666	29,361,294
Expenditure on Grant/Subsidies Etc.	22	-	-
Interest/ Bank Charges	23	5,004	2,198
Loans & Advances	29	62,944,144	68,024,498
Loans & Advances (Ear Marked)	32	-	394,070
Investment (L/C Margin Money)	35	30,300,000	53,100,000
Fixed Assets	36	74,012,040	49,241,824
Ear Marked Fund Expenses	33	526,221	497,880
Grant - in - Aid (Ear Marked) Refunded	30	-	-
Closing Balance	25	69,807,158	28,345,663
		388,780,492	**373,280,174**

Significant Accounting Policies	37
Contingent Liabilities and Notes on Accounts	38

"As per our separate report of even date"

FOR **GOYAL BHANOT & CO**
CHARTERED ACCOUNTANTS

Sd/-	Sd/-	Sd/-	Sd/-
CA RAJNISH BHANOT	**HARISH CHANDRA**	**DINESH CHANDRA**	**PROF. ANIL K. GUPTA**
(FCA, Partner)	(Finance & Accounts Officer)	(Registrar)	(Director)

Date : 15th July, 2011
Place : Dehra Dun

WADIA INSTITUTE OF HIMALAYAN GEOLOGY, DEHRADUN

SCHEDULE FORMING PART OF ACCOUNTS FOR THE YEAR ENDED 31ST MARCH 2011
SCHEDULE - 37: SIGNIFICANT ACCOUNTING POLICIES

1. ACOUNTING CONVENTION

The financial Statements are prepared on the basis of historical cost convention, unless otherwise stated and on the cash method of accounting except interest accrued on fixed deposits.

2. INVENTORY VALUATION

a) No items are retained by the institute for which inventory is being held by the institute except the stock of publications.
b) Publications are valued at cost or net realizable value, which ever is lower. Cost of publication i.e. Himalayan Geology Volume is determined by considering the cost of printing material, labour and related overheads.

3. INVESTMENTS

Investments classifieds as "long term investments" are carried at cost.

4. FIXED ASSETS

a) Fixed Assets are stated at net book value as recommended in the "Uniform Accounting Format" of financial statements for the Central Autonomous Bodies as made compulsory by the Ministry of Finance w.e.f. 01.04.2001.
b) Additions to fixed assets are taken at cost of acquisition, inclusive of freight, duties and taxes, incidental and direct expenses related to acquisition.
c) Fixed Assets received by way of non-monetary grants, are capitalized at current cost, by corresponding credit to Corpus Fund.
d) Fixed Assets transferred from projects sponsored by other agencies are capitalized at net book value on closure of project activities.

5. DEPRECIATION

a) Depreciation is provided on Written Down Value method as per rates specified in the Income Tax Act, 1961.
b) When an asset is discarded or sold or deleted, the original cost is deducted from the gross block, the W.D.V. is deducted from the W.D.V. block and accumulated depreciation on the asset upto the date of deletion is deducted from accumulated depreciation of the respective block.
c) In respect of addition to/ deduction from fixed assets during the year, depreciation is considered on full yearly basis.
d) When an asset is transferred from the projects sponsored by other agencies, the original cost is added to the gross block and the accumulated depreciation till date is added to the depreciation fund account, resulting in asset transferred on net book value.

6. MISCELLANEOUS EXPENDITURE

Deferred revenue expenditure, if any, will be written off over a period of 5 years from the year it is incurred.

7. ACCOUNTING FOR SALES & SERVICES

The consultancy services provided by the institute are through consultancy project only and are accounted for on net services basis.

8. GOVERNMENT GRANTS / SUBSIDIES

a) Government grants of the nature of contribution towards capital cost are transferred to Capital/ Corpus Fund directly.
b) Government grants of the nature of contribution towards Revenue cost are transferred to Income & Expenditure account and the surplus or deficit after deducting all the expenses is transferred to Capital / Corpus fund.
c) Government Grants towards Earmarked / Endowment Funds are directly transferred to the respective fund account.
d) Government grants / subsidy are accounted on realization basis.

9. FOREIGN CURRENCY TRANSACTIONS

a) Transactions denominated in foreign currency are accounted at the exchange rate prevailing at the date of payment of the asset.
b) Current assets, foreign currency loans and current liabilities are not converted at the exchange rate prevailing as at the year end, as the institute is maintaining accounts at cash basis.

"As per our separate report of even date"

FOR **GOYAL BHANOT & CO**
CHARTERED ACCOUNTANTS

Sd/-	**Sd/-**	**Sd/-**	**Sd/-**
CA RAJNISH BHANOT	**HARISH CHANDRA**	**DINESH CHANDRA**	**PROF. ANIL K. GUPTA**
(FCA, Partner)	(Finance & Accounts Officer)	(Registrar)	(Director)

Date : 15th July, 2011
Place : Dehra Dun

WADIA INSTITUTE OF HIMALAYAN GEOLOGY, DEHRADUN

SCHEDULE FORMING PART OF ACCOUNTS FOR THE YEAR ENDED 31ST MARCH 2011
SCHEDULE - 38: CONTINGENT LIABILITIES AND NOTES ON ACCOUNTS

1. CONTINGENT LIABILITIES

(Amount in Rs.)

a)	Claims against the Entity not acknowledged as debts		- Nil -
b)	In respect of		
	i)	Bank Guarantees given by /on behalf of the Entity	- Nil -
	ii)	Letter of credit opened by Bank on behalf of the entity	30,300,000
	iii)	Bills discounted with banks	- Nil -
c)	Disputed demands in respect of		
	i)	Income Tax	58,36,245
	ii)	Sales Tax	- Nil -
	iii)	Municipal Taxes	- Nil -
d)	In respect of claims from parties for non-execution of orders, but contested by the Entity		- Nil -

2. CAPITAL COMMITMENTS

Estimated Value of contracts remaining to be executed on capital account and not provided for (net of advances)		
a)	Construction of Building	- Nil -
b)	Other Assets	-Nil -

3. LEASE OBLIGATIONS

Future obligations for rentals under finance lease arrangements for plant and machinery amount to Rs.	- Nil -

4. CURRENTS ASSETS, LOANS AND ADVANCES

In the opinion of the Institute, the current assets, loans and advances have a value on realization in the ordinary course of business, equal at least to the aggregate amount shown in the Balance Sheet.

5. TAXATION

In view of there being no taxable income of the Institute under income tax Act, 1961, no provision for Income Tax has been considered necessary.

6. FOREIGN CURRENCY TRANSACTIONS

a)	Value of Imports Calculated on C.I.F basis:		
	i)	Purchase of finished goods	- Nil -
	ii)	Raw Materials & Components (including in transit)	- Nil -
	iii)	Capital goods	- Nil -
	iv)	Stores, Spares and Consumables	- Nil -
b)	Expenditure in foreign currency		
	i)	Travel (for attending Seminar/Conference abroad)	- Nil -
	ii)	Remittances and Interest payment to Financial Institutions / Banks in Foreign Currency	- Nil -
	iii)	Other expenditure	
		Commission on Sales	- Nil -
		Legal and Professional Expenses	- Nil -
		Miscellaneous Expenses	- Nil -
c)	Earnings		
	i)	Value of Exports on FOB basis	- Nil -
	ii)	Grants	- Nil -

7. The payments to auditors during the F.Y. 2010-11 is as follows:

Remuneration to auditors		
i)	As Auditors	7,500/-
	Taxation matters	- Nil -
	For Management Services	- Nil -
	For Certification	5,000/-
ii)	Others	- Nil -

8. The grant of Rs 7,40,12,608.00 as per Schedule 8 has been transferred to Non Recurring fund on account of purchase/transfer of capital assets from total grants received from the Department of Science & Technology, Government of India.

9. The total overhead charges transferred from projects sponsored by other agencies is Rs. 5,35,000.00, however, the overhead charges accounted in the books of the Institute are Rs. 5,95,000.00. The difference of Rs. 60,000.00 is due to cheques in transit for the last financial year, received in the current financial year.

10. The details of projects which were closed during the financial year and transferred to the Institute are as follows:

S. NO	NAME OF PROJECT	NON-RECURRING FUND	DEPRECIATION FUND	GROSS BLOCK
1	TOTAL WORKSTATION	10,71,204	13,43,021	24,14,225
2	CDS PROJECT (PB)	18,42,559	23,10,103	41,52,662
3	DDBC (BS) PROJECT	1,69,940	2,13,064	3,83,004
4	SEISMO (GPS) PB	82,22,921	66,23,932	1,48,46,853
5	EREC PROJECT	5,52,984	4,57,224	10,10,208
6	MBGH (JTG) PROJECT	10,83,322	13,58,215	24,41,537
7	SIACHEN GLACIER	58,407	36,753	95,160
	TOTAL	**1,30,01,337/-**	**1,23,42,312/-**	**2,53,43,649/-**

11. Separate Financial Statements are prepared for:

a) Wadia Institute of Himalayan Geology.
b) Contributory / General Provident Fund.
c) Pension Fund.
d) New Pension Scheme.
e) Consolidated financial statement of projects sponsored by other Agencies.
f) Projects sponsored by other agencies

12. Corresponding figures for the previous year have been regrouped / rearranged, wherever necessary.

Schedules 01 to 38 and Annexures 1 to 18 are annexed to and form an integral part of the Balance Sheet as on 31st March, 2011, Income and Expenditure Account and Receipts & Payments Account for the year ended on 31st March, 2011

Sd/-	Sd/-	Sd/-
HARISH CHANDRA	**DINESH CHANDRA**	**PROF. ANIL K. GUPTA**
(Finance & Accounts Officer)	(Registrar)	(Director)

Date : 15th July, 2011
Place : Dehra Dun

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