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WADIA INSTITUTE OF HIMALAYAN GEOLOGY
DEHRA DUN
(An Autonomous Institute under Department of Science & Technology, Government of India)

ANNUAL REPORT
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PRÉCIS FROM DIRECTOR

The Wadia Institute of Himalayan Geology all through the years has been continuously striving to unravel the geological truth related to building of the majestic Himalaya with a purpose to improve our understanding of geodynamic processes, climate-tectonic interactions, evolution and extinction of life, processes of ore formations, and glacier melt water contribution to river systems. The environmental change in general, and climatic change in particular in the Himalayan region, are likely to impact significantly upon resources such as water, soil, transforming present-day landscapes and their ecological characteristics. An impact due to earthquakes and landslides greatly influence progress of the socioeconomic developmental activities, and is of concern to people occupying the unstable hill slope areas under the pressure of increasing population. Effect of natural as well as anthropogenic chemical toxicity and deficiencies because of geological and climatic factors are compounded by socio-economic conditions. Considering these societal aspects, the research activities of the Institute are planned accordingly, and major thrust has also been given to societal aspects of geoscientific research activities, which include natural disasters and their management, environmental studies pertaining to sustainable development activity and natural resources.

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. Its research activities are grouped into five mission mode projects that are implemented through long-term and short-term projects of the Institute. These are supplemented by sponsored projects focused at various themes within the ambit of the evolution and geodynamics of the Himalaya. An overview of the on-going activities shows that the year witnessed all around progress in all the research projects and has yielded interesting and useful results. An executive summary of the significant contributions in each mission mode project is highlighted below along with other activities of the Institute.

Himtransects

A preliminary picture of subsurface structure below the Eastern Himalayan Syntaxial region, obtained from receiver function estimations of BBS, shows a dipping structure of Moho from west to east. The results obtained from modelling of receiver functions confirm the gradual increase in Moho depth in the E-W profile, from ~45 km at Brahmaputra valley (near Mahadevpur) to ~63 km further east of tiding suture zone (near Walong).

The resistivity images of crustal section inverted from magnetotelluric investigations along Bijnaur (U.P.)-Malari (Garhwal Himalaya) provide geophysical evidence on the geometry of down-going Indian plate beneath the Outer Himalaya.

Orientation patterns of magnetic susceptibility axes from AMS study performed on soft sediment samples from a trenched fault zone across the Himalayan Frontal Thrust (HFT), western Himalaya helped to identify co-seismic structures in Late Holocene surface sediments.

A comparison of petro-textural and geochemical characters of siliciclastics of the Outer Lesser Himalaya Zone and Inner Lesser Himalaya Zone of Garhwal and Kumaun Himalaya suggest that the Palaeoproterozoic sediments of both these zones have common similarities.

Studies of granodiorites from the Pangong Migmatite-Granodiorite assemblage (PMG) suggest their emplacement during simple shear regime, and later during re-activation of the Karakoram Fault Zone (KFZ). These rocks along with intruded felsic veins were subjected to low temperature near-surface deformation, and show array of last stage entrapment of low saline fluid inclusions.

Climate-Tectonics Interactions

An attempt was made to collate the data on Quaternary deposits of the Ladakh-Lahaul-Spiti region to help synthesize the palaeoclimatic and palaeo-environmental developments. Analysis has shown that the Ladakh-Lahaul-Spiti region is currently faced with cold and dry climate but various phases of warm and moist climate have also prevailed during the late Quaternary period.

Fluvial terraces representing channel, landslide generated and/or flash flood deposits are present extensively between MCT and MBT along the Bhagarithi valley. Sedimentological studies show evidence of cycles of aggradation/incision. The valley aggradation initiated at ~40 ka and continued up to 25 ka, followed by incision. The second phase of aggradation is from 20 to 10 ka, followed by incision resulting in cut and fill terraces, strath terraces, epigenetic gorge and fossil valleys.

A detailed investigation of Patsio paleolake deposit, near the Bara Lacha Pass, has revealed that it was developed due to climate-induced landslide and resultant blockade of the Bhaga River ca. 8-7 ka BP. The termination of fluvial sedimentary sequence and sudden onset of the glacial lake deposit marks an abrupt climate shift towards significant warmer conditions around 6.3 Ka BP. This corresponds to one of the significant global climate events (i.e. mid-Holocene optimum) of the Holocene.

Speleothems are very reliable to interpret the paleoclimate and Monsoon patterns of the past. The long term rainfall and precipitation variability over the Himalaya from NW to NE using stable isotopes indicate higher monsoon rainfall during the Holocene.

Two alluvial fan sequences, an older (36-29 Ka) in the southeastern part of the Soan dun and younger (23-10 Ka) in the northwestern part, indicate creation of accommodation space due to Soan Thrust activity. The termination phases of these fans occurred in the known reported increased monsoon phases, and are correlated to climate change. The termination phase of older fluvial fan sequence around 29 Ka in the paleo-gorge suggests the simultaneous occurrence of channel abandonment and subsequent shifting of the Satluj River.

Biodiversity-Environment Linkage

The Muth Formation in Pin valley is dominated by quartzite facies with ichnofossil throughout the succession. The ichnofossils represents a variety of ichnogenera which show intertidal or littoral settings having a soft and sandy substrate and presence of annelid worms indicative of deep marine environment.

Minamiite, a Ca-bearing hydrous sulphate mineral, is reported for the first time in India from the Deccan Volcanic Province at Matanumadh (Kachchh, Gujarat). These hydrous sulphates of secondary origin can serve as a potential Earth analogue for the Mars and the Martian conditions.

Basin architecture of the South Shillong Plateau, Meghalaya suggests passive continental margin setting of Mahadeo sediments. These were deposited in tensional rifted basins where divergent continents India, Antarctica and Australia separated and new Neotethys ocean formed. Cretaceous – Paleocene boundary is considered to lie in upper part of the Mahadeo Formation based on sedimentological, foraminifera and from the new microfish remains from overlying sediments.

Mineralogical, textural and geochemical characters of the high-silica rhyolitic tuff breccia, at the base of the Subathu Formation in Kalakot, provide stratigraphic evidence of early collision between the Indian and Asian plates. It thus forms an important time-synchronous stratigraphic marker horizon in the foreland stratigraphy.

Fossils bones and dentitions of primates and other mammals recovered from the horizons corresponding to Early Eocene Climatic Optimum show a rather close similarity with the contemporaneous fauna from Europe indicating faunal connection with that continent during the Early Eocene (~53 million year ago).

From chemical characterization of organic remains from Dharmsala Group of Kangra valley it is postulated that beginning of orogeny was apparently key driver for resurgence of life on southern flank of the Himalaya during early Miocene time. The early Eocene life known from the sequence was plausibly wiped out by global sea level fall as a precursor to the beginning of Ice Age Earth.

Sustainable Natural Resources

Glacier monitoring of Dokriani in Bhagirathi basin and Chorabari in Alaknanda basin revealed that both the glaciers are retreating with negative mass balance trend. The specific balance and the snout recession rate indicate that the processes of mass balance and snout retreat are two different phenomenon, and may not totally governed by the climate, as other factors like orientation, shape and size, bed rock slopes, debris cover thickness and geometry of the snout area also play vital roles in regulating the dynamic process of the glaciers.

The melt-water chemistry of Chorabari glacier shows a low concentration of NO_3 and Cl, and relatively higher concentrations of lithogenic ions (e.g., Ca, Mg, K, SiO_2, HCO_3, So_4). The average daily concentration of cations in meltwater of Chorabari glacier are $Ca^{2+} > K^{+} > Na^{+} > Mg^{2+}$ and of anions are $HCO_3^{-} > SO_4^{2-} > Cl^{-} > NO_3^{-}$. Diurnal variations in TDS, conductivity and all ionic concentration indicate that sub glacial water may be the major source of water during the summer. The pattern of solute concentration variation is consistent with release of the ion-rich melt-water.

The initial results of ore chemical and fluid inclusion studies on the polymetallic sulphide mineralization from the Chiplakot crystallines suggest plausible hydrothermal origin for the mineralization.

Geo-accumulation index (I-geo), applied for the purpose of environmental evaluation of heavy metals distribution in Pinjaur Dun area, indicated that leaching of metals from garbage and industrial sewage has led to enhancement of metal concentration (Pb, Zn and Cu).

The climate change impact on ecologically sensitive ecotones such as tree line and snow line of Dokriani glacier has been studied. *Betuls utilis* (1 to 4 m tall) represent new tree line that have migrated and invaded the elevation of 3800m a.m.s.l. The old and mature tree line is being represented jointly by *Quercus semicarpifolia* and Betula *utilis*. Spatial migration of tree line towards higher elevation and changes in its floristic composition are indicative of change in drivers of ecotones such as temperature, humidity, pressure etc. The Snow line was reported earlier at an elevation of 5085 m a.m.s.l.

The petrochemical studies of gabbroic intrusives within the carbonate and calcareous-quartzite of Miri-Buxa Group in the Siang Window of Eastern Himalaya suggest that they are derived from enriched mantle source in a continental rift tectonic environment.

The petrochemical studies of assemblage at the base of Lesser Himalayan sequence from Eastern Almora Nappe, Askot Crystallines, and Chhiplakot Crystallines suggest for probable arc magmatism during the Paleoproterozoic times.

Real Time Geology for Society: Coping with Natural Hazards

Ashok Kumar Dubey
Acting Director

PROGRESS IN RESEARCH PROJECTS

MMP-1 : HIMTRANSECTS

Component 1.1

Multiple Geophysical studies for imaging deep Lithospheric structure Investigation beneath Himalaya

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

With the objective of imaging deep subsurface in terms of electrical resistivity, seismic velocity and other parameters, broad band magnetotelluric investigations (1 Khz- 4096 sec), seismological methods like receiver function analysis, seismic tomography and seismicity studies were carried out in Eastern and North west Himalaya.

Receiver Function analysis and Seismic Anisotropy study for investigation of deep subsurface structure and mantle deformation pattern in Himalaya

(i) Eastern Himalayan Syntaxis - Deep subsurface structure of Eastern Himalayan Syntaxis (EHS) region has been studied based on Receiver Function estimations in 12 broadband seismic stations in Lohit valley, Arunachal Pradesh. A total of 971 receiver functions were obtained using good quality waveforms from 273 teleseismic earthquakes in the epicentral distance of 30° to 90°. These receiver functions were stacked according to backazimuth and ray parameter in order to reduce the noise. The present study reveals complicated and azimuthally varying lithospheric structure in the NE corner of Indian plate in EHS. The most prominent feature of Receiver Function (RFs) is the absence of clear Moho P-to-S converted phase for the earthquake waveform of NE backazimuths (30° – 90°) that pierces mostly the NE Indian Plateau and Tibetan Plateau. In contrast to it, RFs from other backazimuths clearly show Moho converted phase. This observation supports indenter hypothesis where due to the intense crust mantle interaction, the character of Moho might have been lost beneath the syntaxis. Modeling of RFs suggests a gentle dipping structure of Moho towards north and east, which is consistent with the underthrusting of Indian plate beneath Eurasian plate. The depth of Moho increases gradually in the NW-SE profile from ~45 km at Brahmapura valley (near Mahadevpur) to ~63 km further east of Tidding suture zone (near Walong).

The clockwise rotation of crust and mantle material surrounding EHS particularly in Tibetan plateau is well established, whereas the mantle flow/strain in NE India lithosphere in EHS is poorly understood due to paucity of geophysical data in the region. An attempt is made to study the mantle flow pattern in the region using shear wave (SKS) splitting technique. A total 142 splitting parameters (delay time, δt and fast polarization direction, ϕ) estimated from teleseismic SKS phases reveal considerable strength of anisotropy (delay time ~1.2-1.9s) in upper mantle with predominant E-W fast axis direction indicating the direction of mantle flow or strain. This E-W mantle flow continues beyond Tidding Suture zone and Walong thrust, and connects to the N-S dominated mantle strain regime in Sichuan, SE Tibet. The splitting parameters from this study along with the existing results from Tibetan plateau surrounding the EHS clearly shows the complicated strain partition in the upper mantle of EHS and indicates a transition from collision controlled mantle deformation in NE India to deformation influenced by other forces in SE Tibet. However, further studies are needed to establish the nature of transition in more details. The discrepancy of E-W trend of fast axis direction with present day crustal movement of NE India (NE directed) indicates the possibility of crust mantle decoupling in the region.

(ii) Northwest Himalaya - The teleseismic earthquakes recorded by the VSAT connected seismic network (consisting of 10 broadband seismic stations) operated by WIHG, Dehradun

have been analysed using Receiver Function Method to study the Moho and intra crustal layers. Total about 200 earthquakes have been analysed at the 10 broadband seismic stations. The RFs shows clear azimuthal variations of crustal structure. The mid crustal ramp is very clear from the comparision of RFs among the station pairs namely: Adibadri (ABI) - Tapovan (TPN), Ghuttu (GTU) - Gaurikund (GKD) and Chakrata (CKA) - Kharsali (KSI). The modelling of these receiver functions are in progress for detailed study of crust and upper mantle in NW Himalaya.

Fault Plane Solutions of significant felt earthquakes of the NW Himalaya

Significantly felt earthquakes (M$\geq$ 3.5) of NW Himalaya occurred during the last year (2009) were located with recently developed 1D velocity model of the NW Himalaya. The source region around refined source locations were analysed using the seismic waveform and obtained Fualt Plane Solutions (FPS). These include six seismic events having good station azimuthal coverage to constrain FPS, five out of these occurred along the Main Central Thrust (MCT) and one to the south of Himalayan Frontal Thrust (HFT) near Deoband. These solutions are dominated with thrust/reverse faulting providing oblique deformation along strike-slip movement in this highly stressed region of NW Himalaya. In addition a deep seated event was also located near to South Tibetan Detachment (STD) north of Gaurikund having Normal fault mechanism. The four thrust type of FPS which were near the MCT have their nodal plane oriented towards East-west direction with P-axis directed towards north perpendicular to the trend of Himalayan fault/thrust system. But the FPSs south of Himalayan fault system shows pure thrust type of faulting nature, with its Nodal plane N-S oriented and the P-axis is E-W directed, which is Parallel to the trend of Himalayan mountain belt.

Seismogenesis of clustered seismicity beneath Kangra-Chamba region

Combined interpretation of variation of P- and S-wave velocities along profiles passing through cluster seismicity in the Kangra-Chamba region and the deformation inferred from focal mechanism are utilised to assess the seismogenesis in this region. As shown in figure 1, the variation of sub-surface structure and the deformation during intermediate size earthquakes were studied along three profiles. Two profiles, AB and CD have been taken across the major tectonic features while one profile was selected parallel to these tectonic features. In this part of the NW Himalaya, the Main Boundary Thrust (MBT), the Palampur Thrust (PMT), the Punjal Thrust (PT) and the Chamba Thrust (CT) are dipping towards northeast having steep dip near the surface which flatten out with depth and finally merge with the gentle dipping detachment (decollment). Along these three profiles, the variation in both P- (Vp) and S-wave (Vs) have been observed but without any particular linkage with tectonic discontinuities, however the ratio of these waves (Vp/Vs) has provided much information. Therefore, the variation of Vp/Vs has been shown in figure 2 along with tectonic discontinuities. The gently dipping detachment plane is traced out by the top interface of Vp/Vs at an average depth of ~ 15 km near the MBT in the southeast part along profiles AB and CD.

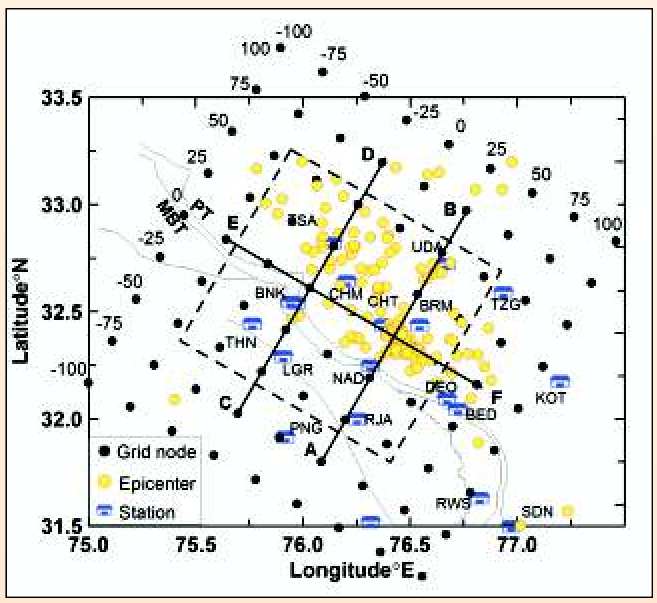


Fig. 1. Profile location along Kangra-Chamba region.

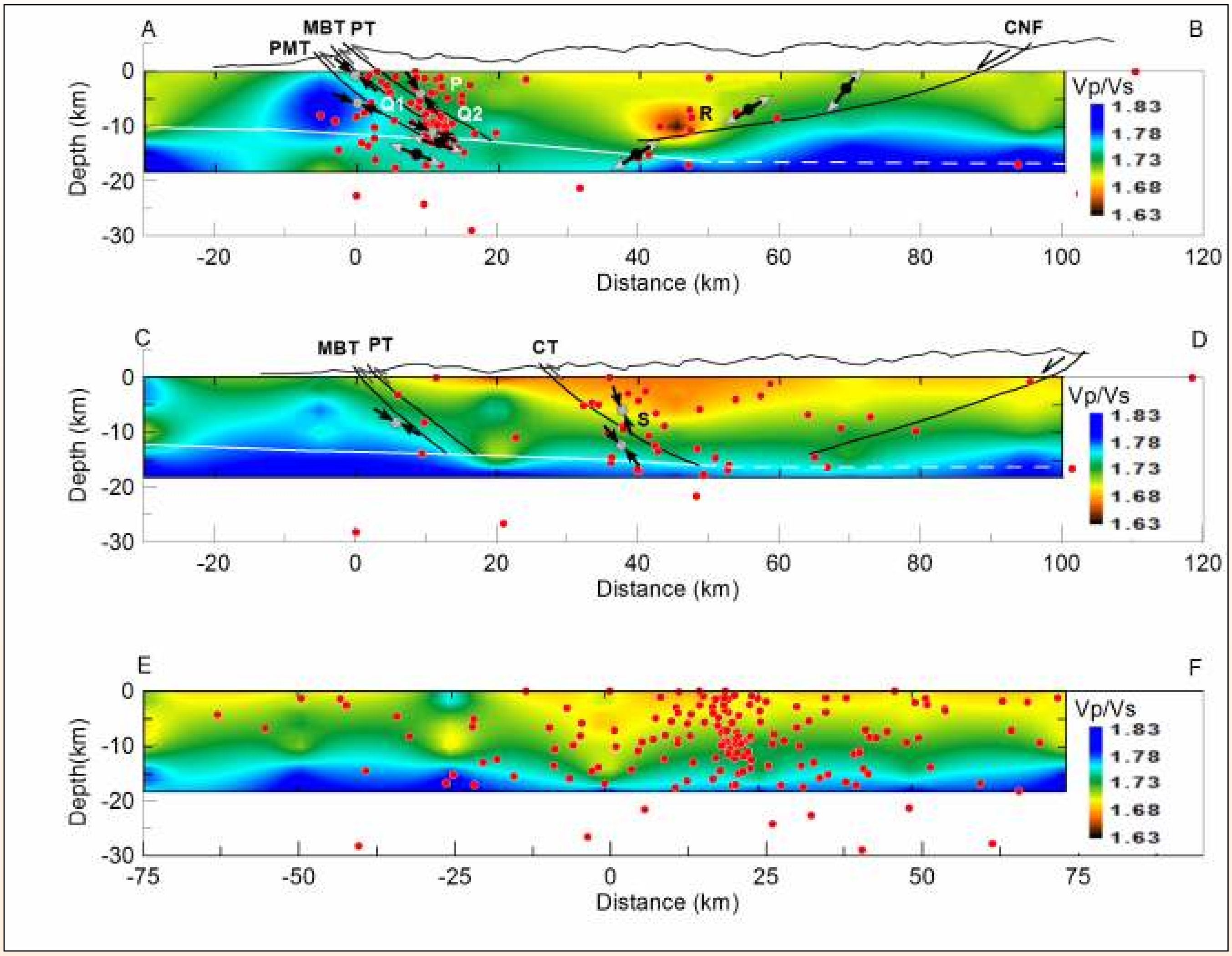
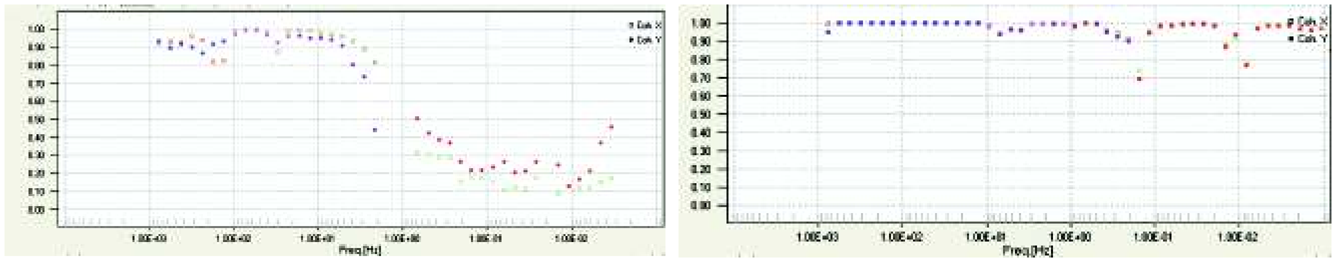


Fig. 2. Vp/Vs variation along profile AB, CD, EF.

In depth sections above plane of detachment most of the earthquake hypocentres are concentrated at the sharp transition in velocity structure along profile AB that is reflected in Vp/Vs plot demarcating major litho-tectonic boundaries. Along CD profile the interface of low and high Vp/Vs plot demarcates the major tectonic units of MBT and PT but the earthquakes are not concentrated along these tectonics. In this seismogenic fault, the CT is located in the northern side where as contrast in Vp/Vs is not visible. This marked difference appears to be related to varying limits of southward extension of Chenab Normal Fault (CNF), which is limited by CT in the western part. In the northeast part of these two profiles a weak cluster of seismic events is visible which can be inferred along a plane portrayed as subsurface extension of southwest dipping Chenab Normal Fault (CNF). Different clusters of seismic events (P, Q1, Q2, R and S) have been observed along these profiles which have tectonic linkage. Irrespective to this along profile EF only demarcation of high Vp/Vs has been observed at an average depth of 15 km indicating the separation of two tectonic units as demarcation of detachment plane.



Year 2009 Year 2010

Fig. 3. Coherency between electric and magnetic field measurements during the years 2009 and 2010.

The plunge angles of the axis of maximum stress is related to the thrust dominated earthquakes on the northeast dipping PT/MBT as well as CT varying from 30°-35° in the shallow section to low dips of 10°-15° at the deeper part along detachment plane. However along the sub-surface extension of the CNF focal mechanisms are dominated with normal fault type showing NE-SW directed extensional stress. Hence the synthesis of seismicity, crustal velocity structure, distinctive focal mechanisms and the nature of stress distribution allow new insight into operative dynamics that controls the seismotectonics of the Kangra-Chamba region.

Magnetotelluric Investigations

Magnetotelluric investigations are primarily focussed in Garhwal Himalaya and electro-magnetic field variations are measured along Bijnaur – mallari profile. Since last couple of years minimum phase of solar cycle hinder the estimation of transfer function beyond 1 sec. This poses a great challenge for getting data at periods greater than 1 sec in Himalaya during last couple of years. This year onward, rising phase of solar cycle is witnessing increasing solar activity and thus provides natural signals for getting information for periods greater than one sec. (Fig. 3).

Sounding curves along the profile not only depicts characteristic pattern of their location in broad tectonic framework but also shows variation in their pattern within defined tectonic boundaries. Dimensional and decomposition analysis along the profile reveal that most of site has 2D character of regional resistivity distribution. Multi-site multi-frequency strike analysis shows that regional strike follow tectonic trend. 2-d inversion of existing station reveals existence of mid crustal conductor at a depth of decollement. The geometry of this conductor around MCT is unclear due to absence of good quality transfer function around MCT. Upper crust is mostly resistive all along the Himalaya, whereas upper crust along Indo gangetic plains is moderately conductive. Observing the increased solar activity, gap along the profile will be covered this year for executing 2-d inversion along entire profile.

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)

The study area lies in the eastern part of the Ladakh and Karakoram. The most striking feature of this region is the bifurcation of the main Karakoram Fault, namely the Muglib Strand and the Tangtse Strand. The easternmost part of this area consists of the Karakoram Plutonic Complex.

This complex is characterized I and S type of granitoids. The inner part is characterized by quartz monzonite, granodiorite and tonalite assemblage, while the outer part displays younger garnet-bearing two mica granites. To the east of this batholith lies the Pangong or Karakoram Metamorphic Complex. It consists of calc-silicates, slate, mica schist, greenschist/amphibolite and marble along with augen gneiss and granite mylonites The Muglib Strand separates the Pangong Metamorphics from the Pangong Migmatite-Granodiorite (PMG). This unit comprises alternate layers of migmatite and granodiorite. The granodiorite displays evidence of solid state deformation. Near the Tangtse Strand the granodiorites are mylonitized.

The Pangong Migmatite-Granodiorite assemblage (PMG) constitutes an important component of the Karakoram Fault Zone (KFZ). Field investigations reveal that Granodiorites were emplaced, as leucosome part of the Migmatite escaped from the system due to non-coaxial deformation. Later on they were intruded by felsic veins, which subsequently suffered brittle deformation. Microstructures reveal presence of microfracturing of plagioclase phenocrysts and subgrain and bulging recrystallization of quartz. Back Scattered Electron (BSE) images show that area reduction of the plagioclase has taken place by fracturing and replacement of Na by K in its rim and fractures, which indicate a solid state deformation at green schist condition. Based on these findings, it is inferred that the Pangong Granodiorites were emplaced during simple shear regime and later, along with the felsic veins that intruded them, were subjected to low temperature near-surface deformation during re-activation of the KFZ. Later on they got partially overprinted by the last stage entrapment of low saline fluid inclusion array. This study combined with published geochronological data suggests that non-coaxial deformation prevailed in this region even before the believed maximum age of initiation of the Karakoram Fault Zone.

P-T data and fluid chronology of Tso Morari Gneissic (TMG) dome expressed in terms of fluid inclusion isochors plots to see the reasonable metamorphic path within wide range of temperature and pressure. The isochors plot has been displays against the P-T trajectory; broadly they are grouped in to two; as gaseous inclusions and high (brine) to low saline aqueous inclusion. Isochors of gaseous inclusions containing N_2, CH_4, and CO_2 phases which is occupied and spread comparatively in the lower part of the P-T-plot upto P ~5 kbar. It shows the re-equilibration must have faced considerable amount of leakage, this resulting only low density fluid is leftover in the inclusions. However, presumed isochors plots for the N_2 and CH_4 gaseous phases could have been occupied at or near the peak P-T condition, ~39 kbar and 750°C and CO_2 presumably at the eclogite-granulite transition, ~12 kbar and ~800°C. The population of aqueous inclusions (high and low) is plotted on Tm (Temperature of melting; salinity)-Th (Temperature of homogenization; density) diagram. In that the marked five zones displays low saline aqueous inclusions trapped in the matrix quartz showing homogenization temperature in the range of 100-160ºC, though same could also be homogenized at high temperature ~260ºC, this possibly modified and explained through the leakage process. The isochors has been selected for each category corresponds to maximum and minimum Th/Tm, this occupies at the retrograde part of the P-T trajectory between P~5-12 kbar. However, isochors plots at lower part of the P-T plot at ~4-7 kbar and 650 to 500°C have been greatly influenced by the later stage modification during the last stage of exhumation. Though, the P-T trajectory illustrates the fact that the last stage of exhumation path doesn't follow by single reaction.

Stratigraphic and structural mapping in Ladakh suggests that, ophiolite and ophiolitic mélange of the Indus Suture Zone were emplaced diachronously along eastward progressing collision plane. Immediately after the initial collision with Dras Volcanics and volcanic arc sediments of the Nindam Formation, the ophiolitic mélange emplaced as the Sapi- Shergol Ophiolitic Melange (S-SOM) in western Ladakh during late Paleocene and its lateral eastward extension terminates to the southeast of Lamayuru. The Khalsi ophiolitic mélange (KOM) emplaced to the north of S-SOM emplaced during later part of middle Eocene terminated near Nalbukar in eastern

Ladakh. With continued N-S contraction, the collision boundary in eastern Ladakh which was passing through the KOM shift north of the Tso Morari Crystalline Complex and form a new collisional boundary demarcated by Zildat Ophiolitic Melange (ZOM).

The NNE-SSW trending Tso Kar Fault and its parallel series of faults cross cut the rocks of the Hemis Member of the Indus Formation of middle to late Eocene age and joins WNW-ESE trending Zildat Normal Fault zone along which the ZOM was emplaced. Numerous thin bands of serpentinized ultramafics of the ophiolitic mélange along the Tso-Kar Fault (TKF) exhibit slickensides suggesting NNE-SSW sinistral movement. These ultramafic rocks observed along the Tso Kar Fault plane near Thukche are also brecciated. These ophiolitic mélange belts of the Indus Suture Zone have originated in response to multiple collisional phases as the collisional boundary progressed from west to east due to anticlockwise rotation of the Indian plate. The emplacement of Sapi-Shergol, Khalsi, Zildat ophiolitic mélange and Nidar ophiolitic complex rocks at different times and even at different places reflects the kinematic deformational stages of the India-Asia collision during Cenozoic time in the NW Himalaya. Based on present mapping, the KOM was emplaced during late Paleocene to later part of Early Eocene to Middle Eocene while ZOM emplaced within the Hemis Member of the Indus Formation during terminal part of late Eocene to Oligocene time respectively. The presence of ultramafic rocks and erosional outlier of flysh and molasses of Indus Formation within the ophiolite sequence signify that the Nidar Ophiolitic Complex (NOC), in the southeastern Ladakh has exhumed faster than the western Ladakh. As the northward movement of the Indian Plate continued, the oceanic crust along with volcanic rocks of Nidar Ophiolitic Complex were thrust over the Zildat Ophiolitic Melange to the south and Hemis member of the Indus Formation or the Kargil Formation to the north respectively as a pop up structure during early Miocene observed along the Sumdo-Mahe section. To the western part of the southeastern Ladakh, a narrow upper part of the NOC with dominant chert is emplaced oblique to the strike of the Indus Formation and terminates to the north of Rumtse with Khalsi Ophiolitic Melange.

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)

The anisotropy of magnetic susceptibility (AMS) study was performed on soft sediment samples from a trenched fault zone across the Himalayan frontal thrust (HFT), western Himalaya. Well-defined vertical magnetic foliation parallel to the flexure cleavage in which a vertical magnetic lineation is developed, high anisotropy, and triaxial ellipsoids suggest large overprinting of earthquake-related fabrics (Fig. 4). The AMS data suggest a gradual variation from layer parallel shortening (LPS) at a distance from the fault trace to a simple shear fabric close to the fault trace. An abrupt change in the shortening direction (Kmin) from NE–SW to E–W suggests a juxtaposition of pre-existing layer-parallel shortening fabric, and bending related flexure associated with an earthquake. Hence, the orientation pattern of magnetic susceptibility axes helps in identifying co-seismic structures in Late Holocene surface sediments.

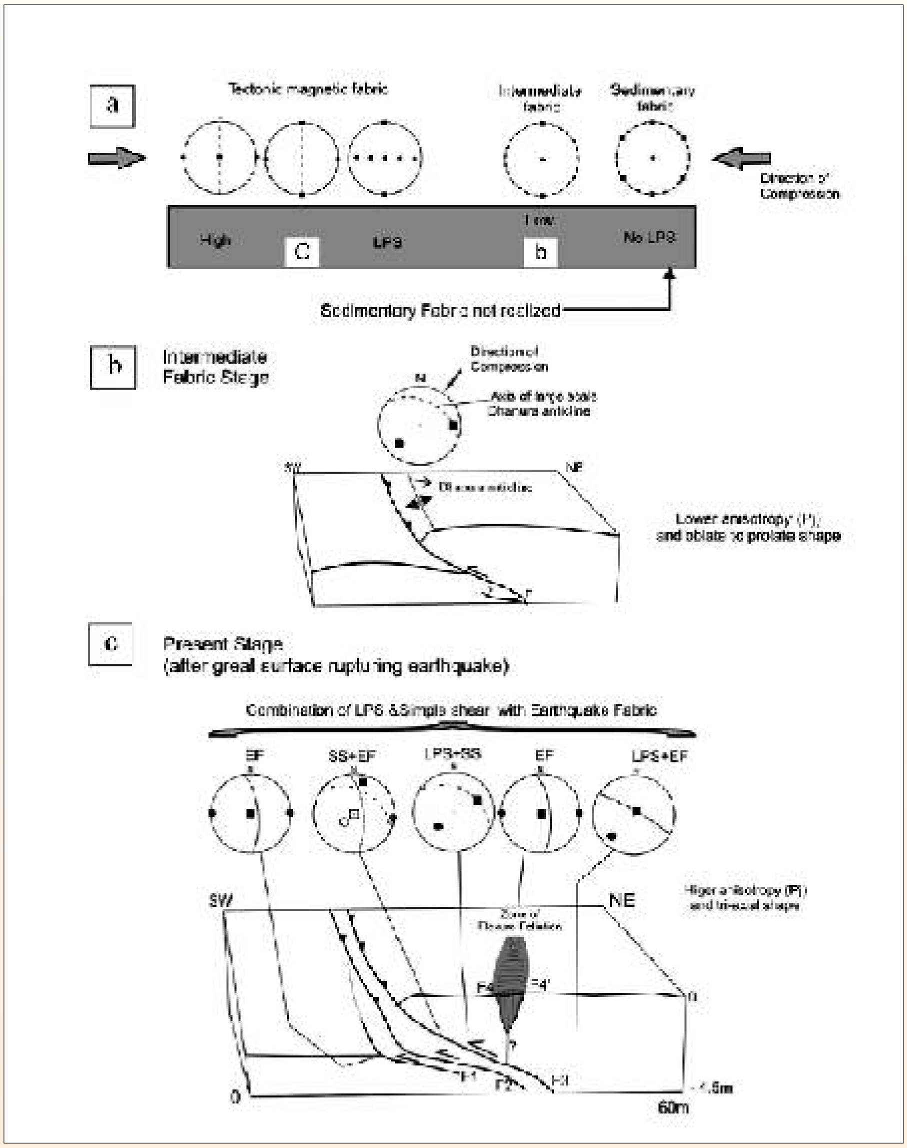


Fig. 4. a) A schematic representation of evolution of magnetic fabrics and orientation of susceptibility axes with respect to degree of layer parallel shortening (adopted from Saint-Bezar et al. 2002) (equal area lower hemisphere projection). b) A simplified cartoon depicting intermediate fabric stage during the development of DA. Note that Kmax is aligned normal to the direction of compression. c) A simplified cartoon of the trench showing earthquake induced fabric pattern. At the back end of the basal thrust within the extensional fault zones F4–F40, a large earthquake fabric shows vertical fracture foliation, magnetic foliation, and magnetic lineation (Kmax) with EW alignment of the Kmin dominates. Broken lines magnetic and slaty cleavage; solid line magnetic foliation and flexure or fracture cleavage. Near the basal thrust (F2), AMS fabric shows simple shear (solid symbols) and earthquake fabric (EF, hollow symbols), whereas away from the basal thrust, simple shear fabric (SS) is overprinted on pre-existing layer parallel shortening (LPS) fabric. The Kmin axis is parallel to the regional shortening direction (NE–SW).

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 reporting period, the work is mainly focused on the long standing issue about the correlation of sedimentary packages of the Lesser Himalayan zones. Based on stratigraphic disposition of the Garhwal and Kumaun Lesser Himalaya, the sedimentary rocks are grouped as Outer Lesser Himalaya zone (OLHZ) in the south and Inner Lesser Himalaya zone (ILHZ) in the north. The OLHZ comprises Proterozoic Chandpur and Nagthat formations of the younger Jaunsar Group and ILHZ consists of Proterozoic Chakrata and Rautgara formations of the older Damtha Group. Field study suggests that the siliciclastic packages of Nagthat of OLHZ and Rautgara of ILHZ lie in the same stratigraphic plane. Similarly the argillite packages of Chandpur of OLHZ and the Chakrata of ILHZ (partly also in the OLHZ) lie in the same stratigraphic plane, only it is the lateral facies variation. In addition an attempt also has been made to correlate the sediments of OLHZ and ILHZ, using petro-textural and geochemical characters of the Lesser Himalayan succession of the Garhwal and Kumaun regions.

Comparison of the petro-textural and compositional characters of siliciclastics of both the zones suggests that OLHZ siliciclastics are relatively rich in rock fragments and ILHZ is rich in feldspar. This trend seems to be somewhat reverse as ILHZ represents the more distal end and sourced from the south then it is expected that it would be rich in quartz, poor in feldspar and rock fragments and quartz arenitic. Grain- size wise the ILHZ siliciclastics should be finer and well sorted. Overall the ILHZ siliciclastics should be both texturally and compositionally mature than that of the OLHZ siliciclastics. Texturally siliciclastics of both zones are medium grained, sub-angular to sub-rounded and moderately sorted. The marginal decrease in grain size towards north favours southerly source and therefore ILHZ may possibly a part of the distal end of the shallow sea. The quartz types (monocrystalline non-undulatory- MNUQ, monocrystalline undulatory- MUQ, and polycrystalline-Qp) and the Qm / Qp ratio do not reveal any significant variation from OLHZ to ILHZ. The average MNUQ type content is more in ILHZ and reverse is the case with MUQ, it is more in OLHZ. The Qm / Qp ratio is more in OLHZ. As per the stability, MNUQ type is following usual trend. Normally the MNUQ are relatively more stable and therefore can survive towards the distal end. Similarly, the feldspar types (plagioclase -PF and potash- KF) and the PF/ KF ratio also do not reveal any significant variation from OLHZ to ILHZ, except PF and KF is marginally high in ILHZ and OLHZ, respectively. This unusual trend may possibly indicate local supply, as in the case of quartz. Some unusual trend is noticed in MUQ , Qm / Qp ratio, PF and KF detritals may possibly indicate local supply or it may be caused due to landward progradation of the shoreline as observed in the Nagthat Siliciclastic. Zone wise no apparent variations also noticed within the rock fragment types (igneous -Ri, metamorphic-Rm, and sedimentary- Rs). However, in terms of specific rock fragments, relatively chert and metaquartzite dominates in OLHZ and siliciclastics, argillites, low grade metamorphics and basic volcanics in the ILHZ .The trend is again unusual. Being the OLHZ near to source, relatively unstable argillite, low-grade metamorphics, and volcanics detritus should dominate in this zone. Which is not in this case, thus possibly indicate an uplifted mass may be present between this OLHZ and ILHZ or it may be caused due to landward progradation of the shoreline.

Similar trend is also noticed from geochemical data. Both the OLHZ and ILHZ sedimentary rocks display compositional variation from that of argillaceous to arenaceous. This can be best viewed by the linear array of different major oxides against SiO_2 and Al_2O_3. Except Na_2O and CaO, majority of the major elements show inverse relationship with SiO_2 and a positive correlation with Al_2O_3. The distribution of CaO is highly scattered, no trend can be ascertained from this plot whether it is with SiO_2 or Al_2O_3. Although a negative trend is observed from SiO_2 vs Fe_2O_3 plot. Similar behaviour is also observed in case of MgO. The relationship between K_2O and Al_2O_3 is very good for both OLHZ and ILHZ. TiO_2, Fe_2O_3, MgO and K_2O exhibit positive trend with Al_2O_3. The Al_2O_3 and K_2O relationship shows very high correlation coefficient (0.93) which indicates clay mineral control on the major element composition that is diluted with increasing quartz content of both OLHZ and ILHZ. The Na_2O exhibits varied behaviour, the Chandpur and Chakrata formations from both OLHZ and ILHZ sediments show a positive trend with SiO_2, but no trend observed for Nagthat and Rautgara formations. However, the concentration of Na_2O is less than UCC, TTG (Proterozoic and Archean) and granites but the composition of PAAS is in the range of Lesser Himalayan rocks. This indicates plagioclase do not have major control on the Al_2O_3 as well as early decomposition of plagioclase feldspar prior to the decomposition of K-feldspar. CaO shows wide scatter against both SiO_2 and Al_2O_3. Except K_2O, in terms of alkali metal the Rautgara sediments exhibit wide scatter for both argillaceous as well as arenaceous packages. Moderate to high CIA value, presence of illite and muscovite in most of the samples in A-CN-K plot is typical of non-steady state weathering condition. The clastic sediments of Lesser Himalaya are enriched in LREE with pronounced negative Eu anomalies. HREE patterns are moderately depleted. High Zr and Th contents and Th/Ni, La/Sc and $(La/Yb)_N$ ratios as well as Sc vs Th/Sc relationship suggest a dominant felsic source for these rocks. From this study, it is inferred that there are similarities between the Palaeoproterozoic sediments of both the zones of the Lesser Himalayan regions.

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

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

Geochemical and isotopic studies of the riverine phases (water and sediments) and the source rocks from the Indo-Ganga system are being carried out to understand the sources of sediments and erosion over individual sub-basin. Along with the other lithologies in the headwaters of the Indo-Gangetic systems, quartzites are the major source rocks and therefore have important control on the geochemistry of the river sediment. These source quartzites have varying isotopic and chemical composition with different depositional settings indicating variation in their protoliths. We have collected quartzite samples (collected from the either side of MCT zone) from Kaliasaud in Alaknanda Valley, Joshimath-Malari along Dhauli Ganga river and Joshimath-Badrinath traverse (Pandukeshwar quartzite).This work is aimed to address the source (provenance) and nature (evolved or primitive) of these Quartzites. Towards this the major and trace elements and isotopic ($^{87}Sr/^{86}Sr$ and $^{143}Nd/^{144}Nd$; ε_{Nd}) studies on these Quartzites were done. Preliminary results of Neodymium isotopes ($^{143}Nd/^{144}Nd$) show that Lesser Himalayan Quartzites (Kaliasaud-Alaknanda region; Nd ranging from -20.8 to -23.5) are different than those from higher Himalayan region (ranging from -16.5 to -19.6 except one sample -27.7). The reasons of this depleted value (-27.7) is yet to understood. Though, the depleted values from the lesser Himalayan region indicate a more evolved crustal source than those from Higher Himalaya, however, the less evolved crustal source which sourced these Quartzites looks dominating.

Further work as a part of this project is underway to study provenance characteristics and sediment budgeting in the Himalayan sub-basin. These regions include the Ganga (Bhilangana, Bhagirathi, Alaknanda, Mandakini, Pindar, Nandakini, Dhauli, Birahi & Saraswati) and the correlation between TiO_2 and SiO_2. This indicates homogeneous character of Bhaironghati granite and Gangotri granite. P-T estimates of Higher Himalayan crystallines reveal increase in both pressure and temperature across the Vaikrita Thrust from south to north. Temperature increases from 500 to 750°C and pressure from 6 to 10 kbar across the MCT zone. Also, THERMOCALC software was used to understand and calculate partial melting equilibria for metapelites of the Higher Himalayan Crystallines.

Component 1.7

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

(Keser Singh)

The Chenab valley around Doda and Kishtwar regions represents a unique cross section through the Himalaya, where the Lesser Himalayan rocks (LH) are exposed as thrust sheets as well as in a window, the HHC as a large thrust sheet and the structurally highest Tethys Himalayan rocks as nappes i.e., Chamba and Kashmir Nappes. From south to north, the Lesser Himalayan rocks are thrust over the Siwalik Group and the Murree Formation along the Main Boundary Thrust (MBT). The Lesser Himalayan thrust sheets toward foreland are the Shali Imbricate Zone (SIZ) and the Chail Thrust Sheet (CTS) occurring as NW-SE trending nearly linear belts. Along the Chenab valley, the SIZ comprises imbricated limestone, slates, basic volcanics and orthoquartzite sandwiched between the MBT and the Panjal Thrust (PT; equivalent of Chail Thrust). The CTS, positioned over PT, comprises phyllites, slates, quartzite, mica schist, basic volcanic rock and Cambro-Ordovician granitoids such as Mandi/Dalhousie, Kundkaplas, Ramsu granitoid. Transverse to this general trend and more than 30 km. inside toward northeast, an oval shaped body comprising dominantly quartzite, phyllites and various granitoids of the Lesser Himalayan rocks, encircled by the HHC, has been described as the Kishtwar Window. The tectonic contact along the window was described as the MCT. However, the present study of the window indicates that its western side is bounded by a high angle NE dipping reverse fault (Kishtwar Thrust). The structural analyses reveal that this fault is younger than the MCT. Present observations suggest that the rocks of the window and the northeasterly lying HHC have been folded and exhumed together as an antiform along the Kishtwar Thrust. The HHC occurring south of the Kishtwar Window have actually been thrust over the Lesser Himalayan thrust sheet. The recognition of a tectonic break along the Chenab valley, south of the Kishtwar Window, where the High Himalayan Crystallines thrust over the Lesser Himalayan rocks, is observed for the first time and marked as the Main Central Thrust as per convention along the length of the Himalayan belt. The Kishtwar Thrust appears to have breached through the MCT, and is, therefore, interpreted as a “breach-thrust”. The uplift along the Kishtwar Thrust also explains the recurrence of concealed portion of the overthrusted High Himalayan Crystallines/Lesser Himalayan sequence, now exhumed together as the Kishtwar Window. In other words, the HHC(E)-Lesser Himalaya contact pre-dated the formation of the Kishtwar Window, suggesting that the MCT was already developed, thus this uplift along the Kishtwar Thrust, have again exposed the deeper part of the MCT brought to the surface by Kishtwar Thrust, north of the already exposed MCT.

MMP 2 : CLIMATE-TECTONIC INTERACTION

Component 2.1

Climato-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)

During the year attempt was made to collate the data on the Quaternary deposits of the Ladakh-Lahaul-Spiti region to help synthesize the palaeoclimatic and palaeoenvironmental developments in the region. The detailed lower than the MWP. Primarily magnetic result from the Chorabari glacier region reflects that climate influenced on the sediment production in higher Himalayan region.

Component 2.3

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

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

Cut-and-fill type fluvial terraces are ubiquitous in the Lesser Himalayan zone of the Bhagirathi-Alaknanda-Ganga (Ganges) rivers system which flows, perpendicular to Himalayan litho-tectonic units and traverses a steep climatic gradient. This year we studied six sections located at Bhatwari, Malla, Gangnani-Maneri, Gyansu, Atheli and Chinyalisaur along the river Bhagirathi. The lithofacies analysis of the sedimentary sequences of cut-and-fill terraces was carried out that indicate that the valley aggradation took place via (1) channel bar development and excess sediment supply, (2) debris flows composed of mixed rounded to sub-rounded lithoclasts, resulting from episodic high intensity rainfalls in the upper catchment or (3) debris flows or rockfalls generated by local landslides. The luminescence chronology indicates that valley aggradation took place in two phases of ~49–25 ka and 18–11 ka. This strengthened our views on the aggradation and incision of the Himalayan Rivers. The incision of the fill started soon after 11 ka. Paleoclimatic records from marine sediments indicate that the aggradation and incision in the Alaknanda-Ganga River has oscillated in-phase with global climatic variations. Glaciation–deglaciation processes in the upper catchment produced huge amount of sedimenst between 63 and 11 ka, which was fluvially transferred to the lower valley via several cycles of erosion and deposition, leading to extensive aggradation. The climatic amelioration at ~11 ka and the completion of deglaciation processes led to increased fluvial discharge and decreased sediment supply, conditions conducive for incision of the alluvial fills. Records from the Indo-Gangetic plain and the Ganga Delta demonstrate that the phase of aggradation was regional but that incision in the foreland started at least 2–3 ka later, after 7 ka. This study suggests that during the last 50 ka river dynamics in the Himalayas were dominated by monsoon variability and the role of tectonic activity was limited to bedrock incision in few reaches only.

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 much 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 (Fig. 6). Speleothems from the Sahastradhara cave, Uttarakhand and Mawsmai and Mawmluh caves from Meghalaya in east Khasi hills were studied for palaeoclimate interpretation. Samples were collected for the sedimentological facies, carbon and oxygen isotopic variation 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 precipitation variability over the Himalaya is not well established. The isotope data from the Sahastradhara and Mawsmai caves have been obtained and show mostly negative values for the carbon isotopes. Negative carbon isotope value has been recorded for the speleothems from both the areas and is consistent with the data available from other caves, indicating higher monsoon rainfall.

Component 2.5

Late Quaternary climate changes and monsoon variability along the NW Himalaya

(N.R. Phadtare)

Detailed investigation carried out in the Spituk-Leh

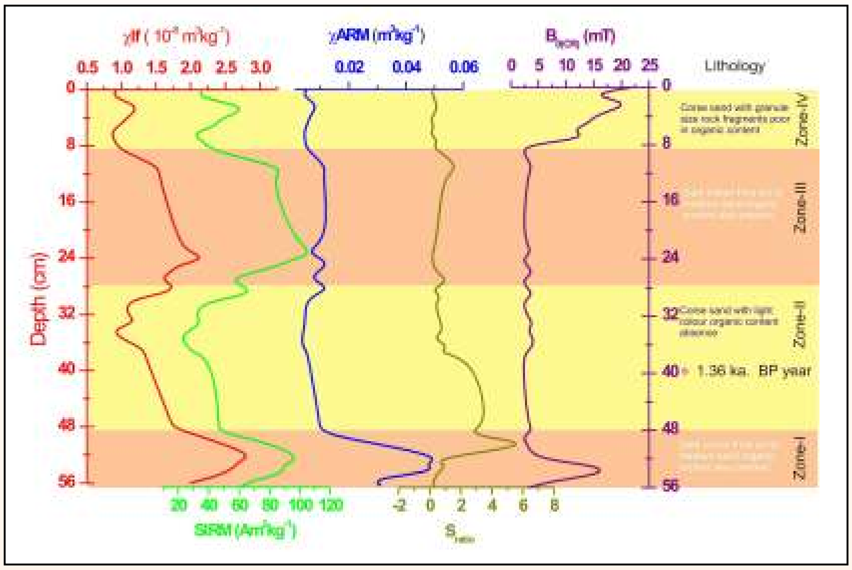


Fig. 5. Down core variation of Magnetic Susceptibility (Xlf), Saturated Isothermal Remnant magnetization (SIRM), Susceptibility of Anhysteretic remnant magnetization (Xarm), Coercivity of remanence (B0cr) and Sratio for Chorabari lake core sample.

gravels, belongs to 3 or 4 facies assemblage. At places, these fans are abruptly truncated by the Soan River, resulting in toe erosion (Fig. 9) and these fluvial scarps are wrongly marked as tectonic scarps by other workers. To the south of the axial river, two types of deposits are observed; horizontally bedded grey sand-mud facies or sloping beds (towards northeast) of buff to reddish brown colored sand-mud and gravel units. The characteristic feature observed is high angle depositional slope observed for fans deposited from south to north, i.e., from the detached Siwalik hills. In addition, vast exposures of fluvial deposits are observed in the paleo-gorge in the detached Siwalik Hills. These fluvial successions are dominated by gravel and sandy facies (Fig. 10) and the sediment architecture suggests its deposition by a major river, probably by Satluj River. These fans and the fluvial deposits were subsequently entrenched by streams and the surfaces were cut off from any sedimentation. Luminescence chronology was carried out to constrain the various events. Based on quartz optically stimulated luminescence (OSL) dating, two fan sequences are identified; older (36-29Ka) and younger (23-10 Ka) fans. The older fans are exposed in the southeastern part of the dun where as the younger sequences were observed in the northwestern part indicating creation of accommodation space in the northwestern part of the dun due to Soan Thrust activity. The termination phase of older and younger alluvial fans occurred in the reported increased monsoon phases and are correlated to climate change. The depositional phase of the fluvial succession in the paleo-gorge is also terminated around 29 Ka suggesting the channel abandonment and subsequent shifting of the Satluj River might have occurred simultaneously with the termination phase of older fan sequence.

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 Dibang, Subansiri and Kameng Valleys of Arunachal Pradesh. The rivers flowing from North to South cut through the Proterozoic to Cenozoic rocks that occur in the

Fig. 6. Stalagmites in the Mawmluh cave, South Shillong Plateau near Cherrapunji, Meghalaya.

ichnofossil assemblage represents different behaviour and biological functions such as feeding, dwelling and locomotion. Absence of body fossil makes ichnofossils more important for understanding the depositional environment. The Middle Cambrian succession of the Parahio Valley contains a variety of trilobite assemblages. The most important trilobite, *Pagetia* is present throughout Middle Cambrian successions. The study of ontogenic developmental stages of *Pagetia* and some other forms like: *Oryctocephalus*, *Eodiscus*, *Opsidiscus* is in progress. These assemblages of trilobite genera will help to understand the paleoenvironment of Parahio section.

The Ordovician and Silurian succession is well exposed in the Pin and Parahio valleys. The carbonate horizons of the Pin section have yielded abundant dasycladacean green algae along with bryozoans, which are useful parameters to define the depositional environment of this sequence. The *dasycladacean* calcareous algae recognized in the carbonate facies is *Salpingoporella and Dasyporella*, these forms are usually accompanied by *Vermiporella and Moniliporella* in the same section along with bryozoans in association with Dasycladacea. In the present studies two new Dasycladales calcareous green algae were identified as *Salpingoporella and Moniliporella* from the Thango Formation of the Pin valley. A

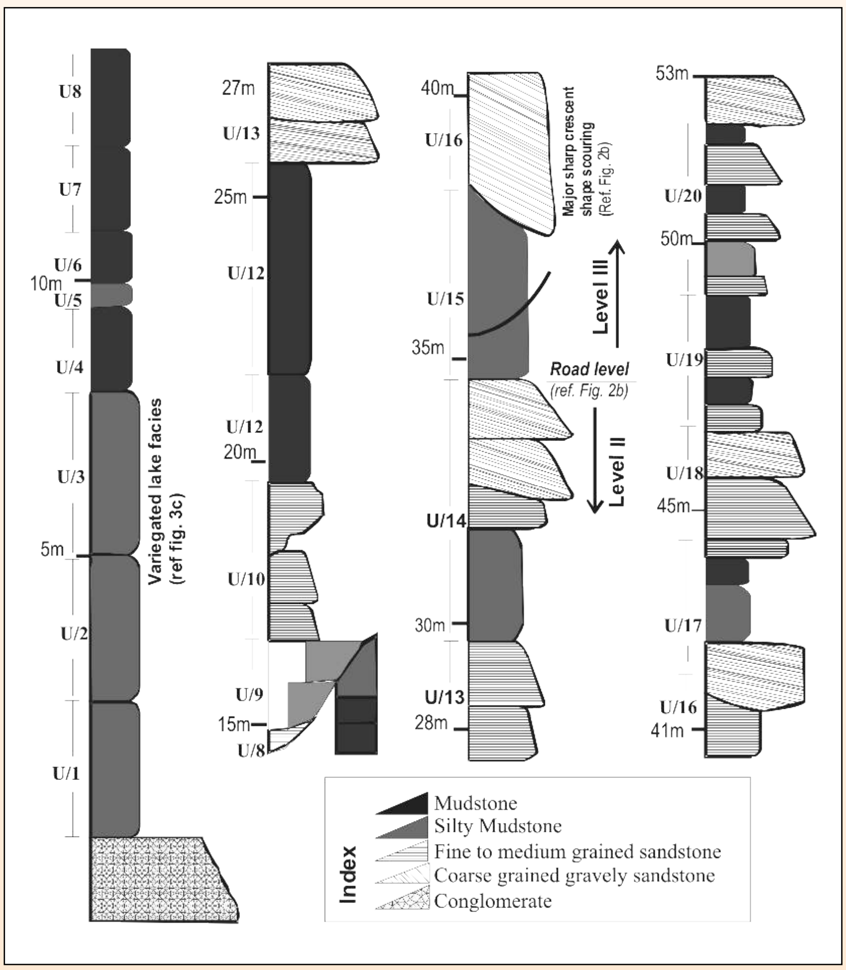


Fig. 7. Documentation of a lacustrine sedimentary profile in Markha Valley is significant to infer the Late Pleistocene damming and probably Early Holocene outburst of the Indus River in Ladakh Himalaya.

benthic marine chlorophyte group, is confined to shallow water and indicates shallower part of the phase of the evolution-induced supply of macronutrients by inland water channels originating in the orogen.

Exotic carp fishes from Miocene Dharmsala beds of Kangra Valley in HP, India: implications for the Himalayan evolution

Many-fold enlarged fossil carp collection from Dharmsala Group through ongoing systematic

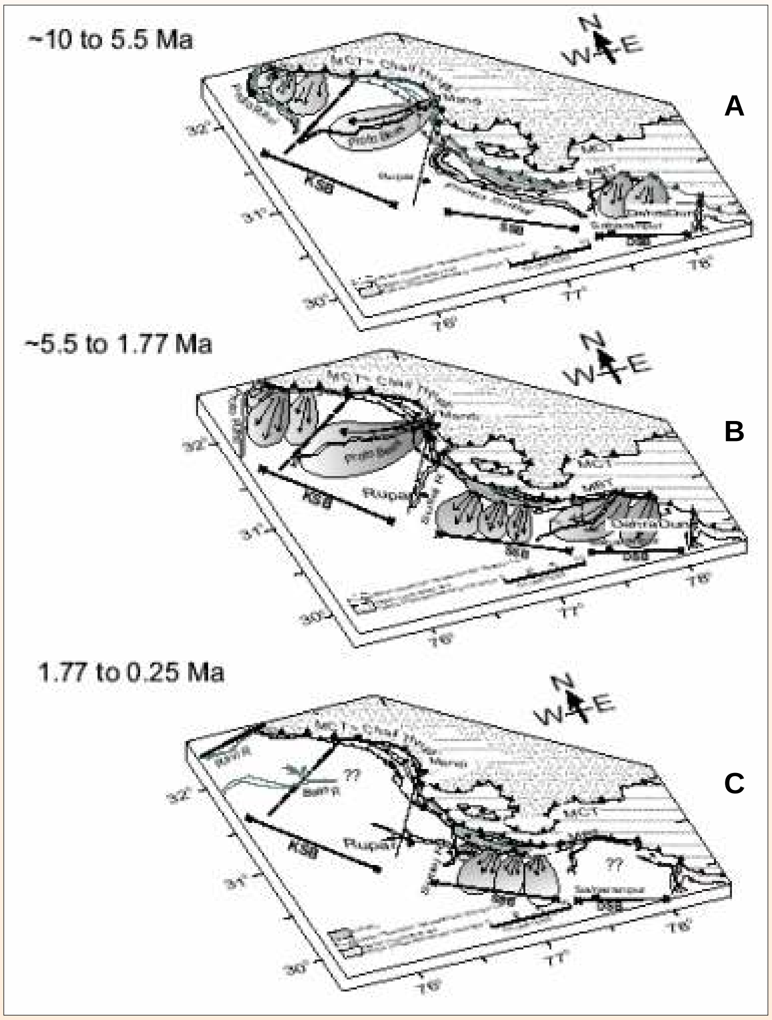


Fig.8. Conceptualised depositional model depicting sequential modifications and spatial relationship of fluvial system between River Ravi and Ganga (displacement of various transverse lineaments are adjusted to give the pre-faulting scenario). (A) Between ~10 and 5.5 Ma, the sub-basins have two axial drainage systems flowing towards southeast in the NW and extremely SE part of Kangra sub-basin and two transverse trunk drainage system in the SE part of KSB and DSB. This time interval recorded major uplift along MCT with intensified Indian Summer Monsoon. (B) Between 5.5 and 1.77 Ma, major drainage re-organisation took place in response to MBT activity. Both axial drainage disappear while new piedmont drainage initiated at around 4.8 Ma in the SSB and transverse trunk drainage in the KSB and DSB shift toward more SW ward. (C) Overpowering of piedmont drainage on already existing trunk drainage in the SSB in response to Intra Foreland Thrusting. MCT= Main Central Thrust; MBT= Main Boundary Thrust.

palaeontological work assumes significance in conjunction with their known occurrence in

Fig.9. Google image exhibiting toe cutting of alluvial fan deposit by axially flowing Soan River. The toe erosion resulted abruptly truncation of the fan.

Fig.10. Thick and vast exposures of fluvial deposit in the paleo-gorge, detached Siwalik Hills. These fluvial successions are dominated by gravel and sandy facies and the sediment architecture suggests its deposition by a major river, probably by Satluj River.

subtle aspects of India-Asia collision

India–Asia collision eliminated marine barrier and thus gave way to mixing of life on either landmasses and as a consequence succeeding horizons deposited in basins adjoining suture zone are characterized by their exotic fossil taxa. Following suturing, Ladakh Molasse Basin apparently served as the meeting ground for the fauna from both bio-provinces and thus eventually provides palaeontological view and constraints to the events that followed the collision. Studies on the similar lines of the fauna from basins on the southern flank of the Himalaya that are more or less coeval to Ladakh Molasse are more insightful in revealing the subtle details of geomorphological changes due to earliest phase of the collisional and deformational dynamics. Induction of exotic deinotheres, native African folivorous beasts, in Dharmsala Basin of Indian Himalayan region in early Miocene is a potential proxy to the fact that basin was having a well drained thick forest, and thus older levels of the region revealing barrenness indicate a big change in the intervening interval. Similarly cyprinids and other species known to have roots and better dispersal history in Asian territories in the north are now well represented in Miocene Dharmsala assemblage; realization of the fact that surface water streams' bound fishes reaching in the Himalayan region from Tibet and across areas of the Asia impels to visualize surface water streams following available slopes due to post-collisional tectonics, that is, an embryonic antecedent river system.

Explanation regarding occurrence of exotic Dharmsala cyprinids through connecting streams in conjunction with their Oligo-Miocene records from Ladakh and earliest phase of Himalayan Orogeny is apparently tenable. Similarly, disjunct distributions of the extant Malayan freshwater fishes in the Indian shield region — core issue explained by Hora's Satpura Hypothesis (now annulled) — can better be explained by taking into account orogeny driven multiple river reorganizations that are known to have taken place.

Component 3.4

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

(Kapesa Lokho)

Reconnaissance field survey was under taken in the Middle Bhuban and Upper Bhubhan Formation in and around Aizawl town (Mizoram). Data on sedimentary structures and faunal assemblages was collected from different outcrops along the road sections (Fig. 11). The Miocene succession of Middle Bhuban Formation bears assemblages of ichnofossils. The significance of ichnofossils in reconstruction of paleoenvironmental setting has been discussed by several workers (Pemberton and Frey, 1985; 1987; Pemberton et al., 1992b; MacEachern et al., 1999; Gingras et al., 1998, 2001, 2002; Campbell and Nesbitt, 2000; Nesbitt and Campbell 2002; Nesbitt and Campbell, 2006). The recovery of the ichnofossils from the Midldle Bhubhan Formation is important paleoenvironmentally and stratigraphically as there are only a few available literatures on it till date. Probably, this finding may be the first record of a significant trace fossil from the Middle Bhuban Formation (Surma Group), Mizoram. The ichnofossils were collected from the sandstone and silty shale beds. Identification and consultation of literatures to understand the paleoenvironmental setting and biostratigraphic dating of the Middle Bhubhan Formation is under process.

Uvigerinds, other benthic and planktonic foraminifera were recovered from the Upper Bhubhan Formation at Thingdawl village, Kolasib district, Mizoram. The present findings record an outer shelf envionrment for the Upper Bhubhan Formation.

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. Siva Siddaiah and Kapesa Lokho)

Component 3.5a

Biotic, mineralogical and geochemical

PROGRESS IN RESEARCH PROJECTS

PROGRESS IN RESEARCH PROJECTS

Fig. 11. (A) Field photograph of silty shales and sandstones, (B) Cross beddings, (C) Ripple crest, (D) Load cast of Middle Bhubhan Formation, Mizoram.

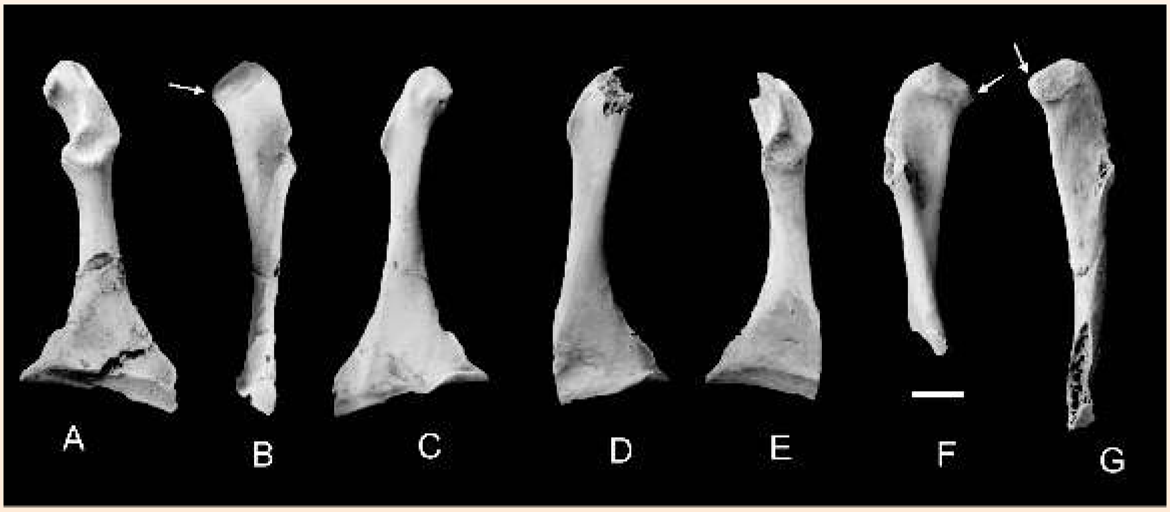


Fig. 12. Coracoid bones of *Vastanavis cambayensis* n. sp. (a bird) from the early Eocene Cambay Formation in India. A-C, right coracoid (holotype) in dorsal (A), medial (B), and ventral (C) view. D, E, incomplete right coracoid in ventral (D) and dorsal (E) view. F, incomplete left coracoid in medial view. G, incomplete right coracoid in medial view. The arrows indicate the ventrally projecting facies articularis clavicularis of *V. cambayensis*. Scale bar equals 5 mm.

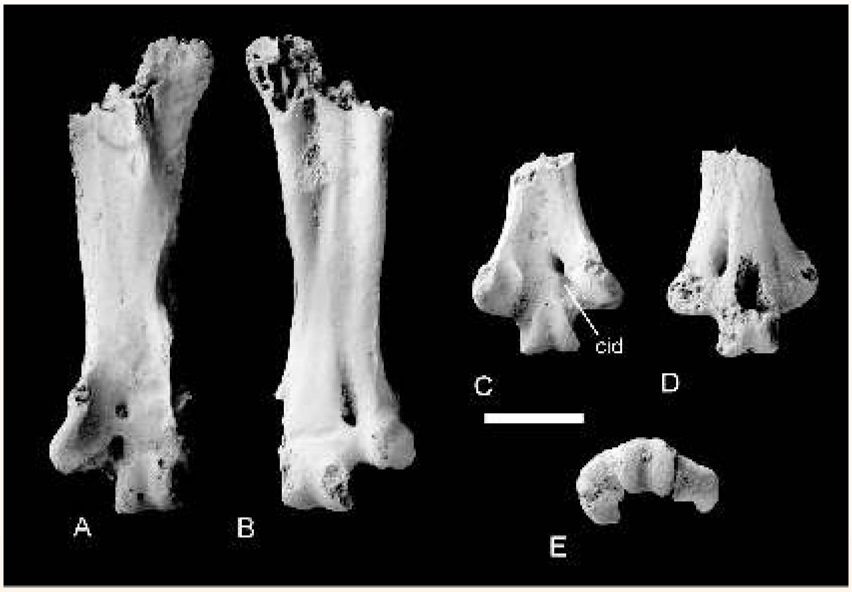


Fig. 13. Tarsometatarsi of *Vastanavis sp.* from the early Eocene Cambay Formation in India. A, B, left tarsometatarsus in plantar (A) and dorsal (B) views. C-E, distal end of right tarsometatarsus in plantar (C), dorsal (D), and distal (E) views. Abbreviation: cid – canalis interosseus distalis. Scale bar equals 5 mm.

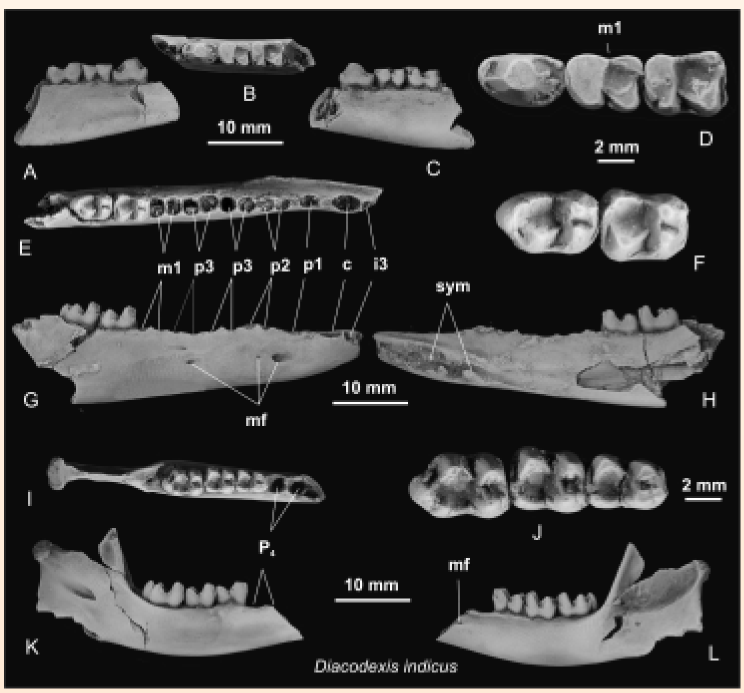


Fig. 14. *Diacodexis indicus* from the early Eocene Cambay Formation in western India. A–D, left dentary with p4–m2 in lingual, occlusal, buccal and enlarged occlusal views respectively; E–H, right dentary with m2–m3 and alveoli for i3–m1 in occlusal, enlarged occlusal, buccal and lingual views respectively; I–L, right dentary with m1–m3 in occlusal, enlarged occlusal, buccal and lingual views respectively. Alveoli and mental foramina (mf) are identified.

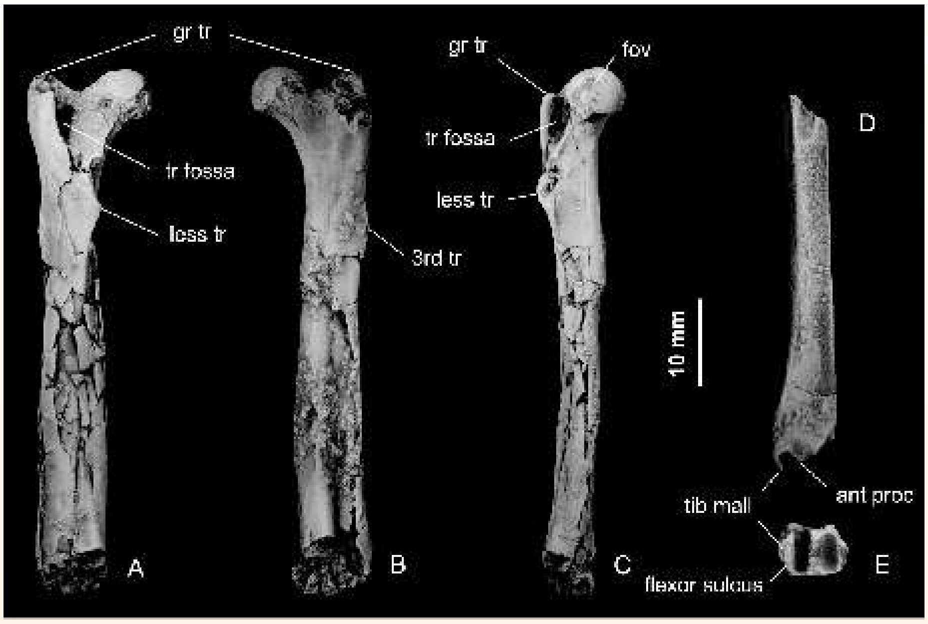


Fig. 15. Diacodexeid femur and tibia from the early Eocene Cambay Formation in western India, tentatively referred to *Diacodexis indicus*. A–C, Left femur in posterior, anterior and medial views, respectively. D–E, Distal left tibia (GU 755) in anterior and distal views. Abbreviations: ant proc, anterior process; fov, fovea capitis; gr tr, greater trochanter; less tr, lesser trochanter; 3rd tr, third trochanter; tib mall, tibial malleolus; tr fossa, trochanteric fossa.

Some of the important non-vertebrate fossils studied during the reporting year include well preserved fossilized fruits, and several specimens of very well preserved trace as well as body fossils of some wood-boring mollusks.

Based on additional palaeontological data gathered from a detailed biostratigraphic work, a revised and more precise zonal scheme, than available earlier, was proposed for lower Paleogene sections of the Zanskar Tethyan and Indus–Tsangpo Suture zones. The revised biozones are correlated with the shallow benthic zones (SBZ) established earlier for the Tethyan realm (Mathur, Juyal & Kumar 2009).

While exploring the Paleocene-lower Eocene sections for vertebrate fossils and ash deposits in western India, a peculiar bed of white chalky volcanic ash like material was noticed in the basal part of the Matanomadh Formation that overlies the Deccan traps. Its detailed mineralogical, textural and geochemical study revealed the presence of hydrous sulphate minerals dominated by minamiite [(Na,K,Ca) Al_3 $(SO_4)_2$ $(OH)_6$] and natroalunite [$NaAl_3(SO_4)_2(OH)_6$] with traces of alunite and kaolinite. Minamiite is identified by its characteristic d-values and chemical composition, and is reported for the first time in India. Hydrous sulphates are abundant on the planet Mars but not common on Earth because they form under extreme conditions (low pH and high Eh). Minamiite is pseudocubic or rhombohedral in habit and its crystal size generally ranges between 1 and 2 µm (Fig. 16). Individual crystals are white to colourless with vitreous lustre but without any dissolution marks on their surfaces, indicating absence of late stage acid sulphate or meteoric weathering. Euhedral morphology of crystals of hydrous sulphates from Matanumadh indicates their authigenic origin. Chemically, the bulk sulphate samples are characterized by higher SO_3 (38.1–38.5 wt %), Al_2O_3 (35.99–36.8 wt %) and loss on ignition (13.2–13.7 wt %). Calcium (CaO =

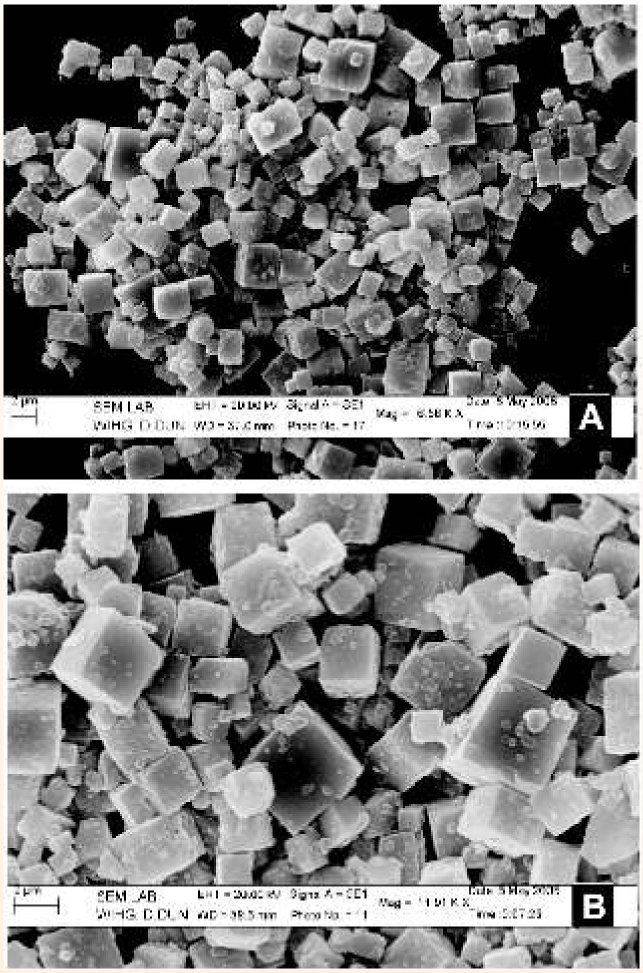


Fig. 16. Scanning Electron Microscope images of hydrous sulphate sample from Matanumadh showing well– developed crystals of minamiite. (A) Low–magnification view of minamiite crystal morphology displaying pseudocubic structure. (B) Minamiite crystals showing their pristine nature and clear vitreous luster.

0.45–0.5 wt %) and iron (Fe_2O_3 = 0.1–0.62 wt %) contents are relatively high, whereas TiO_2 (0.29 wt %) and MgO (0.26–0.38 wt %) contents are low. The geological setting, mineralogy and geochemistry suggest that the sulphate layers at Matanumadh were produced via solfataric alteration of volcanic ash. The hydrous sulphates found in the Deccan Province Volcanic (DVP) are similar in terms of their geologic association, depositional environment and genesis to those described from Mars. The DVP with its extensive volcanic plains, cones and craters as well as abundant hydrous sulphates of secondary origin, approximates the geological (including thermal plume origin), geomorphological and environmental conditions on the Mars, and thus appears to be a promising analogue site for improving our understanding of the Martian surface as well as for comparing the geologic processes on the two planets (Siddaiah and Kumar 2009).

A total of 36 days field work (Leh-Kargil, Solan, H.P. and Jammu-Kalakot area) was carried out during the reporting year for prospecting of Paleogene sections for vertebrate and other biotic remains. The trips were reasonably successful particularly from the viewpoint of recovery of fossils. From Kargil area, the collection of plant fossils was substantiated by the recovery of a few more leave impressions. From Himachal Pradesh, bulk samples were taken from a bone bed that was discovered during an earlier trip to the area and was at that time partially submerged. For mineralogical and geochemical study samples of basal Subathu lithologies were taken from the Kurla Nala section, which is among the very few sections that have the complete basal Subathu succession exposed. The short trip to Kalakot resulted in the discovery of a crab specimen from the basal beds of the Subathu succession. Apart from the fossils, numerous samples of Chert Breccia and Sirban Limestone were taken for detailed mineralogical and geochemical analysis to study the nature of volcanic signatures already noticed in a preliminary study.

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. Siva Siddaiah and Kapesa Lokho)

The breakup of the Eastern Gondwana Supercontinent (India, Antarctica and Australia) resulted in the development of Indian ocean and Neotethys ocean during the Cretaceous Period. The anti clockwise northward drift of India continued and the new intracratonic basins and shelves developed. These early foreland basins formed the floor for the Tertiary basins in the Indian subcontinent including Himalaya. Early foreland basin evolution during Late Cretaceous – Paleogene in the South Shillong Plateau, Meghalaya is of global significance. The rifting initiated with extrusion of widespread basaltic traps (Sylhet Traps) and the development of new basin (Neotethys ocean) took place. The basin architecture, depositional model (Fig. 17) and evolution of the Shillong shelf is reconstructed on the basis of our extensive field work and various sedimentological, stable isotopic, paleobiological, and geochemical laboratory studies during 2009-2010.

Lower Cretaceous sediments are not deposited in the Shillong shelf. The Middle and Late Cretaceous (Campanian – Maastrichtian) sediments (Jadukata Formation and the Mahadek/ Mahadeo Formation) directly overlie the Sylhet Traps in the Um Sohryngkew River section in East Khasi Hills of the Shillong Plateau. The fluvial boulder beds and the pebbly sandstone of the Jadukata Formation are the oldest sediments in the area which is overlain by the marine glauconitic sandstone of the Mahadek (Mahadeo) Formation of Late Maastrichtian age. The overlying Langpar Formation of Paleocene age is a coastal marine sequence of thinly bedded shales, marl and limestone with planktonic foraminifera. The Cretaceous – Tertiary Boundary lies within this section. In this K/T boundary succession, several fossiliferous beds of the gastropods, ammonoids, echinoids and foraminifera- algal limestone has been recorded. The fish remains have been recorded for the first time in the maceration from the Langpar Formation (type area , well exposed about 5 km from Mawsmai , on Mawsmai – Shella road section). The fish remains are found associated with the shallow marine benthic foraminifera of Paleocene age from the same locality. Figure 18 shows the microfossils (1-6) fish teeth possibly representing enchodontids, 7 ?

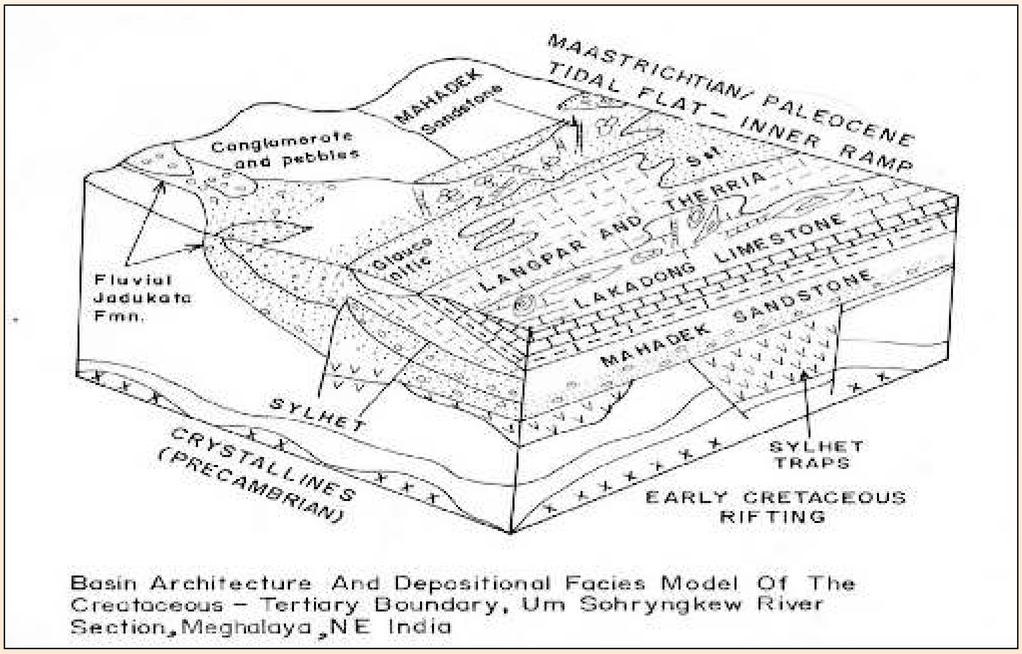


Fig. 17. Basin architecture and depositional facies model of the Cretaceous – Tertiary Boundary, Um Sohryngkew River section , Meghalaya, NE India.

PROGRESS IN RESEARCH PROJECTS

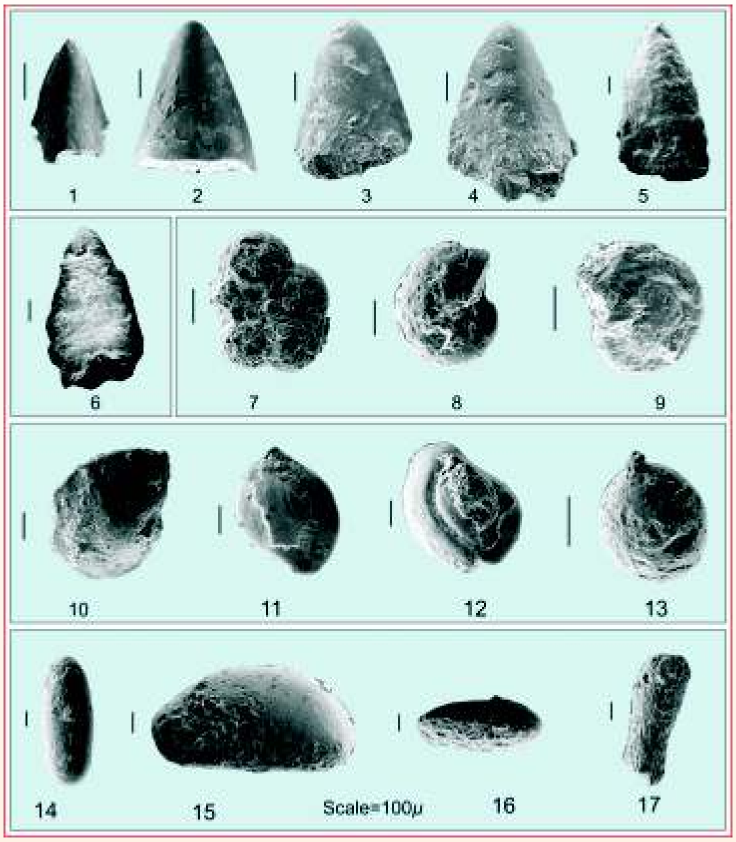


Fig. 18. Scanning Electron Microscopic photographs showing the microfossils (1-6) fish teeth possibly representing enchodontids, 7 ? *Parvularugoglobigerina* sp. (planktonic foram) *Hetrolepa* sp., 8-9 (umbilical and spiral views), 10, *Lenticulins* sp.11, *Quinquelocuilina* sp., 12, *Spiroloculina* sp., 13, *Lagena* sp., 14, *Pseudonodosaria*, 15-16, unidentified ostracodes ,17, Echinoid spine.

Parvularugoglobigerina sp. (planktonic foram) *Hetrolepa* sp., 8-9 (umbilical and spiral views),10,

–vis the Higher and Lesser Himalayan Rocks had shown a close link between them. It is stated that the foothills zone or the Siwalik Foreland Basin of the Indian Himalaya in the Uttarakhand State consists of clastic sediments that were produced by the uplift and subsequent erosion of the rising Himalayan Ranges during Tertiary, which were deposited by the rivers in this tectonic depression. The tectonic activity during the Tertiary Himalayan Orogeny had played a very vital role in the deposition of the Siwalik Group rocks in the Foreland Basin and in the formation of palaeoplacer gold occurrences in the Siwalik clastic sediments around 15 MY - particularly during the Dharmsala Phase (2^{nd} Phase of Himalayan Orogeny, Rawat, 2009). However, the Siwalik Phase (3^{rd} Phase of the Himalayan Orogeny) is responsible for the open folding, faulting and erosion of the raised Siwalik Ranges in the Foredeep, which in turn produced the placer gold in the recent sediments in the river tributaries arising with in the Siwalik domain itself. This event had also contributed the placer gold in the recent sediments, south of the MFT. It can be summarized that the palaeoplacer gold is confined to the rocks of the foreland basin in the foothill zone, while the recent sediments in the Gangetic Foredeep and along the river courses in the Himalayan zone are of recent origin. Placer gold occurrences in the Middle and Upper Siwalik sediments are unevenly distributed along the strike length. The gold in the recent placers is mainly derived from the Siwaliks and to a lesser extent from the Lesser Himalayan front but the source is definitely from igneous, metamorphic and sedimentary pre-Tetiary rocks (Fig. 19). The association of U- Au (Mahadevan, 1991) and pyrite (Fig. 20) / framboidal pyrite occurrences in the Siwaliks indicate presence of some sort of fluids and biogenic activities, besides presence of carbonaceous and phosphatic materials is there to influence the deposition of placer gold.

Fig. 19. Au with native Cu in the quartz pebble from Chalthi, Kumaun.

Fig. 20. Euhedral pyrite in sandstone pebble, Dugadda, Garhwal.

This study indicated that the primary source for palaeoplacer gold occurring in the Siwaliks sediments exists in the Lesser and Higher Himalayan rocks-from basic to acidic and in volcanoclastic sediments. However, the Siwaliks palaeoplacers subsequently acted the source for the recent placer gold in the foredeep – Gangetic Basin and along the streamlets within the Siwaliks Ranges. This happened under the denudation cycle in the Himalaya where the gold particles / flakes or as gold bearing particles in other minerals or with the fluids as gold bearing complexes (Rawat, 1995 & 2000) got transported from the original source to the Siwalik Basin and later got deposited under suitable environmental conditions. After the oxidation of polymetallic sulphides- particularly of pyrite, the gold combined with the chloride rich fluids (generated during the metamorphism of the pre-Tertiary Himalayan rocks) got transported from the Himalayan terrain to the present foreland basin as chloride complex, which in the presence of carbonaceous materials of inorganic or organic (biogenic origin) - got precipitated with other metals (U-Au occurrences in Siwaliks). Presence of certain organic materials or fluids facilitated the solution as well as deposition of gold in the Siwalik sediments within a tectonic basin.

Further, the study of complex fluids vis-à-vis the study on the mineralization in the Uttarakhand Himalaya revealed that the lithology and the tectonic set up of the area play a vital role for the potential mineralization in a terrain. Keeping this in mind, new mineralized zones were located at a number of places in the Himachal Lesser Himalaya during this year's field work (Figs. 21 to 24). The field study in Himachal Himalaya when combined together with the mineral paragenesis study clearly indicated the influence of deformation and metamorphism on the granitic plutons (Fig 25 and 26) as well as on the mineralisations and the associated host rocks (Figs. 21 and 24).

Further, the field observations on the structure and tectonics of the Uttarakhand Himalaya were reinterpreted to know their relationship with the sub-surface geology and it is concluded that the Himalayan mountain chain including Uttarakhand in the Indian Sub- Continent had witnessed many major earthquakes in the past, crushing of rocks and damages along the various thrusts in the Uttarakhand Himalaya during the major earthquakes is a pointer to the reactivation of pre-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 earthquakes in the Himalaya. There exists a relationship between the hidden major sub-surface basement structures and the major transverse folds and faults in the Himalaya and as such at many places the reflection of Aravalli trend is present in the Uttarakhand (Rawat, 1980 & 2009) and is thus responsible for the seismicity.

Fig. 21. Sulphides in the graphitic schist, Katolakhad, HP.

Fig. 22. Sulphides in the black slates, Katolakhad, HP.

Fig. 23. Mineralised quartz veins at the vicinity of Mandi granite at Katindi, HP.

Fig. 24. Fluorite bearing Mandi Granite.

Fig. 25. Undeformed euhedral feldspar phenocrysts in Karsog granite.

Fig. 26. Phenocrysts parallel to the foliation at the margin of Karsog granite.

Fig. 27. Typical mylonitic rock at the base of Chail Crystallines, Jatingiri, HP.

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 (Pinjore - Una Dun) of Himachal Himalaya

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

Geochemical mapping and other applications of surficial geochemistry are relevant to a wide variety of subjects, particularly because they can throw light on various problems concerning mineral exploration, geology and environment. It is also an appropriate technique for establishing geochemical baseline for environmentally sensitive and economically important metals like As, Hg, Cr, Cd, Cu, Pb and Zn. The results of investigations may reveal patterns directly related to the geochemistry of bed rock. Also anomalies related to mineralization may be discovered. Superimposed on these patterns are, however, patterns related to human influences such as pollution resulting from waste dumps, industrialization and urbanization. Therefore geochemical baselines or natural background concentrations of elements in the secondary environment are needed for environmental legislation and decision making. Such investigations/studies were carried in the Pinjaur Dun taking stream sediments as medium to provide geochemical baseline for major and trace elemental abundances for future impact assessment. A total of 97 bulk stream sediment samples covering an area of over 600 sq. km. collected earlier from Pinjaur Dun were studied to understand their geochemical dispersion pattern. Considerable variation in heavy metal concentrations (Cu, Zn and Pb) is mainly observed around highly populated areas. The higher concentrations of these elements might be due to the presence of the municipal areas as well due to the existence of several industries mainly chemiplast group of industries.

Statistical treatments to trace metal anomalies in sediments have been used by many workers (Forstner and Wittmann 1979; Siegel 2002). The distribution of many elements in natural materials, such as sediments, approximates to the log-normal and such distributions have been used to establish various characteristic population parameters, such as background and threshold levels (Chester and others 1985). Thus, a threshold was calculated using the equation:

$$\text{Threshold} = X + 2\sigma$$

where, X is the mean, σ is the standard deviation. Concentrations for potentially toxic metal/ metalloids $> X + 2\sigma$ are natural and / or anthropogenic contaminants. These can be considered pollutants values if they degrade the normal functioning of living environments (Siegel, 2002).

Few samples exceeded this threshold indicating the absence of anomalous metallic occurrences within the vicinity of the investigated area. However, for the purpose of environmental evaluation of the heavy metals distribution in the investigated area, the method of calculating the geo-accumulation index (I-geo) (Muller 1969; Ntekim and others 1993) was applied. Geo-accumulation index (I-geo) indicates that the sediments are moderately contaminated with Cu and Zn and strongly contaminated with Pb.

A strong relationship between Fe and Mn with other heavy metals in sedimentary processes, due to their high absorbance capacity, has been reported by several workers. Such a relationship was not observed in the study area, which might indicate that the enrichment of heavy metals (Cu, Zn and Pb) is related to other than sedimentary processes or lithological factors, most probably anthropogenic input.

The natural metal/aluminium relationships was used to distinguish natural from contaminated sediments for a number of metals and metalloids commonly released to the environment due to anthropogenic activities. Aluminium was chosen as a reference element to normalize sediment metals concentrations as it is assumed to have had a uniform flux to the sediments over the past century from crustal rock sources, and its concentration is generally not influenced by anthropogenic sources. This allows a better insight into the source characteristics and also to obtain clues about the heavy metal accumulation. In addition to this aluminium is the second most abundant metal in the earth's crust, silicon being the most abundant. Most metals transported are tightly bound in the aluminosilicate solid phases and, as a result, there is very little fractionation between the naturally occurring metals and aluminium during the weathering. Since much of the natural constituents of metals in sediments are chemically bound in the aluminosilicate structure, the metals are generally non labile, where as the adsorbed anthropogenic component is more loosely bound.

In spite of considerable variation in heavy metal concentrations, the normalized data reveal a rather narrow range with some interesting patterns. The percentage standard deviations about the mean for Co, Ni, Mn, Ti and Fe are typically < 32% and that of Cu and Zn are >52% and in case of Pb deviation is >160%. Also, Co, Ni, Ti and Fe show very good correlation with Al (correlation coefficient >.60), thus suggesting their inherent relationship with silicate and in particular with clays. Thus, the data reveals that Co, Ni, Mn, Ti and Fe are closely related to aluminosilicate, whereas Cu, Zn and Pb are related to some other source. Since the latter three elements have higher abundance close to municipal industrial areas, it is more likely that their abundances are anthropogenic related.

Component 4.2b

Mineralization, metallogeny and the petrological investigations of host rocks in Kumaun region, Uttarakhand

(Rajesh Sharma and D. Rameshwar Rao)

A new occurrence of blue lazulite near the Main Central Thrust in the northeast Kumaun Himalaya is hitherto unreported. The lazulite (Fig. 28) occurs in crystalline form clustered randomly in the quartz veins, and appears to be of semiprecious gem variety. The microscopic study shows presence of subhedral to anhedral large crystals of lazulite having prominent pleochroism. The other coexisting minerals in the quartz veins are muscovite and biotite. The lazulite has been confirmed through XRD (Fig. 28) and the Raman spectroscopy at the Institute laboratory using 514 nm LASER whereby consistent Raman shift is obtained, and with its secondary peaks the spectra perfectly point to the lazulite. Raman spectroscopy is also carried out on the opaque minerals occurring within the lazulite. The EPMA studies show that in the solid solution series from Mg-rich lazulite to the Fe-rich schorzalite, the observed mineral is Mg rich lazulite. The fluid inclusions trails in the lazulite are strictly restricted and terminate at the lazulite-quartz boundary, which gives implication of the fluid loss in quartz grains during later recrystallization, probably during development of annealing texture, but lazulite remained unaffected. The microthermometry shows the aqueous saline nature of the fluid, confirmed through the Raman shift for carbonic phase and with a mould of water nearly always present. The lazulite formation conditions when compared with the host vein quartz, present that this mineral preserves early records whereas such records in quartz are largely obliterated by recrystallization.

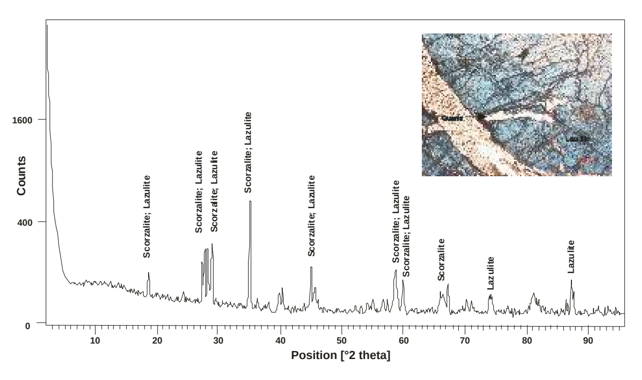


Fig. 28. Figure of the Raman spectra bands obtained for lazulite, inset shows photomicrograph of the blue colour lazulite.

In continuation of our earlier studies on the reported new occurrence of polymetallic sulphide mineralization near Gasku, about 6 km north of Tawaghat in Kali valley, ore chemical work has been carried out using EPMA. The analyses of chalcopyrite, pyrite, sphalerite, minor galena and pyrrhotite are conducted. This suggests the presence of S, Cu, Fe, Zn as major elements and Cd, Mo, Mn, Co and Ni, as trace elements. Chalcopyrite shows an average 0.5 wt% Mo, 770 ppm, Zn and 290 ppm of Cd. High concentration of Zn in chalcopyrite and vice versa is attributed to solid solution between chalcopyrite and sphalerite. Also that a_{Zn}^{2+} in the ore forming fluid was high as indicated by high Zn concentration in pyrite and chalcopyrite and the presence of sphalerite in mineral assemblage. The Mo is invariably distributed in all the analysed minerals whereas concentration of Co and Ni are higher in pyrite than in chalcopyrite. The Co/Ni ratios are low, and unlike to the pyrites from Ramgarh Formation, the Ni is always higher than Co in the pyrite from Gasku. Pyrite contains an average 1110 ppm Co and 5930 ppm Ni presenting an average 0.19 Co/Ni ratios. Such Co/Ni ratios in pyrite together with very high concentration of Ni and high Co advocate participation of magmatic component for the sulphide mineral formation. Sphalerite is characterized by high Fe and Cd concentration. Fe contents in sphalerite vary between 9.8 to 10.8 wt%, and with an average of 10.43 wt%. This sphalerite is enriched in Cd with an average 2.26 wt% Cd content. Sphalerite consists about 0.8 wt% Cu, 0.5 wt% Mo and an average 130 ppm Mn. High Cd is likely to be present as isomorphous impurity in sphalerite resulted from the substitution of Zn^{2+}. High concentration of metals like Fe, Cd, Cu and Mo in sphalerite is related to the high formation temperature of hydrothermal system. Further contemplation of the microthermometric study implies a dominance of aqueous component with H_2O-NaCl-KCl± Mg/Ca composition, and a low $X_{CO_2} = 0.138$ in the trapped fluid. Primary nature of the fluid inclusions and the localized occurrence of mineralized veins also indicate that this brine rich fluid was active in the thrust zone.

The geochemical studies of the granite gneiss and augen gneiss from the Askot Crystallines, Kumaun Himalaya were carried out in order to understand their origin and evolution. The granite gneiss is generally foliated, with less foliated and porphyritic variety seen in the core part. The K-feldspar shows Carlsbad twinning, while plagioclases show complex twinning. They show euhedral zircon and apatite along with titanite as accessory minerals. The granite gneiss is moderately evolved (mg# ~50) and has granodiorite composition with metaluminous, calc-alkaline trends. They show higher concentration of Ti, Ca, Mg and low abundance of ΣREE (~165 ppm) in comparison to augen gneiss. They show volcanic arc signatures and compare well with Late-Orogenic granites of Proterozoic times distributed world wide. These calc-alkaline granites appear derived from a Paleoproterozoic mafic/intermediate lower-crust reservoir probably involving arc magma underplating. Granite gneiss is also peraluminous with molar A/CNK>1.1, and the heterogeneity of granite gneiss can be explained with the precursor melts experiencing assimilation during up-rise through crust or contamination of source itself involving sediments from the subduction zone. The augen gneiss is more evolved (mg# ~18) and show granite composition. They show megacrysts of perthites in a fine-to medium-grained matrix of feldspars and micas. The REE pattern of the augen gneiss shows much wide compositional variation (ΣREE ~171 ppm) than granite gneiss. It shows syn- to post-orogenic environment and derivation from the partial melting of an upper crustal source. Existing Rb-Sr isotopic data suggest that the granite gneiss defines an isochron age of ~1700-1800 Ma with a Sr_i ratio of ~0.71, while the augen gneiss defines an age of ~1300 Ma with much evolved Sr_i ratio (~1.65). The dominance of granite gneiss in the eastern Kumaun region suggests the production of heterogeneous granitic melts similar to those of Askot crystallines as an important event of crustal growth during Late Paleoproterozoic period in the region. Thus, more focus on the regional studies of eastern Kumaun crystalline rocks of Almora Nappe, Chiplakot and

Munsiari Formation is required for better understanding of Late Paleoproterozoic crustal evolution of the region.

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)

The Lesser Himalaya has an extensive record of mafic magmatism through Precambrian to Eocene. The mafic magmatisms are preserved in the form of volcano-sedimentary sequences, sills/dykes and intrusives. Till date no informations on gabbroic intrusives in Siang window of Eastern Himalaya have been reported. Hence, during the period petro-geochemical studies of gabbroic intrusives emplaced within carbonate and calcareous-quartzite of Miri-Buxa group in the Siang Window of Eastern Himalaya has been carried out to evaluate their petrogenesis and tectonic environment.

The gabbro intrusives are emplaced within the carbonate and calcareous-quartzite of Miri-Buxa group. These gabbros are coarse grained (2 to 6 mm) to medium grained (< 2 mm) and grain size increases from core to the margins of the body. The contact between the gabbros and country rocks is sharp. These intrusives do not show any primary flow alignment or deformation features. Absence of chilling and contact effects suggest a slow up-rise of magma and its emplacement at a depth where the country rocks were being metamorphosed to green schist facies and hence the temperature difference was not significant. The intrusives are devoid of xenoliths of country rocks suggesting their permissive emplacement and lower structural level.

These mafic rocks show subalkaline-tholeiites affinity and identified as low-Ti gabbro (Ti/Y <500; Nb/La = 0.99-1.44). Geochemically they are enriched in LILE and LREE, depleted in HFSE with minor REE fractionated nature $[(La/Yb)_N$ = 2.72-3.35)] and insignificant Eu anomalies (Eu/Eu* = 0.87-1.22). These mafic intrusives appear to have been influenced by an asthenospheric mantle and are less crustal contaminated as indicated by the characteristics of LILE with Na_2O, K_2O and absence of negative Nb, P and Ti anomalies in spidergrams. Similarity in immobile trace element with REE abundances reveal their cogenetic nature and their incompatible trace elements ratios (low Zr/Nb =7.54-11.59; Y/Nb = 2.11-2.78; Ti/Zr = 93.83-144; high Zr/Y = 3.08-4.30) reflect enriched nature of these mafic rocks. The liquidus olivine temperature (T^oliq.) of these mafic rocks ranges from 1262°C to 1380°C and shows a gentle decrease of [Mg] with a steep increase of [Fe], thus trend implies that the rocks related to one another by extent of melting of the source or fractionational crystallization of plagioclase and clinopyroxene. Petrogenetic modeling of [Mg]-[Fe] and REE suggest these mafic rocks probably derived from enriched mantle source with higher Fe/Mg ratio than primitive mantle source similar to komatiitic composition at moderate to higher degree of partial melting (8%-20%). It is also suggested that these mafic intrusive rocks have the influence of a within plate signature which were intruded in a continental rift tectonic environment.

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)

Geomorphology and Lichenometry

The work deals mainly with the Climate change and it's impact on the Himalayan Glaciers on the basis of study of the landforms formed by the Chorabari and Dokriani glaciers, Garhwal Himalaya, and dating of various cycles of their advance and retreat by lichenometry. The most common lichen growing on the slope boulders is *Rhizocarpons geographicum*. It belongs to the yellow green Section *Rhizocarpons* most frequently used in lichenometry. An automated mapping method for the debris-covered glaciers of the Himalayas based on an ASTER DEM and thermal data is evaluated. Morphometric parameters such as slope, plan curvature and profile curvature were computed by the means of the ASTER DEM and organized in similar surface groups using cluster analysis. The results from mapping the debris-covered Gangotri Glacier confirm the strong potential of the present approach based on the ASTER DEM and thermal data from its unique large cave at the snout and its orientation from southeast to northwest in the years 2001 and 2006.

Chorabari Glacier could not be mapped automatically with suitable accuracy due to its complex end moraine near its snout area. The ASTER DEM could not perceive this polygenetic landscape complication, which could stem from the resolution of ASTER data. This indicates that resolution of ASTER stereo data and thermal band is inadequate for mapping small debris-covered glaciers in the Garhwal Himalaya. The post-depositional sedimentation by debris flow/mass movement appeared a great hindrance for the automated mapping of debris-covered glaciers in the polygenetic environment of the Himalayas. It was found that shadow areas strongly affect the single thermal band thresholding which can hamper the automatic mapping of debris-covered areas. It was observed during field work and visual inspection of satellite data that thresholding of slope has a great potentiality to map those debris-covered glacier snouts with ice cave. However, the selection of thresholding possibly depends on height of ice cave and debris load.

Melt Water Chemistry

The compilation of the melt water chemistry data of the Chorabari glacier for the years 2007 and 2008 during ablation season have recorded that the average temp., pH and EC of the meltwater varied from 0.6 to 1.4 ^{o}C, 6.7 (6.6–7.4) and 89 µS/ cm (29 – 90 µS/cm), respectively in both years. The meltwater shows a low concentration of NO_3 and Cl, and relatively higher concentrations of lithogenic ions (e.g. Ca, Mg, K, SiO_2, HCO_3, SO_4). The concentration ranges of major cations are found as Mg^{2+} 0.2–1.4 mg/l, Ca^{2+} 2.6–11.2 mg/l, Na^{+} 0.1–0.8 mg/l and K^{+} 0.6–1.9 mg/l and were significantly different in 2007 and 2008. The diurnal variations in concentration of these ions were also large in two years. In individual samples, the concentration values of Ca^{2+} are generally higher in comparison to Mg^{2+}. The average chemical composition of meltwater showed major percentage of Ca^{2+} (as 72% of the total cations) followed by K^{+} (as ~20% of total cations). However, the chemical compositions of Mg^{2+} and K^{+} were 5 and 3%, respectively. The average daily concentration of cations in meltwater of Chorabari glacier are $Ca^{2+} > K^{+} > Na^{+} > Mg^{2+}$ in both the years. The abundance of anion concentration are $HCO_3^{-} > SO_4^{2-} > Cl^{-} > NO_3^{-}$. Major contribution of anions is in the form of HCO_3^{-} (as 70% of total anions) followed by SO_4^{2-} (25%) and Cl^{-} (5%). NO^{3-} is also present but in much lower concentration. Chloride concentration was high in the beginning of the measurement period and then decreased as the season progressed. Chloride showed increase after rain fall probably because of selective Cl removal by rainwater over snow and ice.

Main sources of dissolved ions

Generally, the chemical weathering taking place beneath a glacier dominates the chemical composition of the meltwater. The chemical composition of cations and anions in meltwater of Chorabari glacier may also be explained on the basis of chemical weathering of different rocks present in the Chorabari glacier catchment. The analysis of data of 2007 and 2008 shows that carbonate derived calcium and magnesium are the major contributors of the total cations in all samples. The Ca^{2+}, Mg^{2+} versus total cations plot shows that the concentration of Ca^{2+}, Mg^{2+} mostly falls along 1:1 line with an average equivalent ratio of 0.91. This indicates that the carbonate weathering of granites could be the major source of dissolved ions in the melt water. The scatter plot of $Na^{+} + K^{+}$ versus total cations shows that all samples fall below 1:1 line with low equivalent ratio), which indicates that there is very small contribution from silicate weathering as also reported by other researchers. High equivalent ratio of (Ca^{2+} + Mg^{2+}) / (Na+ K+) ranging from 2.30 to 38.37 (mean = 11.23) and high (Ca^{2+})/(Na^{+}) ratio ranging from 3.68 to 24.23 (mean = 11.59) also confirmed that carbonate weathering of granite rocks was the major source of dissolved ions in the Chorabari glacier. In case of Chorabari glacier, the (Mg^{2+}) / (Mg^{2+} + Ca^{2+}) ratio 0.5 (0.60) along with high Mg^{2+}/Ca^{2+} ratio (1.67) clearly indicate dominance of carbonate acid weathering and causing biotite dissolution in both year 2007 and 2008.

Calcium and potassium hence are mainly derived from granite rocks through the dissolution of carbonaceous minerals with main contribution from Ca and K rich feldspar. Dissolution of calcite that may be present in traces in granite can also contribute these ions. On the other side, the concentration of bicarbonate is higher than other, anions, and is positively correlated with Ca^{2+} + Mg^{2+} (r2 = 0.81). This scattered plot of (Ca^{2+} + Mg^{2+}) versus SO_4 and HCO_3^- shows that most of the (Ca^{2+} + Mg^{2+}) charge is balanced by HCO_3^- and SO_4 and only a small part is balanced by Cl^- and NO_3^-.

Atmospheric inputs are assessed by considering the ratios of elements to Cl^-, owing to the high concentration of Cl^- in ocean and its low concentration in most of the rocks. The chloride concentration in the Chorabari glacier meltwater is generally less than that of the sodium and potassium concentration. Increase in concentration of Cl^- in some samples without corresponding rise in sodium is probably the result of selective Cl^- removal by seasonal snowmelt. On a piper plots, most of the samples fall towards the calcium and potassium + sodium apex with secondary trends towards SO_4^{2-} and a few points towards the chloride in both the years 2007 and 2008. This further confirms that carbonate weathering of calcic feldspar and calcite from freshly exposed grains of granites due to rapid glacier erosion dominates over silicates. The analysis of acid–alkali associations indicates the dominance of alkaline earths and weak acid ions in the melt water. The higher concentration of Ca^{2+} and Cl^- and lower discharge in the month of October 2008 could be responsible for high strong acid ions in the form of chlorides. The estimation of carbonate and silicate weathering indicates that ~80% of bicarbonate ions come from carbonate weathering and ~20% from silicate weathering. Dominance of carbonate weathering may indicate limited role played by the Chorabari glacier erosion in assimilation of atmospheric CO_2. However, further studies of strontium isotopes are required to confirm it. The episodic nature of Cl release implies that Himalayan glacier meltwater chemistry is strongly influenced by the regional monsoonal precipitation. The result shows diurnal variation in TDS, conductivity and all ionic concentration indicating sub glacial water may be the major source of water during the summer. This pattern of solute concentration variation is consistent with the release of the ion-rich meltwater.

In addition to studies on Chorabari glacier, the hydrochemical studies in Doon valley revealed that the seasonal and spatial variation in ionic concentration, in general, is related to discharge and lithology. The high ratio of (Ca + Mg)/(Na + K) i.e. 10, low ratio of (Na + K)/TZ+ i.e.0.2 and also the presence of carbonate lithology in the northern part of valley is indicative of carbonate dissolution as the main controlling solute acquisition process in the valley. The low abundance of silica content and high HCO_3/SiO_2 ratio also supports carbonate dissolution and less significant role of silicate weathering as the major source for dissolved ions in Doon Valley.

The analytical results computed for various indices show that water is of fairly good quality, although hard but have moderate dissolved solid content. It is free from sodium hazard and lying in C_1-S_1 and C_2-S_1 class of USSL diagram and in general suitable for drinking and irrigation except few locations having slightly high salinity hazard.

Treeline dynamics in relation to climate change

25 days field work was conducted in and around Dokriani and Chorabari glaciers during the months of June and October. In order to assess climate change impact on Ecosystem, the past and present spatial existence of treeline (ecosystem feature) was investigated. The oldest available survey of India map for the year 1962 was taken as base line record. The past status of treeline is determined with the help of geo-morphological, forest features recorded at the base map and their recognition and validation at the ground. While present status is established on the basis of ground check of treeline attributes and their recording and comparison with basic data set. The treeline rise in Chorabari is determined 10.21m/year while it is 1.70m/year in the Dokriani glacier valley (Fig. 29). The climate change impact on ecosystem is revealed and is evident in the form of shifting in spatial existence (elevation) of treeline with in the period of 47 years. Moreover, ecologically, the upwards dynamics of treeline implies the prolonged recession in glacial resources, especially of snowline, mass balance and spatial existence of snout of the related glacier.

The sharp difference, i.e., 08.51m in the rate of treeline shifting of both the glaciers is strongly suggestive of dominance of site specific and local micro-climatic factors rather than regional climate

Fig. 29. Dokriani glacier valley treeline rise @ 1.70 m/year.

feature of western Himalaya. The factors such as snow/water precipitation, temperature, photoperiod, air/soil moisture regime, wind velocity and soil content, etc., are considered main determinants of the climatic scenario related to the treeline dynamics in the study area.

The samples collected during field work from treeline floristic composition of the glacier valley are processed, prepared and mounted in the laboratory and taxonomically identified as *Betula utilis*, *Abies pindrow*, *Rhododendron companulatum* and *Quercus semicarpifolia*.

More interestingly, the gradual change in floristic composition of treeline species is an indication of variable ecological compatibility of different species with respect to climate change.

The preliminary data related to the snowline as a climate marker is also obtained and reference points as a ground bench mark are also identified and installed for regular monitoring of snowline fluctuation in near future.

Component 4.4

Mass balance studies of Dokriani and Chorabari glaciers, Garhwal Himalaya

(D.P. Dobhal)

In continuation of glacier monitoring programme "Study of Himalayan Glaciers vis-à-vis climate change", two glaciers Dokriani (7 sq.km.), in Bhagirathi basin and Chorabari (6.9 sq.km.) in Alaknanda basin are being monitored for long term basis. During the study period (2009) annual mass balance, snout retreat, glacier discharge measurement and meteorological observation have been carried out for the budget year 2008/09. The main objective of the present work is i) to evaluate change in glacier mass and dynamic processes via-a vis climate change, and ii) annual difference in mass balance and snout retreat processes. The studies carried out so far show that both glaciers are retreating and having negative mass balance trend. During the study period specific balance calculated for Chorabari glacier (0.78 mw.e) is almost double compared to the Dokriani Glacier (0.41 mw.e.). On the other hand, snout of Dokriani glacier has retreated 20m where as Chorabari glacier snout retreat was only 5m. The results indicate that the processes of mass balance and snout retreat are two different phenomenon and can not be correlated even both processes are governed by the climate. Beside the temperature and precipitation (main controlling factor), there are several other factors like orientation, shape and size, bed rock slopes, debris cover thickness and geometry of the snout area (Narrow/Wide) also play vital role in regulating the dynamic process of the glaciers. It is also observed that there are not much changes in annual surface melting during the summer but variation in annual mass balance may be due to i) fluctuation in winter snow accumulation and ii) total existing area of accumulation zone. For example, Dokriani glacier has a larger accumulation area (66% of the total glacier area), where as Chorabari has a comparably smaller (46%). This is supported by the observations in the glaciers where the result show the net specific balance (annual loss) is higher for Chorabari glacier (-0.78m w.e) than the Dokriani glacier (-0.41m w.e). Further, the snout recession rate calculated is 5-10m/a for the Chorabari glacier and 18-20m/a for the Dokriani glacier which is just reverse to net annual balance.

The hydro-meteorological data on the both glaciers has been collected for the entire ablation period, the data collected has been analysed and some of the results shown in figure 30.

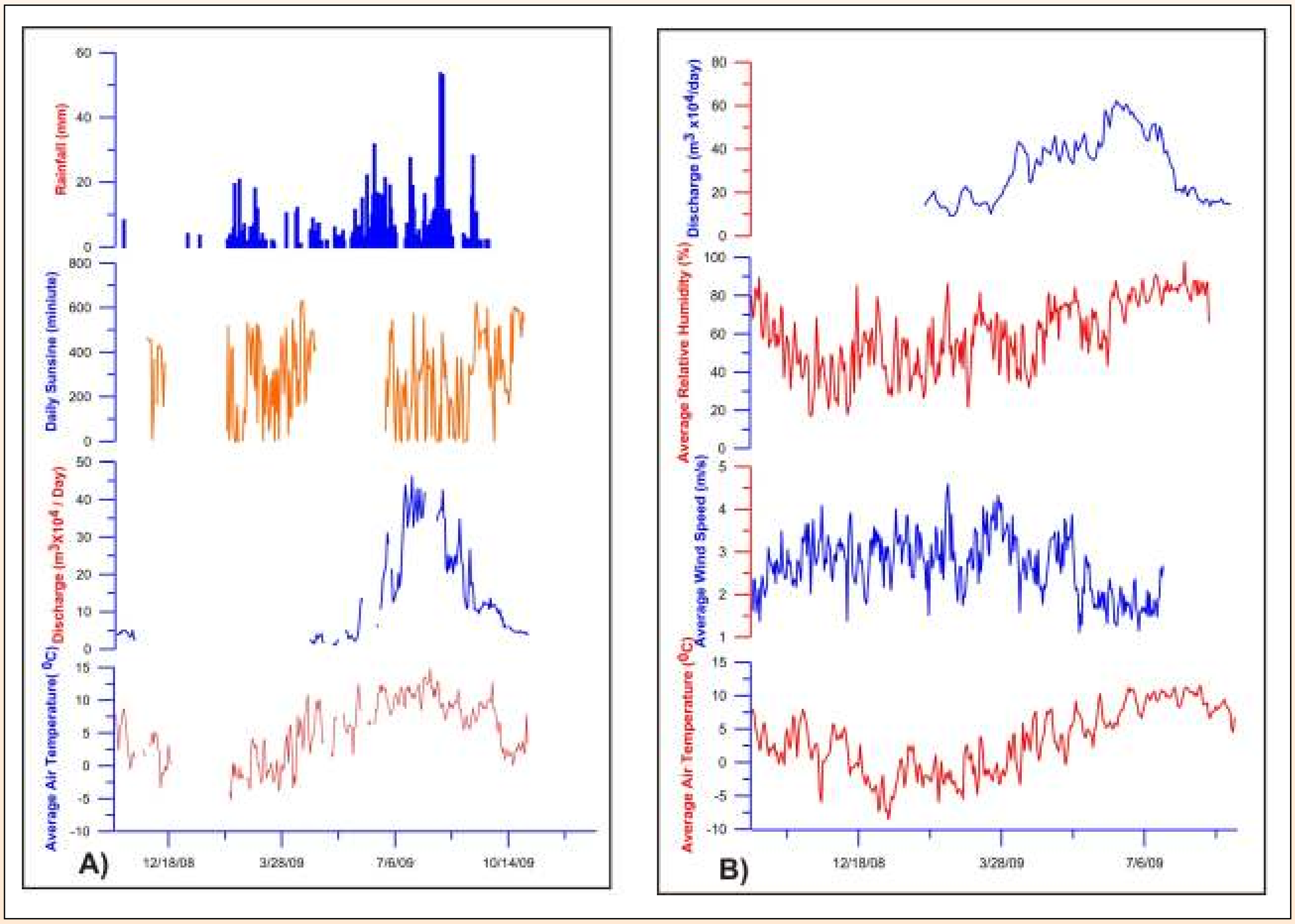


Fig. 30. Relationships between discharge, average temperature, wind speed, humidity and rainfall for the period from Dec. 2008 to Oct. 2009 in Chorabari (A) and Dokriani glaciers (B).

MMP5: 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)

Towards the study of active faults, selected areas in Pinjaur Dun and the Himalayan Frontal Thrust (HFT) near Kala Amb, Himachal Pradesh have been taken up. In Pinjaur Dun, the trench excavation survey across a Quaternary fault, considered to be a splay of the reactivated Nalagarh Thrust, was carried out during the previous year and a variety of data sets were generated. During the reporting year the interpretation of the above field data and laboratory analysis were continued. The final scrutiny of the survey was completed with the OSL age input and the results have been concluded. The investigations along the Nalagarh Thrust, which is between Paleogene and Neogene rocks, clearly illustrate evidence of occurrence of Holocene and mid Late Pleistocene earthquakes in Pinjaur Dun, in the northwestern Sub Himalaya. This Quaternary fault substantiates the seismic potential of Pinjaur Dun and calls for more intensive study of paleoearthquakes of this industrially fast developing and highly populous frontal part of the mountainous region.

Study has also been carried out in the HFT system along the Himalayan front near Kala Amb. The HFT in this area is a north dipping thrust, dips 20°-30° 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. These studies have established that the HFT along the mountain front between Chandigarh-Adh Badri-Kala Amb have ruptured during the last 2000 years and generated multiple major earthquakes (M7or 8). Trending NW-SE, the HFT has however been displaced and offset by numerous later developed transverse faults and lineaments that have also influenced the development of landforms in the area. The most significant of these faults is the Kala Amb tear fault near Kala Amb, which has displaced HFT by over 5km. These studies and many new exposures observed along new water storage structures clearly revealed that the Siwaliks are riding over the fans and terraces indicating not only the active nature of the HFT but also that rupture is propagating to the surface. This is against the popularly propagated opinion that HFT is a blind thrust and no surface rupture is associated with major or great earthquakes occurring along the Himalayan mountain front.

Work was also carried out on another trench excavation survey near Kala Amb across an explicit surface exposure of the HFT. 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 (Fig. 31). 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 cumulative displacement of Quaternary alluvium is of the order of 15 meters which also substantiates multiple paleoearthquake events in this area during Holocene.

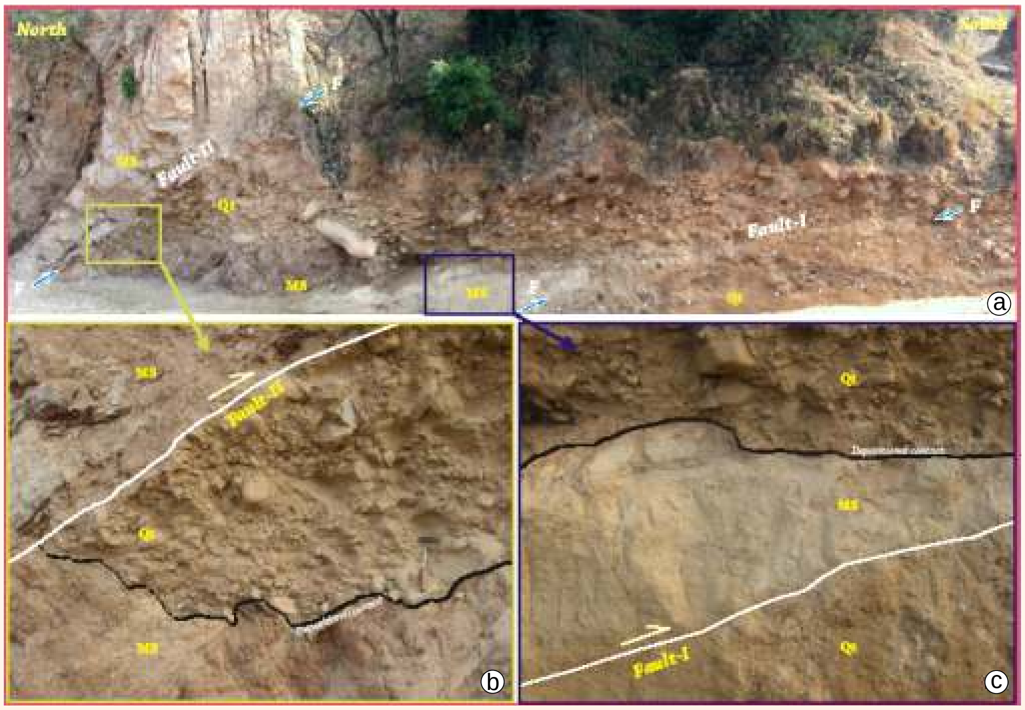


Fig. 31. Trench excavation across Himalayan Frontal Thrust (HFT) near Kala Amb. (a) Panoramic view of the trench wall shows two distinct faults (F-F shown in arrows), where Middle Siwalik sandstone (MS) thrusted over the Quaternary Alluvium (Qt). Preliminary analysis indicates occurrences of two large magnitude paleoearthquakes in this area during Holocene. (b & c) Closeup views of part of the two earthquakes faults. Fault-I, the older and Fault-II, the younger. Depositional contact of Quaternary alluvium with the Middle Siwaliks is shown in shaded lines.

The morphotectonic study carried out along the Kosi, Dabka and Gaula river valleys, Kumaun Himalaya, shows neotectonic activities along and across the Main Boundary Thrust (MBT) zone. At the top of the footwall the Siwalik sediments of the Sub-Himalaya dip steep towards NE. In the steeply dipping hanging wall occur granite porphyries, and a succession of boulder beds, quartzite and phyllite of the Lesser Himalaya. Depositional landforms, such as alluvial fan deposits, bear signatures of later phase of recent tectonic activity that resulted truncation of colluvial fan deposits, development of fault scarps and tilting of stratified fans and terraces. Along the Gaula and Nandhaur river valley sections a segment of the MBT behaves as active normal fault. Soft sediment structures are also recognized near top of the foot wall of the MBT (Fig. 32). The structures, embedded in sandstone of about 9.8 Ma (Kotlia et al., 2001), are interpreted to

Fig. 32. Soft sediment structures developed in Lower Siwalik sandstone, near top of the footwall of the MBT at Jamrani, Gaula valley.

be formed by one or more seismic events, which might have accompanied when the Lesser Himalayan rocks began to thrust over the Siwalik sediments along the MBT.

Along the Kosi river section at the MBT zone, the ~200m wide Kosi river course developed in the hanging wall becomes 1300m wide in the foot wall, where four levels of terraces have developed. High levels stratified fan deposit observed in the hanging wall of the MBT is back tilted by 7° towards NNE. On the basis of development of tectonic geomorphology in the very steep to vertical dipping MBT zone it is inferred that the transverse faults seem to be neoectonically active, also as evident by huge thickness of landslide debris all along the MBT.

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 major palaeo landslide and mass movement blocked sites along the Satluj valley were analysed for detailed study. The field evidences and Quaternary sequences indicate that to the north of Tethyan Thrust the lacustrine deposits are quite intact, uplifted 30-35m from the present Satluj river bed, sitting on the bed rock or erosional terraces suggest that the Tethyan Thrust was quite active during the Quaternary period. It has been observed that the upstream of Satluj-Tidung Khad confluence Satluj takes a right angle turn and form N-S and NE-SW gorge section. Towards the downstream along the strike of the Tethyan Thrust passing through Tirung Khad and Thopan Dogri north of Ribba village the Satluj become wider and filled by Quaternary sediments partly exposing the bedrock in the thalwag. The Palaeo massive debris flow mainly of glacial origin blocked the Satluj and a lake was formed. The river terrace material 50-60m thick along the Akpa village and the glaciofluvial material along the Khadra Dhang indicate the blockade was at least 50-60m high which was breached later on and the outwash material was deposited downstream up to Powari and Kilba section of Satluj valley. The 2000 and 2005 flash flood has eroded considerable amount of these terrace material and Satluj is quite wide at Powari section that lead to lateral erosion and reactivation of unconsolidated hill slope mass particularly between Powari and Shongtong. The terrace material at Ribba dated 4.1+ 0.7 and 2.29+ 0.25Ka indicating the age of lake around ~4000 year old.

The other major Palaeo blocked along the Satluj river is observed at Kilba village. The blockade at this point was created by massive rock fall and glacial debris flow. The Satluj thalwage from Kilba to up stream of Karcham is covered with fluvial terrace partially exposing the bedrock indicates the up stream extension of Kilba palaeo-lake. These fluvial terraces are lying 30-35m from the present riverbed. This terrace as per geomorphic estimates, sediment composition and their compaction appears to be younger than ~4000ka old. These observations indicate that there was a major mass movement due to glacial surging and landslide activity in the area that cause damming and later on breaching of landslide dams as also observed from the earlier studies carried by us in Baspa valley.

Geomechanical characterization of rock mass exposed in the Satluj and Alaknanda valleys is continuing. Destructive and non- destructive tests have been carried out. These tests include density, porosity, seismic velocity (both P- and S-waves) measurement under laboratory condition, Schmidt hammer rebound (R- value) tests and the unconfined compressive strength (UCS) tests. The values of Poisson's ratio and Young's modulus were also computed. Four different lithologies were considered: granites, gneisses, quartzites and marble. It has been noted that there is a significant variation in the density of the granites compared with the other lithologies. Nevertheless, in general, there is a linear relationship between the density and ultrasonic velocities (both compressional and shear) for the different rocks (Fig. 33). However, the strength of the relationship is more pronounced in the quartzite (R^2=0.99 for V_p and 0.98 for V_s) because of its isotropic nature and uniform composition, whereas in the case of gneisses, the

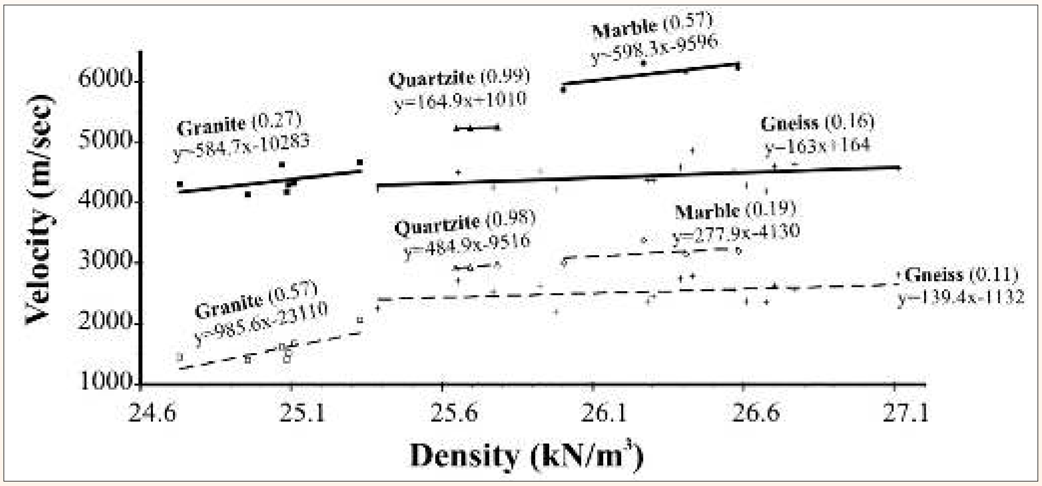


Fig. 33. The relationship between density and ultrasonic compressional (P-) and Shear (S-) wave velocities for granites, gneiss, quartzite and marble belonging to the Higher Himalayan Crystalline (HHC) sheet and the Tethyan metasediments.

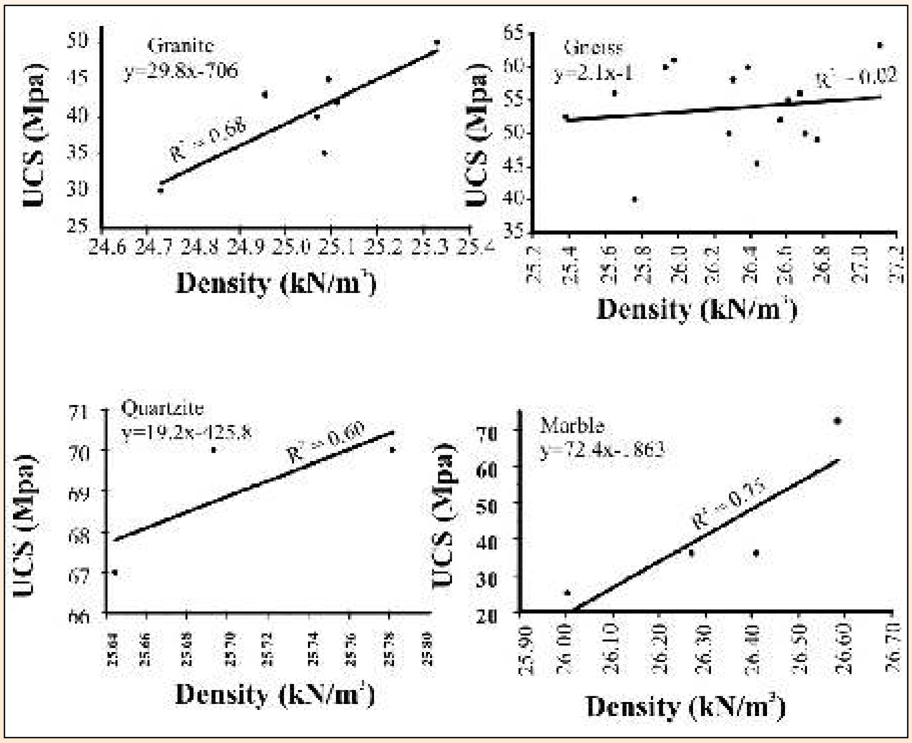


Fig. 34. The relationship between density and UCS for granites, gneiss, quartzite and marble belonging to the Higher Himalayan Crystalline (HHC) sheet and the Tethyan metasediments.

PROGRESS IN RESEARCH PROJECTS

poor relationship (R^2=0.16 for V_p and 0.11 for V_s) is due to their anisotropic nature. Moreover, these recorded 527 local earthquakes (Fig. 36). The focal depths of these local events range between 0 and 40 km, but large number confined to upper 20 km. The local magnitude ranged between 1.0 and 4.9 (Fig. 37). The 527 earthquakes define a relatively narrow belt of earthquake epicenters, which straddles the Main Central Thrust (MCT), named Himalayan Seismic Belt (Fig. 36). The seismic activity in this belt is not uniform longitudinally. The earthquakes of magnitude greater than 3 occurred in the upper crust show fault plane solution of all three main types namely, strike slip, reverse/thrust and normal fault type. The data of one year show one outstanding cluster i.e. a sudden increase in seismic activity observed 50 km SE of Tapovan during April 7 and April 13, 2009. This type of activity is termed as swarm. Earthquake swarms are events where a local area experiences sequences of many earthquakes striking in a relatively short period, but there is no identifiable main shock. During this period, total 45 local events were recorded. The magnitude ranges between 2.1 to 2.8. On 8, 9 and 10

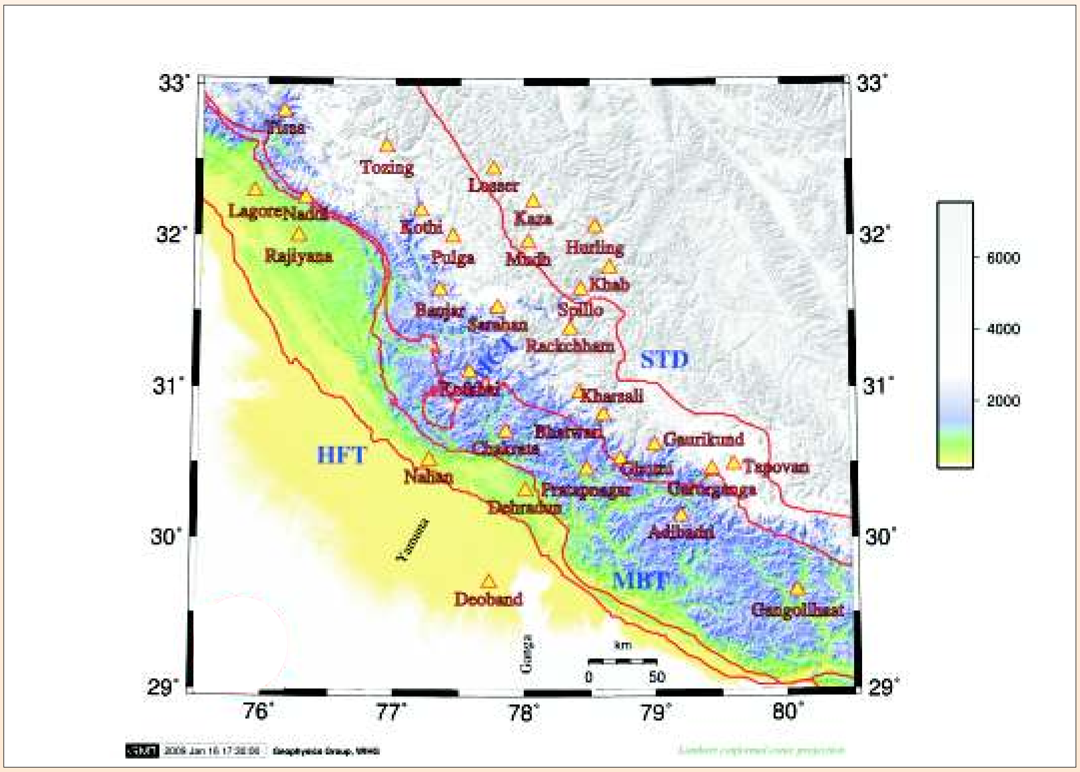


Fig. 35. Broadband and short period seismographs in operation in the NW Himalaya shown with the triangles.

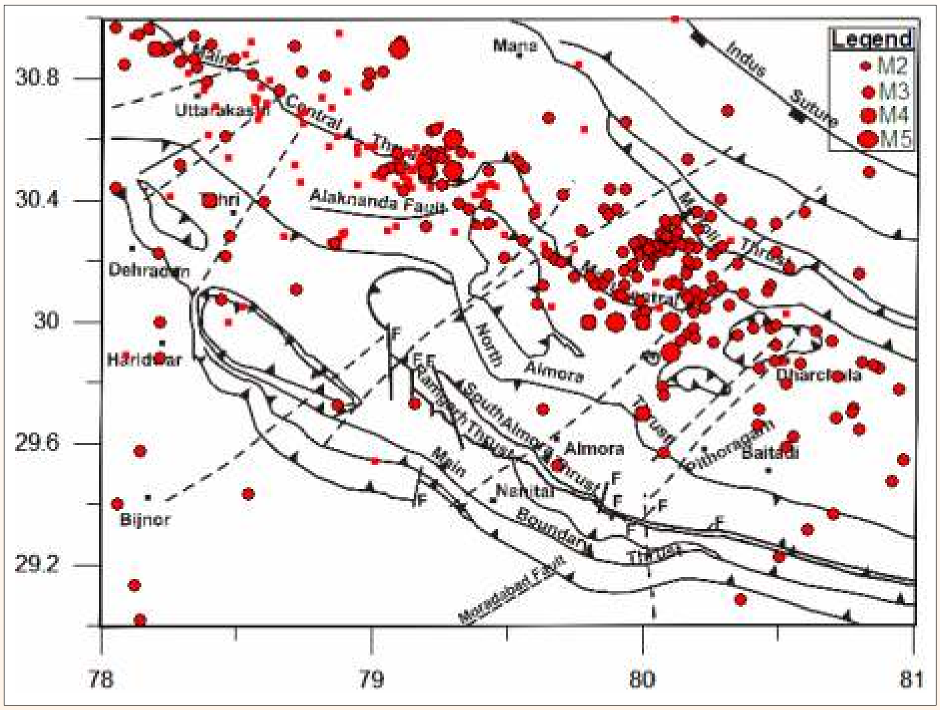


Fig. 36. Epicenter plot of WIHG seismic data from April 2009 to March 2010. The Himalayan Frontal Thrust, Main Boundary Thrust, Main Central Thrust and other fault/Thrust system are shown in the plot. Epicenters are shown with the colored circles. Symbols are described in the legend.

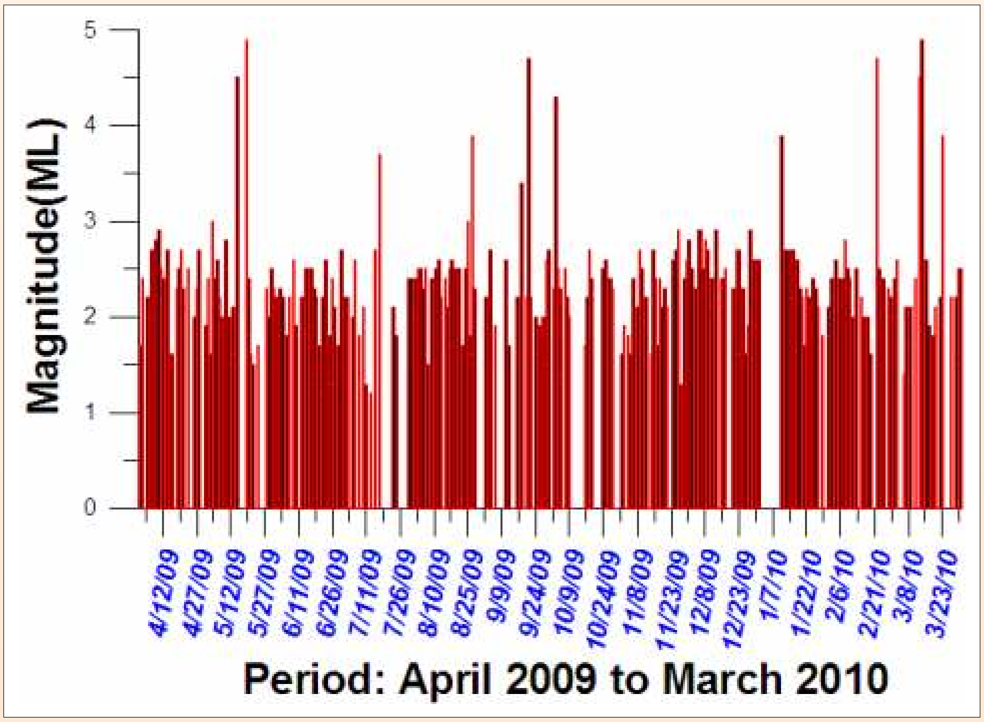


Fig. 37. Histogram of the local Seismic activity.

About the Fault plane solutions analyzed from the current data set

To understand the Seismotectonic behaviour of the region, the P-wave polarity information recorded at different stations for seismic events within the network and having magnitude, more than 3.0 have utilized to obtain the fault plane solutions. We obtain the fault plane solutions of three earthquakes which occurred near Kharsali, Guarikund and Kullu of the study region. Two of these earthquakes show reverse fault motion with strike slip component while the third one near to Gaurikund has pure strike slip movement. The strike slip movement near Gaurikund has nearly vertical dip showing the rupture through a tear fault.

Seismotectonics and State of Stress study in Kangra-Chamba region of Northwest Himalaya

The micro-earthquake data of the NW Himalaya recorded by a dense seismic network of WIHG indicate high concentration around the Main Central Thrust (MCT) and Panjal Thrust (PT). These events have been located using the new velocity crustal structure established for the Kangra-Chamba region that gives the minimum error for source locations of these local earthquakes. The crustal structure has been established using the micro-earthquake data in the magnitude range of 1.0 to 5.0 for the initial period of 2004-2005. As shown in figure 38, the micro-seismicity in this part of Himalaya is mainly confined in the region, where so called Main Himalayan Seismic Belt (MHBT) has been well established. Bigger size seismic events for the period 2004-2009 in the Kangra-Chamba region of Northwest Himalaya were relocated, processed and analyzed for determination of sub-surface deformations. Events with magnitude 2.5<M<5.0 (Fig. 38) were used for Fault Plane Solution (FPS) determination, with clear P-wave first motion availability. In this case 45 events were selected for FPS determination, from which 35 events were sorted out for final analysis. The selection criteria were that the events used for FPS determination should have good azimuthal coverage of the seismic network with clear P-wave arrivals.

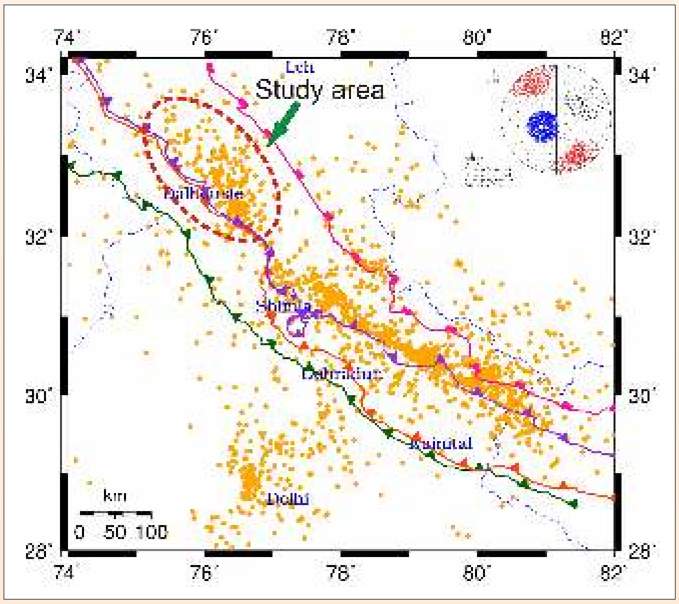


Fig. 38. Seismicity of NW Himalaya obtained using WIHG network during 2004-09 along with the major tectonic features as follow: STD (South Tibetan Detachment), MCT (Main Central Thrust), MBT (Main Boundary Thrust) and HFT (Himalayan Frontal Thrust). The ellipsoidal dotted area is the study region (Kangra-Chamba). The inset at the right top corner is the stress tensor inversion result obtained using fault plane Solutions (FPS) of Kangra-Chamba region.

The FPSs of earthquakes quantify the nature and plane of movement during rupture and these are effective tools to constrain the active tectonics generating earthquakes. Further, the vector decomposition of FPS can help to define the direction and form of principal stresses operative in the seismic regime of the region. These FPSs were utilized to assess the sub-surface deformation along different parts of the tectonic faults nearby to the location of the source of earthquake in the Kangra-Chamba region. Using the Strike, dip and rake information of the FPS, the stress tensor inversion is done to get the maximum compression axis orientation in this region that represents the average deformation of the study region. Also the stress tensor inversion for the three main types of faulting i.e., thrust, strike-slip and normal type of focal mechanisms were obtained. Variation of Stress spatially and with depth and the overall regional stress regimes are also studied. The stress tensor Inversion result shows that the maximum compression axis direction ($\sigma 1$) trends in the NNE direction and plunges 34° and the minimum stress axis (σ_3) trends at NE and plunges at 56° in the Kangra-Chamba region of NW-Himalaya (Fig. 38). The detailed studies on the Seismogenic behaviour of tectonic faults/lineaments of this region are highly significant in quantifying the associated seismic hazards in this part of NW Himalaya.

Fractal Dimension and b-Value Mapping in NW Himalaya

The northwest Himalayan region and the adjoining regions fall in the most intense seismic zone. Earthquakes of varying intensities have hit the region in the past and similar threats remain imminent. In the last 105 years, the main earthquakes occurred are the Kangra earthquake of 1905 (Ms=8.0), the Kinnaur earthquake of 1975 (M=6.8), Dharchula earthquake of 1980 (Mw=6.5), Uttarkashi earthquake of 1991 (Mb=6.6), Chamoli earthquake of 1999 (Mb=6.8) and the Kashmir earthquake of 2005 (Mw=7.6), which resulted in tremendous loss of life and property. The earthquakes occurrence possesses non-linear relation with respect to space and size. Fractal dimension and b-value are determined from 1729 well-located earthquakes, recorded in the northwest Himalaya during 1995-2010 at the WIHG and other Seismic arrays. This data was selected from the total number of 5503 recorded data. A detailed study of the frequency–magnitude distribution and fractal dimension as a function of depth was carried out. The earthquake data with magnitude larger than 3.0 is used to perform the further analysis. The majority of events are located in the NW Himalayan region between longitude 74^0 -82^0E and latitude 28^0 -34^0N. The study region was divided into 33 grids, $1.0^0\times1.0^0$, with an overlapping of 0.5^0. Each grid containing greater than or equal to 50 events to ensure the reliable values of D and "b". Grids having less than 50 events have discarded from the analysis. High b-value at shallower depth implies the heterogeneity of the medium. Low b-value at higher depth implies more stress accumulation. Here a b value varies in the range of 0.35 to 1.03. The contour lines with larger b-values extending from northwest to southeast in the middle part of selected grid in the NW Himalaya, indicating the seismically active part associated with heterogeneity of the medium. The second one with the smaller value of b in extreme northwest and south west side; and the third one mainly with smaller b values south of Main Central thrust regime. The differences in b values are mainly due to the different type of crustal properties in the Higher and Lesser Himalaya. The small b values of that region are due to low seismicity almost in the whole magnitude range (Fig. 39). The fractal dimension D was estimated by co-relation integral technique defined by Grassberger and Procaccia(1983). In this method at first, the total region was divided into a number of grids according to latitude and longitude and then the spacing of a set of points (epicenters) were measured. The value of fractal dimension is low, less than one (Fig. 40). This low value may be due to clustering of epicenters and the distances between the epicentres of each gird, which are very small. In the region the correlation between D and b –value is positive indicates that the medium has achieved a steady state of stress distribution (Fig. 41).

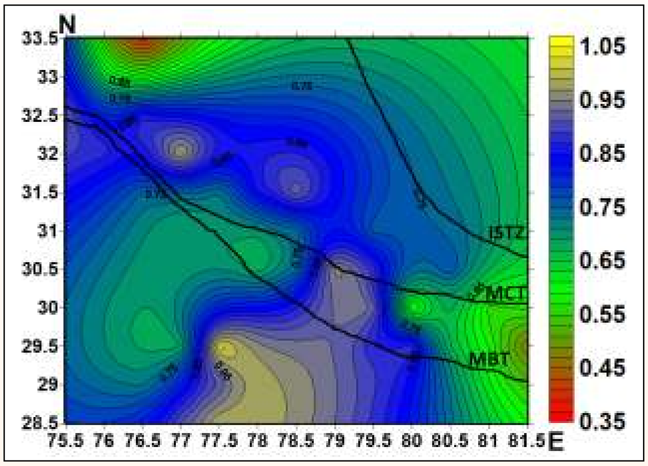


Fig. 39. b value contour map for total 1729 earthquakes (M≥3.0).

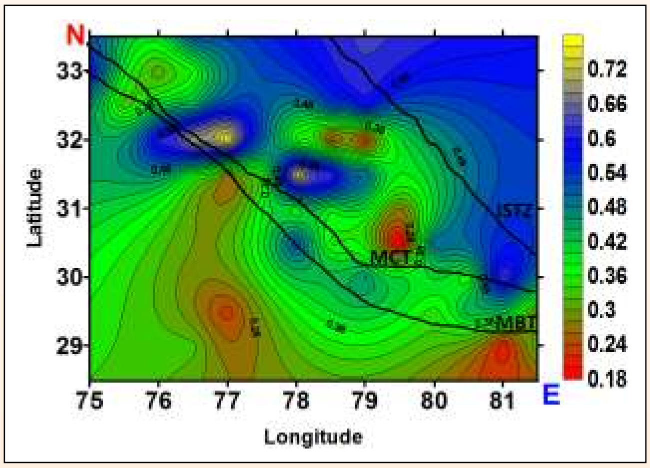


Fig. 40. Fractal Dimension contour map (D) for total 1729 earthquakes (M≥3.0).

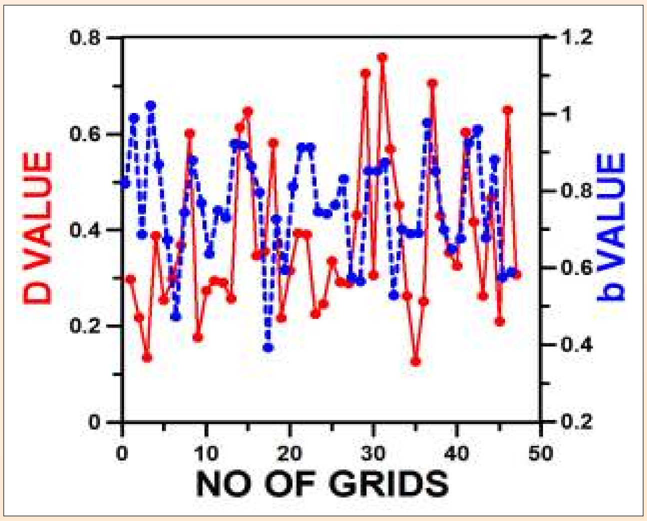


Fig. 41. Variations of D with b value with the different grids in the study area.

Component 5.2b

Multi-parametric Geophysical Observations for earthquake precursory research

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

At Multi-parametric Geophysical observations (MPGO) for earthquake precursory research, various geophysical measurements are being carried out for detecting or isolating earthquake precursory signatures. Main set-up of these observations was started in 2007 after installing 11 sophisticated geophysical instruments at MPGO, Ghuttu in Garhwal Himalaya for taking continuous measurements. These observations are also supplemented with continuous measurement of GPS, total intensity geomagnetic field measurement at Bhatwari and total geomagnetic field at Adibadri. Continuous recording of geomagnetic variations in ULF is started at Bhatwari from this Year. These support site observations are useful for checking the regional trend and removing the background noise levels with cross correlation of different stations data. The recent observations of different parameters are as follow:

Global Positioning System

The Global Positioning System (GPS) study is a major component in attaining the objective of the project. To study the effect of reservoir loading and unloading, fifteen reference points were established around the reservoir. The data has been acquired alternatively pre monsoon and post monsoon regularly in campaign mode since 2006 to 2009 and the data was collected at each reference point continuously for five days. The entire data was processed using the 10.35 version of GAMIT/GLOBK Linux based software and has been tried to observe the effect of pore pressure due to the loading and unloading of the lake on the seismicity as well as the ground deformation etc in the study region. In the processing, we take care for all assumptions and norms which are designed for the precise processing. One month training at NGRI Hyderabad has been obtained for advance processing of the data and cross checking the results. The data of all campaigns (Oct. 06, July 07, Nov. 07 and May 08) have been processed with respect to global IGS sites (Fig. 42) in itrf05 reference frame and analyze the results with different sets of combinations. Later on, for obtaining the regional geological/geophysical changes, we have included our local permanent GPS station at Ghuttu in the processing and got the results with respect to the Ghuttu site. Analyzed data was correlated with the velocity vectors and time series of each reference point for different campaign mode (Fig. 43). The changes in the trend of velocity vectors during different campaign period may be due to loading and unloading of water level in the reservoir (Fig. 44).

Geomagnetic Field

Extra terrestrial effect in geomagnetic field is minimized by considering differential data sets of three observatories. Further to the fact that during local night hours geomagnetic variations primarily have their origin in magnetosphere, use of local midnight data further minimize the external variations and helps to isolate weak tectonic signatures. Variation before and after the Kharsali earthquake (M_L:4.9, 22.07.07 23:02:13.2 UTC) has been identified with this methodology very well. The fact that drift in differential field is observed for station pairs in either side of MCT and absent for station pairs located south of MCT and, indicates drift is caused by magnetization changes in hanging wall of the causative earthquake. Further data variability is explored using principal component analysis of data sets of three stations and anomalous second and third eigen value variations before and after the earthquakes are identified.

A methodology is developed to find the source azimuth of ULF electromagnetic signals emitting from earthquake source area by comparing polarization ellipses (PE) parameters formed by the magnetic field components at the measurements stations. The methodology is tested to the data sets from Koyna region due to availability of more than one station data. The methodology will be applied to data sets from three

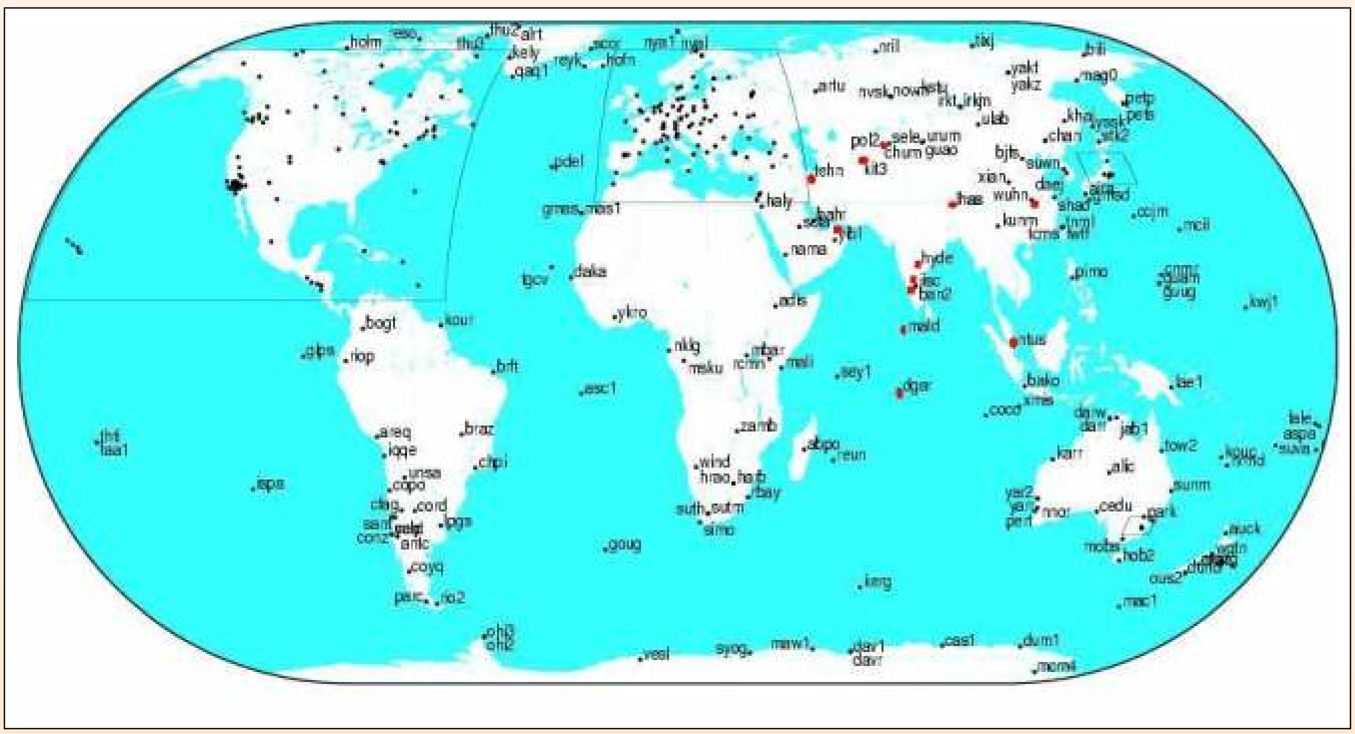


Fig. 42. IGS sites network around the study region.

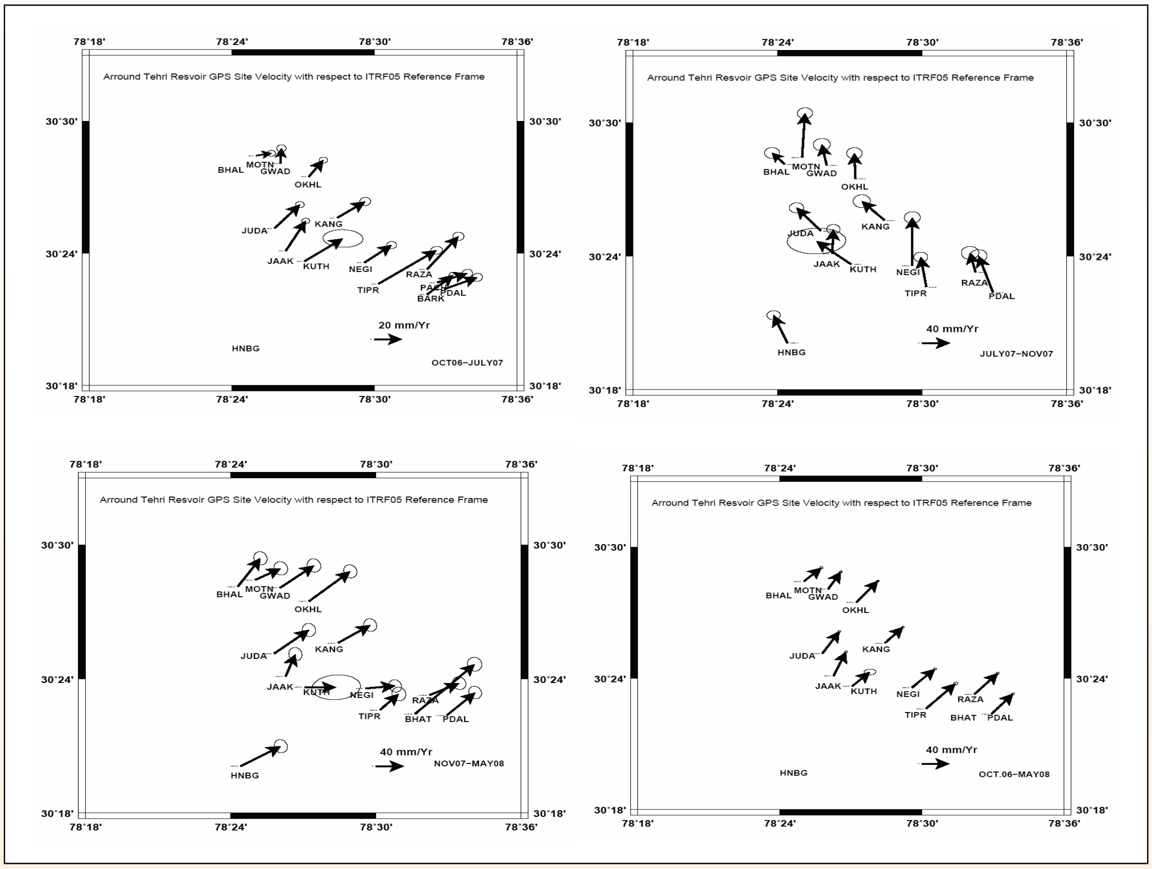


Fig. 43. Velocity vectors of the campaign (Oct. 06-July07), (July 07-Nov. 07), (Nov. 07-May 08) and (Oct. 06-May 08) respectively.

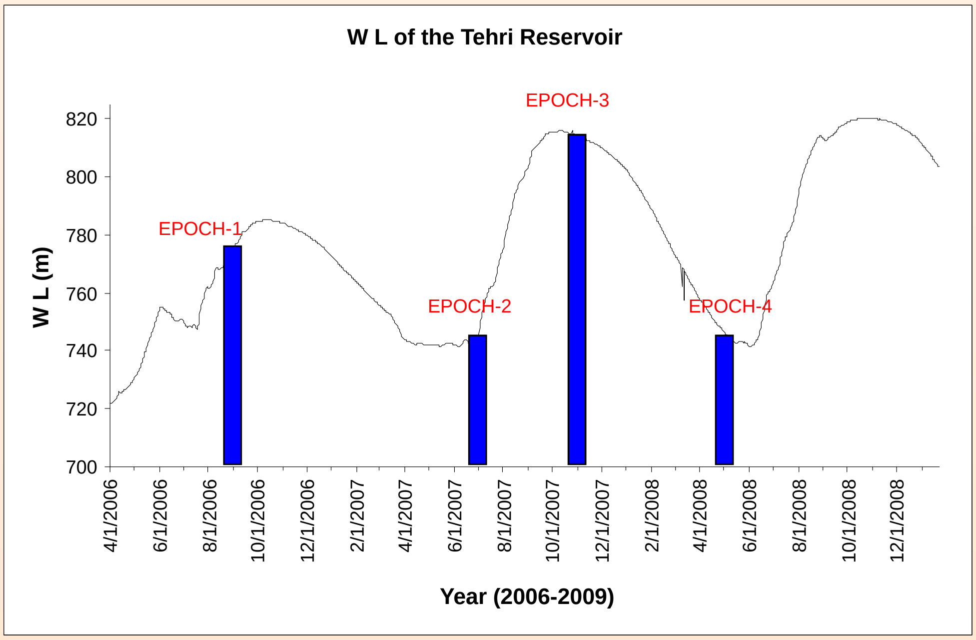


Fig. 44. Reservoir water level from April 2006 to Dec. 2009.

PROGRESS IN RESEARCH PROJECTS

ULF stations in Garhwal region. Discontinuous power supply in remote area of hill state makes continuous operation of ULF data logger difficult thereby loosing continuous data sets. To solve the problem low power PCs are planned to replace ULF data logger for data registration.

Radon Studies

As a part of multi-parametric earthquake precursory studies at Ghuttu, Central Himalaya, radon concentration is being measured at two depths in a 68m borehole. One measurement is taken at a depth of 10 m from surface in the air column above the water table and the second one at 50 m within the water column. Besides radon concentration, air temperature, water temperature, atmospheric pressure, rainfall and water level fluctuations are also recorded with sampling interval of 15 minute. The continuous time series of radon variations at 10m depth along with other environmental parameters over 3 years (2007-2009) recording shows strong variability including well-defined seasonal, day-to-day and diurnal variations. The strong seasonal variations with summer maximum and winter minimum closely follow the similar variations in atmospheric temperature with time lag of few days. The control of temperature gradient in borehole on the emission of radon is evident in the form of different patterns of daily variations. Four types of daily variations are observed (i) positive peaks in late afternoon, (ii) negative peaks in early morning hours (iii) sinusoidal with double peaks and (iv) long intervals when daily variations are conspicuously absent, particularly in winter and rainy season.

Examination and correlation with environmental factors has revealed that when atmospheric temperature is well below the water temperature in borehole, the later show constant value around 19°C in all seasons. In this situation, temperature gradients are not conducive to set up the convection currents for the emanation of radon to surface. Thus, explaining the absence of daily variation in radon concentration in winter. During the rainy season, following continuous rainfalls, once the soil/rocks are saturated with water radon concentrations show fair stability. Long pauses in rainfall give jerky variability during rainy season with no clear pattern of daily variation. During rest of the seasons when surface temperature are always higher than that of water temperature, the nature of observed pattern can be reconciled in the form and amplitude of daily progression in temperature gradient.

Superconducting Gravimeter

Continuous gravity measurements using the superconducting gravimeter (SG) has been carried out at Ghuttu in the Higher (Garhwal) Himalaya since April, 2007. Three years gravity observations (sensitivity of SG is 1 nGal) show a heavy influence of tidal forces, atmospheric pressure and hydrological effect which are to be removed for further study. An earthquake is the result of a sudden release of energy in the lithosphere of earth due to displacement along a fault plane. It results a change in mass redistribution that causes the change in the gravity field of earth in a region around earthquake source. At a point it gives a small change in local gravity acceleration due to apparent addition or subtraction on Earth's mass and a change in the distance to the centre of Earth. A theory has been developed to calculate co-seismic gravity changes for arbitrary fault geometrics on the basis of the dislocation model of the earthquake source. For detection of co-seismic gravity change at Ghuttu, an offset in the data close to the origin time of earthquake is observed taking the data set of 1 hr before and 1 hr after its occurrence after removing the effects of tidal forces and atmospheric pressure. To observe co-seismic gravity offset/change the data of these two blocks were separately fitted with a quadratic polynomial to get different non-linear trends. The difference of the calculated gravity value of the fitted functions at the event time for each event will give co-seismic gravity change. This offset is found to be both positive and negative, and may vary for different earthquakes depending upon whether gravity value has increased or decreased after the earthquake occurrence near to SG station.

A set of 46 local earthquakes of magnitude

> 3.0 that have occurred during July 2007 to March 2009 nearby Ghuttu were taken for observing co-seismic offset. It include M4.9 Kharsali earthquake of July 22, 2007 that occurred 60 km NW from Ghuttu. Its Fault plane solution is a reverse fault having significant strike slip component. A significant offset has been recorded by two gravity sensors of SG for Kharsali earthquake giving values of 55.21nm/s^2 and 19.31nm/s^2. The offset in this earthquake is positive indicating that there was increase in gravity due to the earthquake occurrence. Out of 46, the gravity data of 17 other earthquakes of magnitude > 3.0 that occurred within 300 km was observed. It shows that if the earthquake having magnitude > 4.5 and occurred close to the SG station then a significant offset is detected. The amplitude of the offset goes on decreasing with decreasing size and increasing distance of the earthquake. Based on this observation, the procedure was also utilized to observe the Co-seismic change during big size earthquake (M$\geq$ 5.0) occurred within 1000 km from MPGO site during 2007 to 2009. Twelve earthquakes have shown the variation from 0.1 to 15 nm/s^2 in which the significant Co-seismic offset of 15 nm/s^2 was observed during M7.2 earthquake of 20/03/2008 as shown in figure 45. The epicentre distance of this earthquake from MPGO seismic station is 606 km.

Component 5.2c

Seismic microzonation, site response and shallow subsurface studies in NW Himalaya and adjoining areas

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

Site response studies in Major population centers in NW India

Jammu city, located between two active seismic zones, is subjected to large seismic risk. We used multichannel analysis of surface wave method to derive shear wave velocity of each profile and present site amplification effect in this city, based

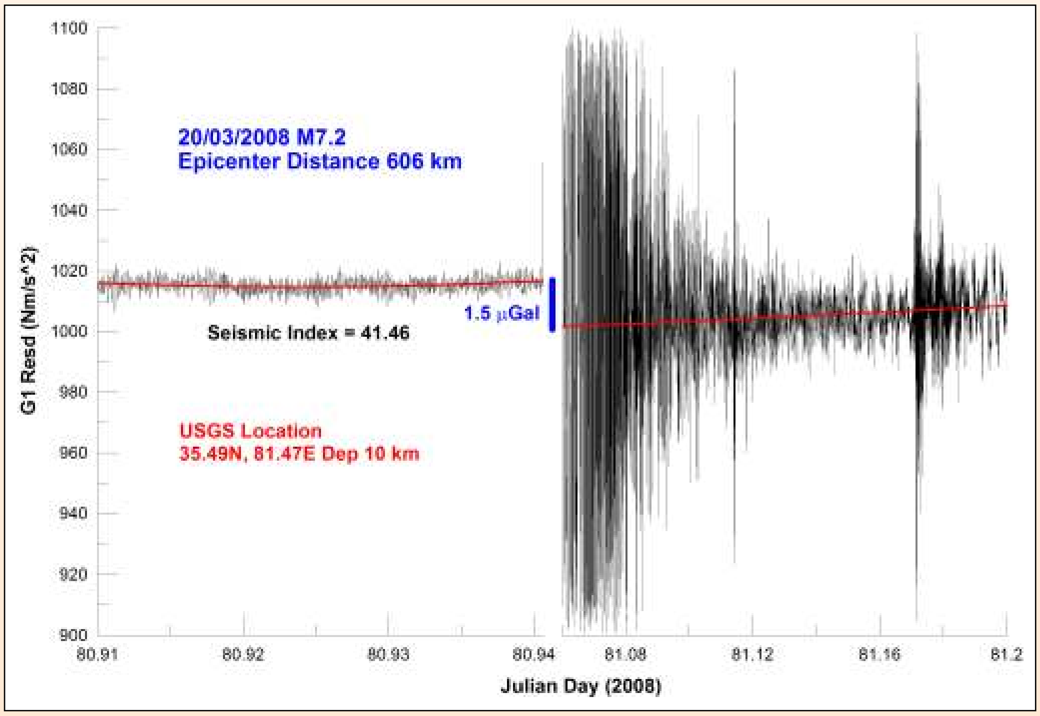


Fig. 45. Co-seismic variation observed in the gravity data of SG (installed at MPGO) during M7.2 of 20th March, 2008.

on shear wave velocity investigation at 30 sites within the city and to compute 1-D site effect. The response analysis carried out using 1-D shear wave velocity (low strain values) with depth coupled with dynamic soil properties of each layer and strong input motion shows resonance frequency of the order of 1.5 Hz to 3.22 Hz. The peak ground acceleration and amplification ratio computed for the top layer suggests 4 times increase in PGA values and 8-12 times increase in amplification ratio (Fig. 46) . Further, extensive Horizontal to Vertical Spectral Ratio (HVSR) survey at 136 sites yields the fundamental resonance frequency of the order of 0.432 to 4 Hz of the sedimentary cover. In general the fundamental frequency derived using shear wave velocity of the 30 m soil column and HVSR shows high frequency (3-4 Hz) in the central part of the city and low frequency (1-1.5) in the peripheral areas. However, there is variation of 0.5 Hz in the values of fundamental frequency derived using HVSR technique and response analysis with Vs information. The variation in fundamental frequency might be due to the lateral variation in the lithology underneath, as the entire peripheral part of Jammu city is underlain by alluvial deposits. The broad/low amplitude H/V peaks further suggest lateral variation and weak velocity contrast in near surface material. The 1-D velocity model derived using ModelHVSR software and MASW technique is in good agreement in those sites where there is a shallow impedance contrast between the overlying sediments and underneath bedrock. The results show that a seismic zonation based exclusively on single station microtremor is not reliable when the underlain sediments are fan deposits with lot of lateral variation.

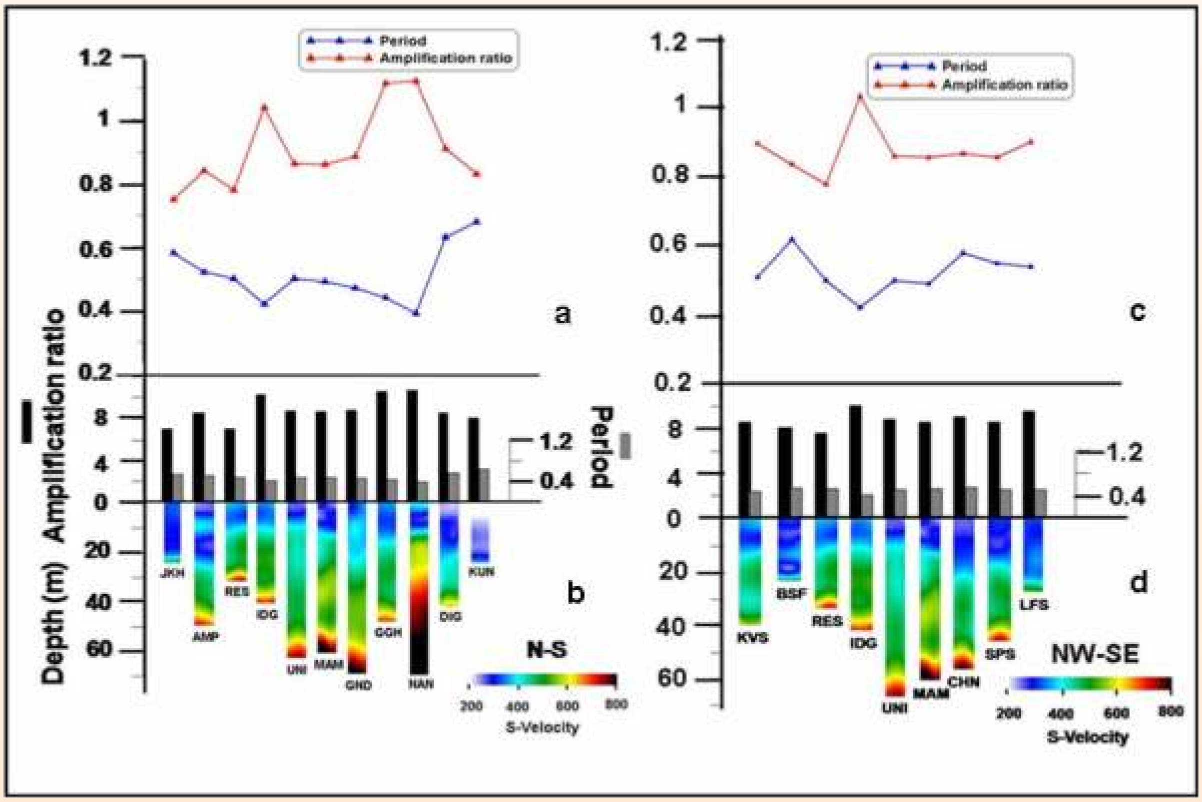


Fig. 46. Peak amplification and corresponding dynamic site period for the suite of sites in a) N-S direction and b) NW-SE direction (normalized to their maximum values).

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)

On lithospheric density anomaly structures beneath the Himalaya-Tibet region

Geoid anomalies obtained from Satellite geo potential method with GPS have been effectively used to understand the role of deeper density anomalies in explaining the GPS observed surface deformations in the Himalaya-Tibet region. Particularly, the present day observed crustal deformation processes in this region like the eastward crustal extrusion of the Tibetan Plateau. The reason for such eastward channel flow was mainly attributed to the flow associated with brittle-ductile regime in the crust. But analysis of geoid performed in short, intermediate and long spatial wavelength ranges explain the significant role of upper mantle density discontinuities as a major source of intense deformation. Results show that major density discontinuities existing in the upper mantle at 220, 410 and 660 km beneath Himalaya-Tibetan region experiencing intense plastic deformation owing to the difference in the gravitational potential energy gradient. The deformations caused by such a deeper flow are attenuated due to the coupling and rheology of the crust-mantle as was observed only a few mm/Yr.

The dichotomy in the distribution of density anomaly field, respectively beneath the Himalaya-Tibet and the Indian Ocean geoid low (IOGL) constitute a strong North to South average geoid gradient of -3m/100 km in the Indian plate. This strong density anomaly field is formed by contrasting gravitational field generated due to (a) mantle upwelling and emplacement of dense relatively cold pre-collisional Tethys oceanic slab beneath the Eurasian plate and (b) Downwelling of mantle material at the southern oceanic region in the Indian plate.

Temporal correlation of Shyok suture formation and India-Eurasia continent-continent collision with Ninetyeast Ridge geoid anomaly and the spreading rate of Carlsberg ridge

The temporal correlation of the events associated with the Himalayan orogeny such as the formation of major suture zones with geoid anomaly variations over the ocean records in spreading Carlsberg ridge and Ninetyeast ridge respectively were studied. It has been observed that there are sharp changes in the geoid anomalies and ridge spreading rates at around 90 Ma and 45 Ma respectively. The opening up of Shyok suture around 90 Ma and that of late continent-continent collision of India-Eurasia are well preserved as changes in the ocean geoid anomalies. The increase of geoid anomaly after 90 Ma in the vicinity of Ninetyeast ridge represents the phase of crustal accumulation followed by the formation of Shyok suture. However, Carlsberg ridge spreading rates were changed from 3.5 cm/a to 1.5 cm/a at around 45 Ma followed by the collision between India and Eurasia.

Solid earth tidal analysis from GPS measured displacement anomalies

The permanent station GPS network of WIHG has improved in its operational status of just two in number to almost nine stations during the year 2009-2010. Apart from this two new GPS stations were constructed first time in the history of Wadia Institute of Himalayan Geology at a region close to HFT, which remained as a major observational gap in the frontal Himalaya. Understanding of surface displacements or slip rates in the frontal part was always remained as conjecture rather than having accurate measurements. The GPS measured surface displacements were subjected to time series analysis and observed major solid earth tidal constituents as shown in figures 47 and 48. It has been observed that long wavelength tidal constituents shown in figure 47 are stronger than the short period shown in

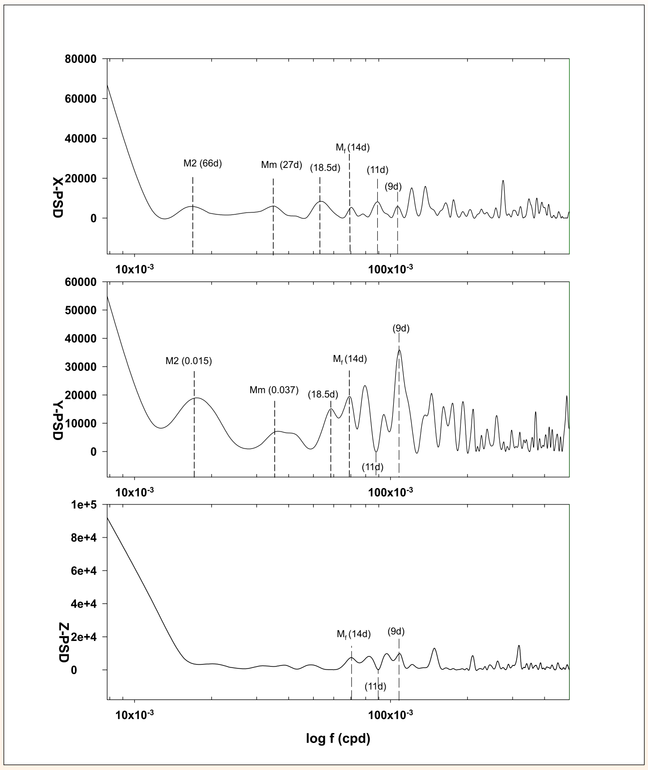


Fig.47. Long period (126 days) solid earth tidal constituents obtained from the analysis of continuously operated GPS measured surface displacements.

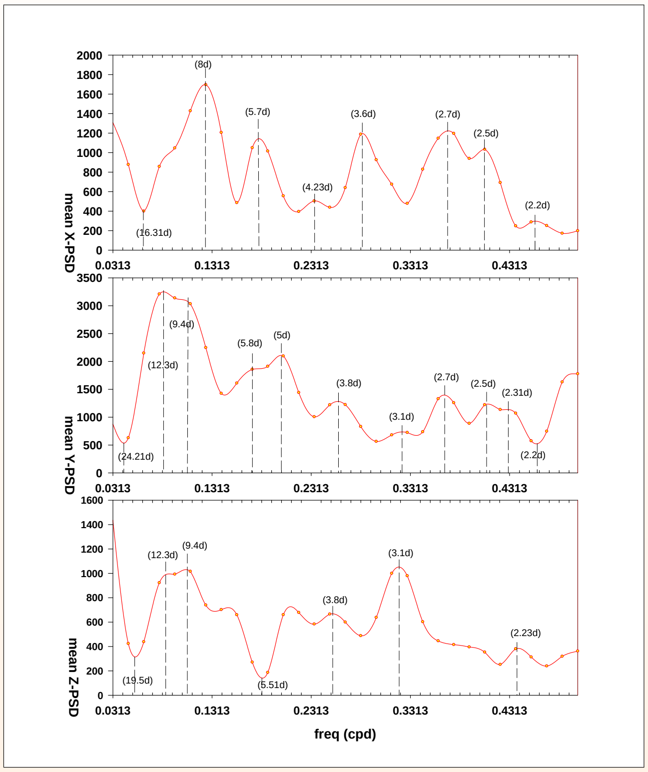


Fig.48. Short period (2 to 32 days) solid earth tidal constituents obtained from the analysis of continuously operated GPS measured surface displacements.

figure 48. Major long period constituents like M2 and Mm are absent from the vertical component oscillations. However, 9d short period component is present in all the three components. The sources of these constituents are currently under investigation. Analyses of results at short and long wavelength also show beating of the frequencies by very near frequency displacement sources.

Component 5.3b

Crustal deformation, Strain accumulation and Geohazard study in the Himalayan region using SAR Interferometric techniques

(Swapnamita Choudhury)

European Space Agency (ESA) approved submitted project "Study of crustal deformation and ground subsidence due to active tectonics and reservoir induced loading in Lesser Himalaya, India", after review by their peer review team. ENVISAT data for study area have been provided in reproduction cost by ESA. The processing of two sets of ENVISAT data around the Tehri region has been done. The analysis shows that the data with a time difference of six months to two years faces coherence loss and suffers from layover and shadow due to the rugged topography of the region. The region is also highly vegetated and changes in vegetation in different time of the year as well as atmospheric conditions do not allow clear understanding of the prevalent tectonic conditions of the region. An attempt is being made to enhance filtering techniques to erase out phase jumps and temporal decorrelations. The processing of one year temporally spaced ENVISAT Kangra datasets show fringes in parts along the frontal thrust in the Kangra window. The topography has been removed using a SRTM DEM. The errors are being calculated and filtering techniques applied. The fringes appear to conform to the observed GPS studies in this region. As part of the objectives of the project, past seismicity using available data was studied. The Chamoli Earthquake deformation field was calculated by Satyabala and Bilham using the Gamma software with two pairs of ascending as well as descending tracks. The feasibility of the windows based software SARscape in a difficult terrain was analyzed by us with the track 12 data processing with a one year temporal resolution for the same Chamoli Earthquake. This set of data though provides a good spatial baseline of 44.093 m (calculated using SARscape), but suffers from layover and shadow due to the rugged topography of the region, especially towards north of the scene. A major decorrelation occurs in this image pair because of the 351 days difference between image acquisitions and also multiple landslides initiated due to the earthquake. However, two fringes corresponding to 6 cm of displacement has been calculated experimenting with several filtering techniques. The limitations of the difficult topographic scenario and temporal decorrelations have been overcomed using our processing techniques. Also the forward modeling of the fault parameters which contributed to the displacement for the Chamoli earthquake using the range change program RNGCHN by Fiegl and Dupre, 1999 have been worked on. The corrections and adaptations of the program for our scenario was successfull after overcoming several limitations. Now, in case of an unexpected earthquake occurrence our programs are available for applications.

SPONSORED PROJECTS

PROJECT

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

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

Multi-Parametric Geophysical Observatory (MPGO) of Ghuttu in Gahrwal Himalaya established by WIHG under the programme of earthquake precursory research of Ministry of Earth Sciences (MoES) has become a leading aspect of the earthquake research in India. The continuous recording and monitoring of eleven geophysical parameters for a period of more than three years is a great achievement at this remote site of Himalaya irrespective of stringent power supply. Dr. Shailesh Nayak, Secretary, MoES has elaborated it as a step in the direction of earthquake precursory research and for the service of society while inaugurating the observatory on 28th May, 2009. The high precision geophysical equipments of high sensitivity record minute changes of characteristic stress-induced perturbation in the thrusting zone of Himalaya. Each data of these eleven parameters has different characteristics and the methods have been formulated to separate the influencing effects of these parameters so as to isolate the recorded data from these effects and use it for observing the anomalous behavior related to nearby big earthquake. The observations obtained from continuous data of different parameters is synthesized below :-

Superconducting Gravimeter

The Superconducting Gravimeter (SG) that records time variation in gravity to sub-µGal level is the most sensitive gravimeter of the world. The continuous measurement of three years data suggests that the highly sensitive equipment is influenced by the environmental parameters like temperature, pressure, rain fall and sub-surface water level fluctuations. It took us more than two years to understand all these minor but most effective and systematic variations as unwanted fluctuations in the continuous gravity data. However, the incorporated relations also strengthen our understanding and forced us to incorporate new models in this Himalayan region as it is the only station in Himalayan region with such a high sensitivity of gravity variation. Now the methodologies have been developed and being incorporated to successfully remove the unwanted effects of spikes, gaps, steps/jumps as well as the influence of tidal forces and atmospheric pressure using the data adopted techniques of wavelet. The gravity changes, especially during rainy season, are marked by two classes of variations, one steep change related to intense events of heavy rainfall and second slow changes, which are apparently related to hydrological mass distribution in the local region. The short period precipitation-induced gravity change, concurrent with heavy rainfall events, is of the order of 1 µGal. However, the ground water level variation exerts slow change in gravity residual up to 30 µGal with time lag of few days to 30 days. The efficacy of tank model and regression approaches used to quantify precipitation and hydrological mass balance are in progress to illustrate the merit and limitation imposed on the isolation of dynamic and earthquake precursory signals.

Removing all these effects including the influence of hydrological, the minor changes are seen in the gravity data which are related with the co-seismic deformation when the source of the earthquake is nearby to SG station. However, so far the changes are not observed before the occurrence of the big size earthquake for relating it as precursory signals. It seems that it can be happened only if the big size earthquake occurs within 4-5 times distance as compared to rupture length of the earthquake source.

Electromagnetic Component

Varied methodology is adapted for discriminating lithospheric and ionospheric EM signals in order to identify precursory signature in geomagnetic field, ULF band variations and total intensity measurements. In this regard formulation of principal component analysis proved an effective tool in discriminating contributions related to magnetospheric and seismotectonic origin in geomagnetic field intensity. Fractal approach is successfully applied to ULF band geomagnetic data sets for distinguishing varied dimensional component associated with distant EM waves resulting from solar wind-magnetospheric interactions and those from near surface waves emanating from the straining of crustal rocks. Whereas polarization analysis in different frequency bands for ULF and three component fluxgate data sets is being routinely investigated for identifying lithospheric origin of anomalies. In order to understand the correlation between seismicity and ULF magnetic intensity, a parameter (defined by Molchanov et al. 2003,3, 203-209, NHESS) characterizing seismic influence at the observational point based on earthquake magnitude, epicentral distance and depth is calculated. Figure 49 shows the variation of seismic index for year 2009 at Ghuttu, Bhatwari calculated utilizing WIHG local seismic bulletin.

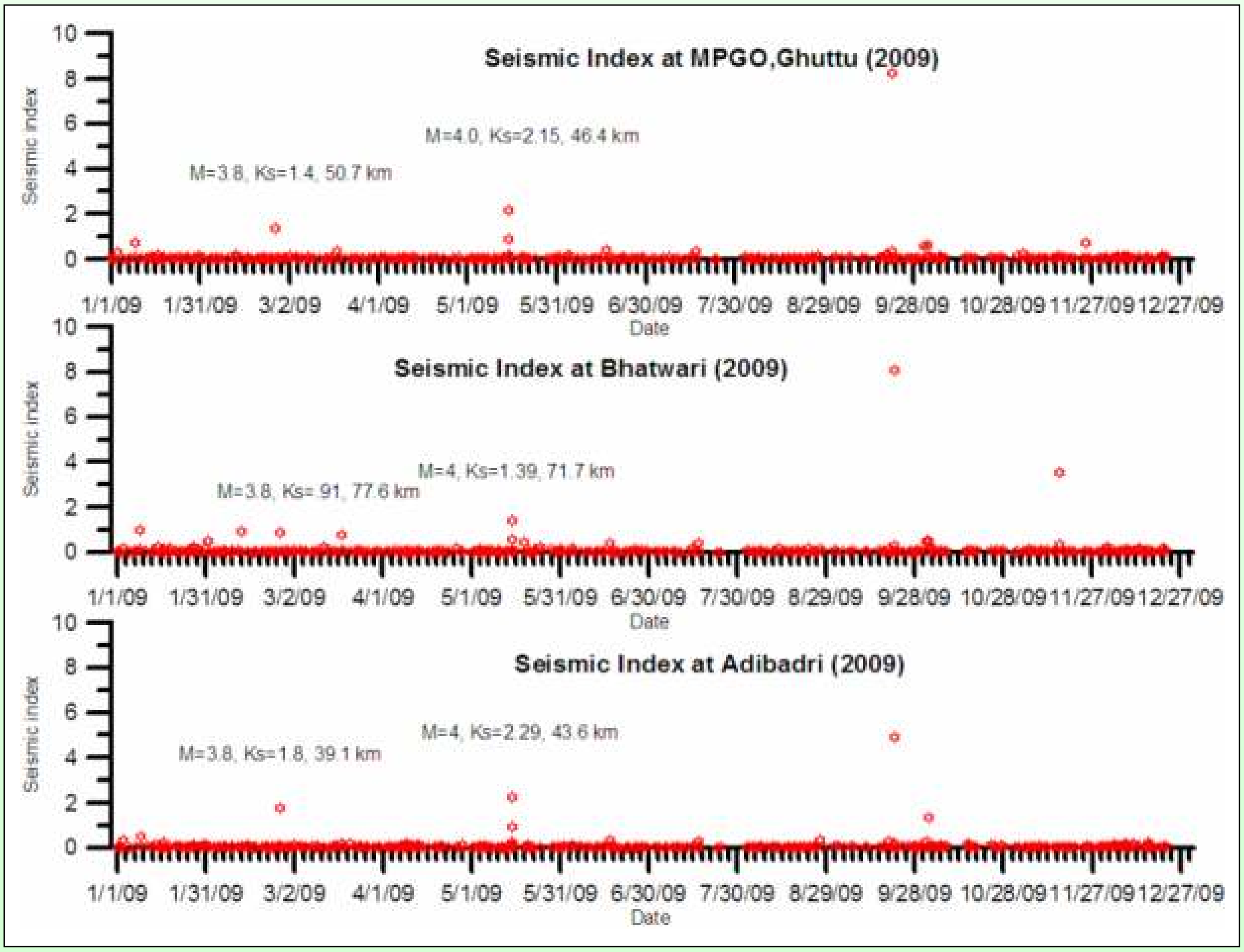


Fig.49. Seismic Index obtained related to local big size earthquakes in 2009 around MPGO station.

SPONSORED PROJECTS

Precursory Changes in Radon and hydrological parameters

A 68 m deep borehole, penetrating into the water table is operated for continuous radon monitoring along with meteorological/geohydrological observations at two points, one at 10 m (in the air column) and the second one at 50 m (within water column) depths from surface. Preliminary studies reveal diagnostic short duration anomalies in radon concentration recorded few days before the occurrence of a nearby moderate M4.9 earthquake at Kharsali on the 23rd of July, 2007. Recognition of precursory phenomena is a very important aspect for earthquake forecast purposes. Available evidence suggests an association between regional stress buildup and radon flux from borehole for the Kharsali earthquake M4.9. After establishing a pattern of radon emanation in the borehole based on long-term and continuous data, monitoring it is possible to identify the tectonic related radon anomaly. The verification of the mathematical formulation with respect to the radon anomaly needs more events in the local scale. Failure of other theoretical and empirical algorithms with respect to the Kharsali earthquake shows that the particular site obeys different anomalous behavior of certain parameters. The earthquake related anomaly in time series data facilitates understanding of the radon concentration pattern with impending earthquake within less than 100 km epicentral radius. After isolating the anomalous behavior of radon with other influential parameters (non-tectonic), the output gives a better perception of the earthquake precursory signal. This kind of integrated approach may be useful for future research on the characterisation of earthquake related signals using time series database. Appearance and non-appearance of co-seismic drops in radon content are indicative of stress states in the region, including opening and closure of micro-cracks. The anomalous fluctuation in radon emanation may have resulted from increase in heat flow, collapse of pore matrix due to stress, and micro fracturing.

Seismic precursory studies

The MPGO site Ghuttu lies in the midst of VSAT linked BBS network. This network was installed in July 2007 with central Recording Station at Dehradun. Precursory studies have being carried out and the graph (Fig. 50) shows the variation of Vp/Vs from July 07 to March'10. 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.

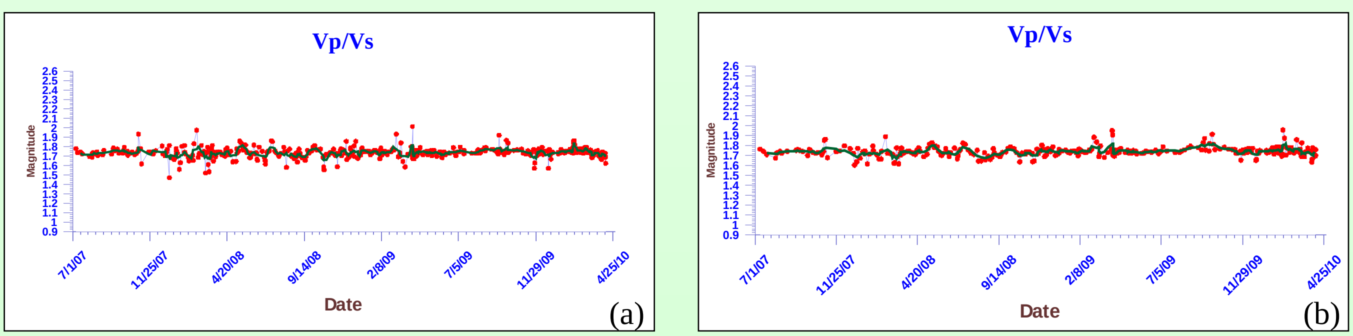


Fig. 50 (a). Plot showing the change in Vp/Vs ratio for the period July 07 to December 08 values with averaging 3 (b) values with averaging 5.

PROJECT

Himalaya School earthquake Laboratory Programme

(A.K. Mahajan)

More than 600 earthquakes (regional and local) have been recorded during the time of operation of HIMSELP project. Although most of our time had been spent in installation and repair of instruments as all the instruments are located at very remote locations and it is difficult to reach each station in a single day, still we have been able to analyze some of the earthquakes whose data has been an input to the WIHG earthquake data base and help in improving the accuracy in epicentral location. The first motion of some of the earthquake helps in understanding the fault plane solution. The 23rd July Kharsali earthquake is an example of this benefit. The epicentral map derived from the HIMSELP data for the period Jan. 2006 to March 2007 is as under. Due to the locations of the seismic instruments and vertical component nature of seismic stations the accuracy of the data is high unless it is being supplemented by other seismic stations (Fig. 51)

Under this project apart from running 59 school seismographs, an interactive web site has been developed for earthquake awareness among school children. This will be very interactive web site having both dynamic and static components. Each school will be provided with a password so that school children can have access to the scientist of the institute and they can ask any question at any time. The interactive web site has been widely used through out the world as per hit values.

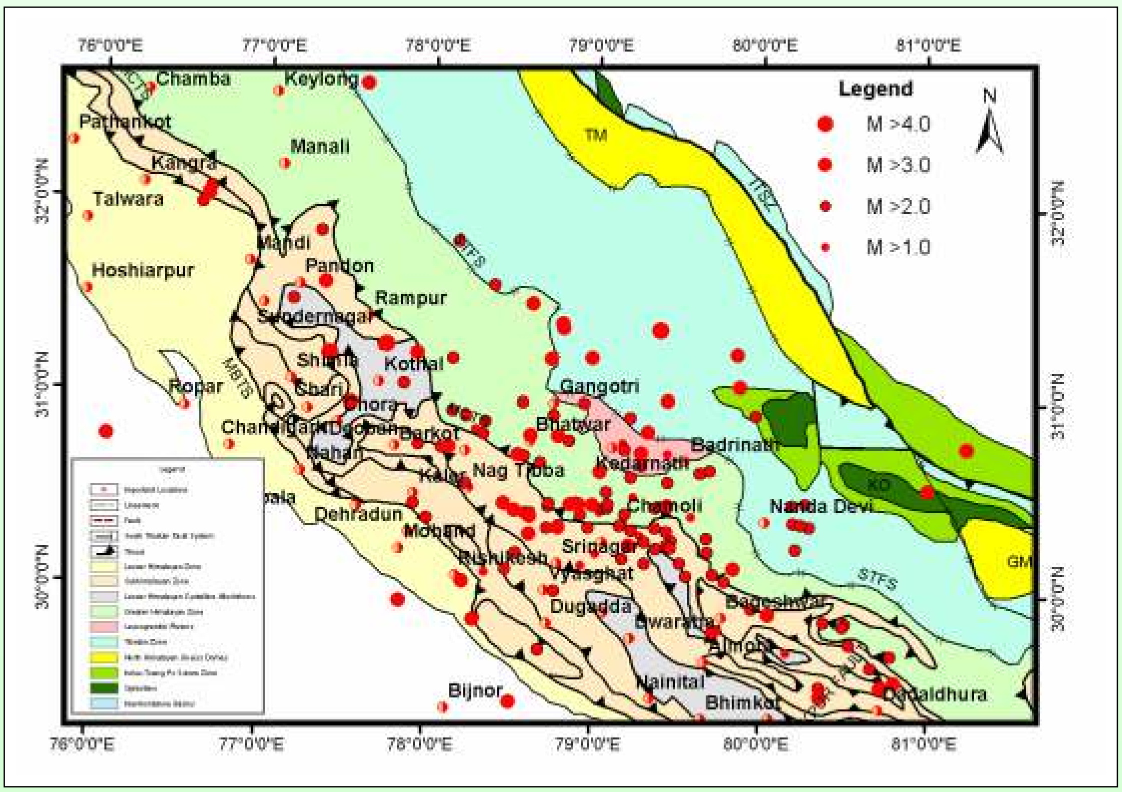


Fig. 51. Epicentral map of NW Himalaya from HIMSELP data from Jan 2006 to March 2007 from most of the stations located in Garhwal region. The horizontal and vertical error in epicentral location is of the order of 5-10 km and 10-15 km respectively.

Under this project fifty nine school teachers and students have been trained in earthquake measurements techniques and how to protect them during a strong earthquake. Lectures have also been delivered at different schools during morning prayers to educate the children in earthquake processes and measurements. Drawing competitions and morning procession have been taken out at different schools to aware the children and masses in general in disaster managements programme towards disaster mitigation measures (Fig. 52).

Fig. 52. Teachers training programme at Dehradun (right above). Interactive lecture to Teachers of GIC, Mussoorie School on earthquake processes and earthquake awareness(right middle above). Exhibition stall at Shimla during a Disaster management workshop organized by the District authorities on 4th April, 2006 to commemorate 100 yrs of 1905 Kangra earthquake(left above and middle) and interactive lectures at Sarkaghat (above) and Sujanpur Titra School (Below) children and teachers at their respective schools(below).

PROJECT

Telemetric Seismic Monitoring of Garhwal for developing hazard scenario in Uttaranchal

(Ajay Paul)

A ten station VSAT connected broad band seismic network is operational since July 2007. All the stations of the network are connected to central station Dehradun. The seismic data is being acquired in real time and processed to monitor the local seismic activity of the region. Each station is equipped with Trillium-240 seismometer with dynamic range (> 138 dB) Taurus data acquisition system (DAS). High accuracy GPS synchronies the DAS clock every minute. Fig. 53 shows the network and seismicity recorded till 31/3/10 on the tectonic map of the region.

Since its installation, seven thousand two hundred thirty (7,230) events have been detected by the network till March 2010. Of these, one thousand eight hundred seventy six events (1876) events are teleseismic (epicentral distance more than 1000 km), two thousand seven hundred twenty eight (2728) regional events (epicentral distance 300 to 1000 km) and one thousand two hundred thirty eight (1238) local events which are located within the network or very near to it. The dense network has brought down the minimum detection magnitude threshold to 1.8M . As shown in the Fig.53 local seismic events in the magnitude range 1.0-5.0 are occurring south of main central thrust (MCT). The space time pattern is regularly examined to demarcate enhanced/quiescence zones that invariably precede the large earthquakes. No anomalous seismicity pattern is identified in this period. P-wave polarity information recorded at different stations for seismic events with in the network and having magnitude more than 3.0 is utilized to obtain the fault plane solutions. The fault plane solutions of earthquakes M>4.0 that occurred near Kharsali and Guarikund show reverse fault

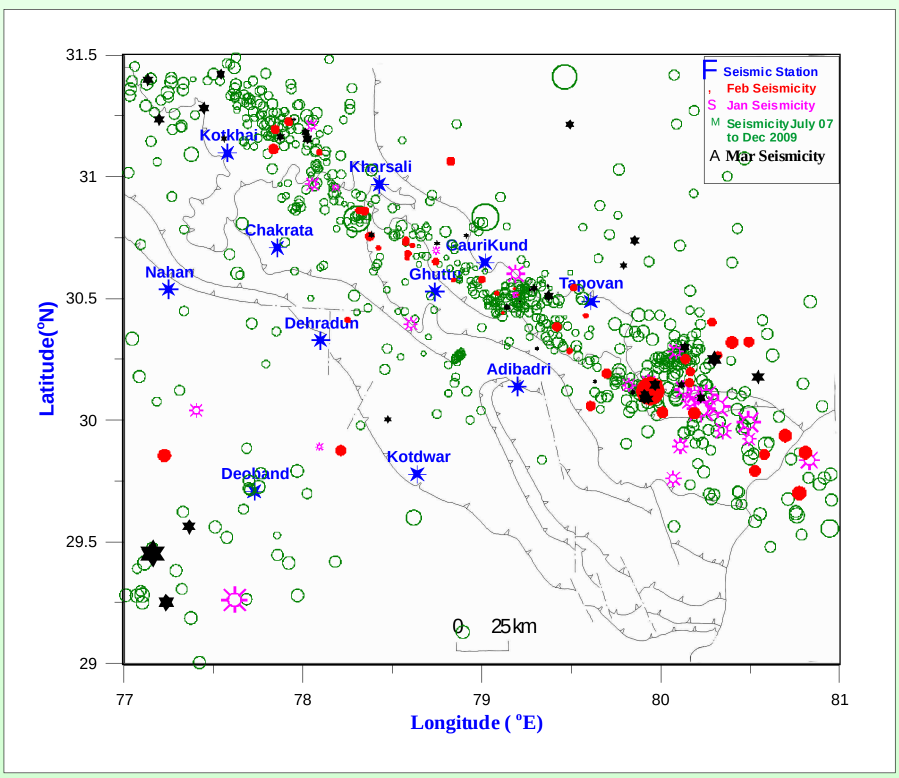


Fig. 53. Tectonic map of the region (after Valdiya 1980) showing VSAT linked seismic stations and seismicity

motion with strike slip component. Seismic hazard has been evaluated on the basis of the contour map drawn from the recorded peak ground accelerations(PGA) for the events of M > 2.5. The regions around Uttarkashi and Chamoli are showing comparatively higher PGA values.

PROJECT

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

(A. Krishnakant Singh)

The chemical characteristics of tholeiitic basalt suggest melt generation in a mid-ocean ridge tectonic setting and were probably derived by partial melting of both N-MORB and E-MORB type asthenospheric mantle sources. Basalts derived from MORB-type magma have high titanium (> 0.7 wt. % TiO_2) contents, whereas basalts from island-arc and inter-arc basins have low titanium (<0.4 wt. % TiO_2). Based on chemical characteristics of mafic volcanics from Manipur Ophiolite Complex (MOC) the Indo-Myanmar Orogenic Belt has been identified as high-Ti type and show close geochemical similarities with MORB type, suggesting they were probably formed at the mid-oceanic ridge environment. Their TiO_2 and Al_2O/TiO_2 relationship shows close similarities of these basalts with MORB type. This feature is further supported by Ti/V ratios (21-43) of these basalts. Enrichment of FeO, TiO_2, P_2O_5 and V in these basalts suggests magma evolution, probably occurring in a mid-ocean ridge open system.

The Platinum group elements (PGEs), which are very refractory, require high degrees of partial melting for extraction from the less depleted mantle source and for concentration in appreciable amounts in resultant magmatic rocks. A high-degree (>25%) partial melt is, therefore, expected to be enriched in PPGEs and its residuum enriched in IPGEs. Os, Ir and Ru have higher melting points than Pt and Pd and tend to be concentrated in refractory residue and in early cumulate relative to Pt and Pd which are more incompatible and tend to be retained in the melt. PGE-poor chromitites (usually <100 ppb) were produced around the Moho transition zone (MTZ) and, to a lesser extent, in the deeper part of the mantle section (usually >100 ppb) in the mid oceanic ridge setting. This was linked to the formation of residual harzburgite with unfractionated PGE patterns and tholeiitic melt under relatively low degrees of partial melting, possibly in a fast spreading, mid-ocean ridge environment. The chromitites from MOC have PGE contents ranging from 135 to 551 ppb and has higher concentrations as compared to MTZ chromitites. This result may indicate that chromitites in MOC were formed in relatively deeper part of mantle sequence of the ophiolite. The negative slope of the PGE pattern in the chromitites from Ru to Pd with PPGE depletion may reflect the low degree of partial melting for the involved magma in the deeper part of the mantle section in the mid-ocean ridge environment. Their enrichment in Os, Ir, Ru, Ni and depleted in Pt, Pd, Cu patterns have been attributed to the early crystallization of the most refractory Os-Ir- and Ru- bearing minerals prior to or coeval with chromite.

The Cr-spinel in peridotites of MOC characterized by low Cr_2O_3 (10.03-23.37 wt.%) and high Al_2O_3 (43.77–55.86 wt.%), FeO (11.45–12.45 wt.%) and MgO (16.98–18.41 wt.%). The Cr # and Al # has spacious ranges of 18.00 to 26.36 and 74.26-88.36 respectively. High Mg # (70.58-73.43) in the samples reflects the subsolidus exchange of Fe-Mg between Cr-spinel and surrounding silicate minerals. Thus their chemistry is comparable to those observed in Cr-spinel of alpine and abyssal peridotites. Their geochemical characteristics in comparison with respect to modern-day tectonic settings depict the host peridotites is of mid oceanic ridge type. Trace elemental compositions in the host peridotites are typical of residual mantle, with high Cr (2090–3431 ppm) and Ni (1926–3583 ppm), and low Rb (1-3 ppm), Sr (4-15 ppm), Zr (0.5-3 ppm), Nb (1-3 ppm). Low Na_2O and TiO_2 contents in clinopyroxene of peridotites are supported their sub-oceanic origin.

Thus, high-Ti tholeiitic basalts (Ti > 1 wt. %; Ti/V = 21-43; La_N/Sm_N = 0.62-0.90; low Ce/Y = 0.38-0.82; Ta/Hf = 0.17-0.53 and Th/Yb = 0.02-0.55); high Al # (73-88) and Mg # (70-73) with low Cr # (10 to 25) in Cr-spinels of peridotites and PGE characteristics (Os ~ 78ppb; Ir ~ 32 ppb; Ru ~ 113 ppb; Rh ~ 12 ppb; Pd ~ 10 ppb; Pt ~ 3 ppb; $\sum$ PGE = 135-551 ppb) in chromitites suggest that the ophiolites of IMOB is a remnant of the Neo-Tethyan oceanic crust generated at mid oceanic ridge tectonic setting.

PROJECT

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

(National Science Foundation,USA)

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

Detrital zircon samples from Cambrian and Lower to Middle Ordovician strata were taken along the strike of the Himalaya from Pakistan to Bhutan. Sampling were done from one time interval for nearly the entire length covering a range of lithotectonic units, we minimize time as a significant source of variance in detrital age spectra, and thus obtain direct assessment of the spatial variability in sediment provenances. This approach was applied to the Tethyan margin of the Himalaya, which during the Cambrian occupied a central depositional position between two major mountain belts that formed during the amalgamation of Gondwana. Detrital age spectra from our Lesser and Tethyan Himalayan samples was dispersed across the northern Indian margins. The detrital zircon age spectra for our samples are consistent with sources for most grains from areas outside the Indian craton that record Pan-African events, such as the Ross-Delamerican orogen; East African orogen, including the juvenile Arabian-Nubian Shield; and Kuunga-Pinjarra transport and high degree of mixing of detrital zircon ages are extraordinary, and they may be attributed to a combination of widespread orogenesis associated with the assembly of Gondwana the equatorial position of continents, potent chemical weathering, and sediment dispersal across a non-vegetated landscape.

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)

(DST Seismology Programme)

(N.S. Virdi and G. Philip)

Field work was carried out for nearly two weeks in the following areas:

a. Subathu-Arki region of the Solan Dist. covering the Kuthar nadi, Arki ki nadi, Kuni khad and Bakhalag or the Bhumti nala major tributaries of the Gambhar river.

b. Patta nala, and Katal nadi in the upper reaches of the Balad Khad along the Main Boundary Fault (MBF) or the Bilaspur thrust.

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

d. Kunihar basin around Hatkot for Quaternary lacustrine and fan deposits.

The terrain in the catchments of Giri and Gambhar rivers is constituted by pre Tertiary sediments of the Krol belt, its basement of Simla-Jaunsar in the south. The Simla Group sediments are thrusted over by the metamorphic thrust sheets (Chail and Jutogh) in the upper reaches. The Chail and the Jutogh thrust sheets occupy high altitude (2500-3500ms) terrain around Simla and Chur peaks and extend further in the Higher Himalaya.

In the terrain investigated so far along the Gambhar river and its major tributaries viz. the Kuthar, Arki ki khad and the Bakhalag khad we observed thick (15-20m) sediments deposited as alluvial fans, debris flows and landslides. These deposits rest over the country rocks with a marked the Lower Siwalik formation. The eastern margin of the basin is bound by a NS trending fault/lineamnet through which the Patwas-ka-Khala presently flows. The western margin of the basin is bound by a major paleolandslide and the southern margin is being controlled by the northwest dipping Lower Siwalik sandstone respectively.

While the MBF is a bounding fault of the Dhon basin in the north, the present-day landform and the drainage pattern shows explicit surface manifestation of Quaternary tectonics experienced in this basin. Three major levels of terraces are observed in the basin. The lowest elevation of the terrace is at 719m where as the highest elevation is at 744m amsl. The elevated and isolated hillocks and the highly jointed and crushed lower Siwalik sandstone also corroborate a prominent tectonic activity experienced in this area. The displaced landforms and the drainage offset (dextral) suggests predominant strike slip component during the faulting. This strike slip (dextral) fault also trends almost parallel to the MBF. Our preliminary investigations points towards Holocene faulting resulting to local ponding and subsequent sediment deposition in the lacustrine environment. Lacustrine sediments varying in thickness from 5-10m consisting of very fine clays with thin gritty and sandy layers were deposited in this lake. Today these deposits support good agricultural activity. The Dhon strike slip fault indicates possible reactivation of this segment of MBF most likely during the Holocene associated with large magnitude paleoearthquakes and displacement of Quaternary deposits.

Displacement of Quaternary deposits along MBF was also observed to the west of Sainwal village along Jalmuse ka Khala. The uplifted Quaternary fluvial terraces are of the order of 3-5m. It is significant to note that the terrace displacement observed at Dhon and the Jalmuse nala are aligned in the same direction and orientation. The disposition of fluvial terraces indicates reactivation of MBF in this segment also

Dadhol Fault

Our field investigations supported with satellite data indicate a major strike slip (dextral) fault in the Lower Tertiaries near the village Kot, which is located about 3km to the southwest of Subathu Township in Himachal Pradesh. The surface expression of the fault is recognized because of prominent drainage offset and tectonic landforms such as triangular facets and displaced ridges. The NNW-SSE trending Dadhol fault is of about 4km in length. The fault, which is parallel to the MBF, has displaced the Quaternary deposits. Highly crushed Lower Tertiary Subathu mudstones in contact with the Quaternary deposits are observed near one of the ponds which are also aligned along the fault system.

Rao khad fault

Rao fault is a strike slip fault affecting the Quarternary lacustrine and debris flow deposits in the Kunihar basin.The fault trends NNW-SSE and has downthrow on the western block.The country rocks consist of slates and sandstones of the Kunihar and Chaosha members of the Simla group. The fault is traceable for about 7km within the Kunihar basin. Traced towards SE, it merges into the main Rao fault traversing parallel to the Rao khad and then passes near Haripur. Further SE the fault extends into the Gambhar valley. Extension of the Rao fault has been reported earlier by Srikantia and Sharma (1977) across the Gambhar through Majotli,Bhumbal and then along the Shingari nala. It merges into the Krol thrust further SE. The fault also show strike slip movement with a dextral slip.

Bhumti fault

The Bhumti fault has been mapped in the Main Boundary Thrust zone within the Lower Tertiary Subathu sediments exposed in the schuppen zone between the Surajpur thrust and the footwall of the MBT . The fault trends N-S and control the drainage of the Bhumti Khad. The Bhumti fault also shows strike slip with a dextral effect . A major stream flowing NW to SE in the western block is dragged towards south. This stream joining the main channel of the Bhumti Khad at Jaghana shows prominent triangular facets. The channel of strengthening of monsoon and increased insolation on both the southern and northern slopes of the Dhauladhar range. The Kangra and Palampur fans sediments and the valley fill deposits of Ravi river represent para-glacial deposits produced as a result of degalciation in the Dhauladhar range. The deglaciation and denudatinal removal of the rock mass from the Dhauladhar range may have invoked isostatic uplift. The valley-fill terraces observed in the Ravi river indicate a major aggradations phase corresponding to deglaciation, followed by degradation phase corresponding to the isostatic uplift phase resulting from removal of the glaciers - sediments load . South of the Kangra fan, Banganga river between Kangra and Guler are characterized by strath terraces showing bed rock incision of 40 - 80 m. The bed- rock incision, indicative of bed - rock uplift, was produced by displacement on the Jawalamukhi Thrust. The bed – rock incision took place during 17-29 ka that coincided with the cold-arid climate.

PROJECT

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

(Pradeep Srivastava)

Fig. 54. Regional tectonogeomorphic framework : Dhauladhar range, acting as water divide, separate the Kangra and Palampur fan deposits from the teriaces access of Ravi river.

The main highlights of the ongoing DST project can be summarized as under.

The detailed geomorphic and Ground Penetrating Radar (GPR) studies combined with digital elevation model (DEM) in the lower Alaknanda valley is carried out in order to understand the Quaternary tectonic activities in the Lower Alaknanda valley. Geomorphological studies enabled us to generate a detailed structural map. One of the important contributions in the limited period was the identification of Kirtinagar Fault (KF) that had in the past and probably in the present time as well exerting significant control on the channel geometry. Digital elevation model prepared in the vicinity of the KF suggests a preferential southward shift in the Alaknanda River which we attribute to the strike slip movement along the KF. GPR study not only validated the inferred structures and subsurface channels, but also located the precise position of the North Almora Thrust (NAT), which is a major structure in the study area.

Sedimentology and Optically Stimulated Luminescence (OSL) dating technique obtained on the fill terraces suggests that fluvial aggradation in the study area was episodic and was modulated by the interplay of climate and tectonic. Two major events of fluvial aggradation were identified during the Late Quaternary. The sedimentary architecture combined with Optically Stimulated Luminescence (OSL) dating suggested that the older aggradation phase-I, occurred due to debris flow originating in the upper catchment of the Alaknanda River until around 25 ka. The younger aggradation phase-II commenced during the climatic transition between 17-14 ka and was characterized by river accretion in braided river conditions with intermittent debris flows. Further, the terrace upliftment rate based on strath surfaces suggests that the area was uplifting at rather high rate (between 9-6 mm/yr). This was attributed to the focused tectonic activity associated with the NAT and KF. Geomorphic indicator in the form of nick point in second and third order tributary streams and eastward deflection are seen. These can be seen along the North Almora Thrust. Kirtinagar Fault off sets 5th order tributary stream Dhundsir

SPONSORED PROJECTS

gad and course of Alaknanda is being shifted in SE direction, which attributed to strike slip of sense

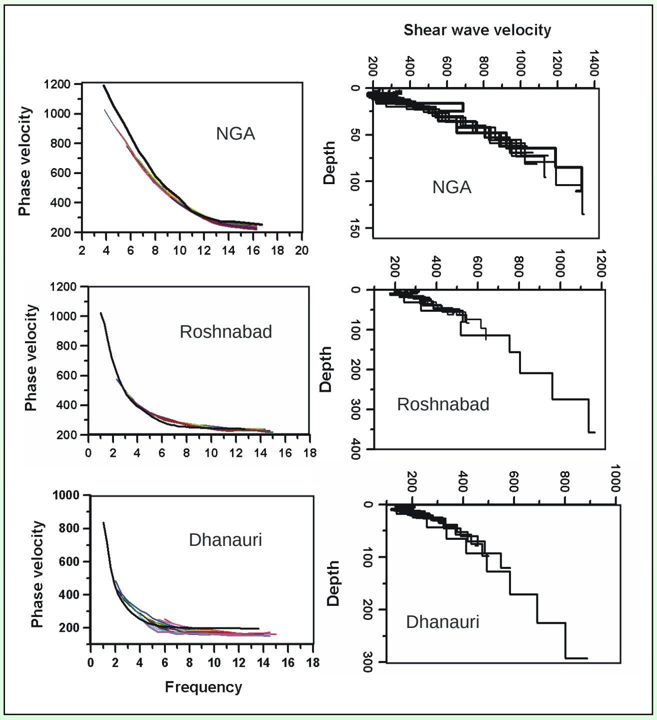


Fig. 54. All dispersion curves of all the twelve shots are plotted in colour. The black line shows dispersion derived from passive remote MASW configuration (left). The inversion of these dispersion curves resulted in 1-D velocity model at each site. All the 1-D velocity model derived from active and passive MASW are plotted, showing good coherency in the 1-D profiles at each site.

PROJECT

Experimental investigations of shallow earth structures using NIMFIS (Near surface Electromagnetic Frequency Induction Sounding) technology Under Integrated Long Term Programme (ILTP)

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

Stresses building up during an earthquake preparation phase also manifest themselves in the form of a so called increased land surface temperature (LST) leading to a thermal precursor prior to the earthquake event. This phenomenon has now been validated by our observations of short-term thermal anomalies detected by infrared satellite sensors for several recent past earthquakes around the world. The rise in infrared radiance temperature was seen to vary between 5 and 12°C for different earthquakes. It was important to understand the different reasons for the generation of such anomalies. Emission of gases due to the opening and closure of micropores upon induced stresses and also the participation of ground water have been propounded as a possible cause for generation of thermal anomalies. Seismo-ionosphere coupling, by which gases like radon move to the earth–atmosphere interface and cause air ionization thus bringing about a change in air temperature, relative humidity, etc., has been put forth by some workers. A mechanism of low frequency electromagnetic emission was tested and experimented by scientists with rock masses in stressed conditions as those that exist at tectonic locations. The proposal of positive hole pairs theory, which received support from several scientific groups was found to be most convincing for the appearance of such anomalies. Positive holes (sites of electron deficiency) are activated in stressed rocks from pre-existing yet dormant positive hole pairs (PHPs) and their recombination at rock–air interface leads to a LST rise. A combination of remote sensing detection of rock mechanics behavior with a perception of chemistry and geophysics has been applied to propose the remote sensing rock mechanics theory. Remote sensing detections of such anomalies confirm so far proposed lab theories for such a hotly debated field as earthquake precursor study by providing unbiased observations with consistency in time and space distribution.

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Mazari, R.K., Sah, M.P., Mahajan, A.K. & Asthana, A.K.L. (Sept. 2009). Geological report on the campus area of University of Petrolium and Energy Studies, Bidhauli, District Dehra Dun, Uttarakhand. Submitted to University of Petrolium and Energy Studies, Bidhauli, District Dehra Dun, Uttarakhand, 14p.

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Sah, M.P. & Gupta, V. (Aug. 2009). Geological feasibility report on Parking sites in Mussoorie Township, District Dehra Dun. Submitted to MDDA, Dehra Dun, 4p.

Sah, M.P., Gupta, V. & Paul, A. (Nov. 2009), Development of cracks in Tarsali and adjoining villages during excavation of Phata-Byung Hydro Electric Project, Rudraprayag District. Submitted to D.M. Rudraprayag, 20p.

SEMINAR/SYMPOSIA/WORKSHOP ORGANISED

Forty Sixth Annual Convention of Indian Geophysical Union and Meeting on Evolution of Himalayan Foreland Basin and Emerging Exploration, October 5-7, 2009

The Forty Sixth Annual Convention of the Indian Geophysical Union (IGU) was organized at the Wadia Institute of Himalayan Geology, Dehradun during October 5-7, 2009. The convention was organized under the joint auspices of Wadia Institute of Himalayan Geology, Dehradun, National Geophysical Research Institute, Hyderabad, Indian Geophysical Union and with co-sponsorship of Oil and Natural Gas Corporation Limited. Sh. Harish Rawat, Hon'ble Minister for State, Labour & Employment, Government of India was the Chief Guest and inaugurated the convention. Dr. Sailesh Nayak, Secretary, Ministry of Earth Sciences (MoES), Government of India, New Delhi was Guest of Honour at the Inaugural function. On the occasion Dr. V.P. Dimri, Director, NGRI and the President of IGU, presented the National IGU Awards to Drs. R.K.Tiwari and G. Parthasarthy who shared the Decennial award, and M.S. Krishnan's Gold Medal to Dr. J.S. Ray.

Recognizing the challenge of understanding the tectonic evolution of Himalayan Foreland Basin and its potential for hydrocarbon exploration, a special session on “Evolution of Himalayan Foreland Basin and Emerging Exploration” was also organized along with IGU. The session focused on our knowledge and new emerging areas of research related to tectonics and hydrocarbon potential. There was overwhelming response from various organizations to participate in the deliberation of the convention and on the special theme of Himalayan Foreland Basin, and was attended by about 170 participants from various institutions/organizations of the country. The participants were from Andhra University, BHU, CESS, IIG, Kurukshetra University, NIO, Osmania University, ONGC, NGRI and WIHG. Sixty Oral and an equal numbers of Poster presentations were made during the convention.

Sh. Harish Rawat, Hon'ble Minister for State, Labour & Employment, Govt. of India along with Dr. Sailesh Nayak, Secretary, MoES, Govt. of India and Prof. B.R. Arora, Director, WIHG, at the inauguration of the 46th Convention of IGU at WIHG.

Workshop on "Seismogenesis to PREDiction of earthquakes: Himalaya and Indian Shield Perspective" [SPRED-2009]

The Workshop on "Seismogenesis to PREDiction of earthquakes: Himalaya and Indian Shield Perspective - [SPRED-2009]" was held in the Institute during October 22-24, 2009. The workshop coincided with the Founder's Day of the Institute. Chief Guest, Dr. Ramesh Pokhriyal 'Nishank' Hon'ble Chief Minister, Uttarakhand inaugurated the workshop and in his inaugural address highlighted the importance of earthquake precursory research being carried out by the Wadia Institute of Himalayan Geology in the Uttarakhand. He also inaugurated the V-SAT seismic network of the Institute which is dedicated for monitoring regional real time seismic activity. Shri Harbans Kapoor, Hon'ble Speaker, Uttarakhand Vidhan Sabha also graced the occasion.

Dr. H.K. Gupta, Raja Ramanna Fellow gave overview about the earthquake precursory research being carried out in the Indian subcontinent during last few decades and highlighted the successful medium term prediction of M7.3 earthquake that occurred in 1988 in the NE Himalaya and the recent short term forecasting of M4.8 in the Koyna-Warna region. About 75 participants from various institutions/organizations participated in this event. The deliberation of the seminar were arranged in five technical sessions, which were devoted mainly on Seismogenesis, Seismic Deformation and Strain Partitioning, Earthquake Precursor and Forecast, Deep Imaging and Earthquake Hazard. In the concluding session, the future road map of earthquake research in India was discussed.

Dr. Ramesh Pokhriyal 'Nishank' Hon'ble Chief Minister, Uttarakhand & Shri Harbans Kapoor, Hon'ble Speaker, Uttarakhand Vidhan Sabha, during one of their visit to the Institute.

Chief Guest Dr. Ramesh Pokhriyal 'Nishank' Hon'ble Chief Minister, Uttarakhand along with Shri Harbans Kapoor, Hon'ble Speaker, Uttarakhand Vidhan Sabha, Dr. H.K. Gupta, Dr. B.R. Arora and Dr. A.K. Dubey sharing the dias during the inauguration function of workshop on SPRED-2009.

VISITS ABROAD

- Prof. B.R. Arora, visited Vienna, Austria to attend the EGU General Assembly from April 19-24, 2009.

- Dr. D.P. Dobhal, visited Nepal for conducting "International Training Course on Mass Balance Monitoring and data interpretation, Yala glacier, Lang Tang Valley, Central Nepal. Organised by HKH-FRIEND Group Snow and ice, Nepal National IHP. ACS-ICIMOPD-UNESCO, from 25 May-15 June, 2009.

- Dr. D.R. Rao and Dr. S.S. Thakur, visited Paris, France to attend one week EPMA Training Program at CAMECA company site from June 7-13, 2009.

- Dr. A.K.Mahajan, visited Norway under joint collaboration between Norway, IIT Roorkee and WIHG from July 7-27, 2009.

- Dr. D. Hazarika and Dr. D.K.Yadav, visited Taipei, Taiwan to attend the International Training Program on Seismic Design of Structure and Hazard Mitigation from Oct. 25-Nov. 1, 2009.

- Dr. G. Philip, visited Active Fault and Earthquake Research Centre, Geological Survey of Japan, Japan, within the framework of the India-Japan Cooperative Science Programme from March 10- 20, 2010.

- Dr. V.M. Choubey, visited Jerusalem (Israel) to participate in International Conference on Radium and Radon isotopes, as Environmental tracers from March 14-19, 2010.

MEMBERSHIP OF NATIONAL/INTERNATIONAL COMMITTEES

Name of the Scientist	Status	Prestigious Committee/s outside WIHG
R.K. Mazari	Member	Executive Council, Indian Society of Remote Sensing, Dehra Dun Chapter
D.K. Misra	Member	Indian Geological Congress, Roorkee, India
G. Philip	Member	Executive Council, Indian Society of Remote Sensing, Dehra Dun Chapter
V.C. Tewari	Member	Editorial Board of the International Journal of Astrobiology, New York, USA
Kishor Kumar	Member	Palaeontological Society of India, Lucknow
Rajesh Sharma	Member Fellow	Board of Management, Gyan Vihar University, Jaipur Indian Geophysical Union (IGU), Hyderabad
T.N. Jowhar	Executive Member Member	Indian Geological Congress, Roorkee Sectional Committee Member of the section of Earth System Sciences of the Indian Science Congress Association, Calcutta
S.K. Parcha	Member Fellow Member	Geological Society of India Paleontological Society of India Indian National Science Congress
D.K. Yadav	Member	Indian Geophysical Union (IGU, Hyderabad).

AWARDS AND HONOURS

- Dr. B.R. Arora, Director of the Institute has been selected for the coveted “Hari Narain Award” by the Council of the Geological Society of India in recognition of his valuable contribution in the field of Indian Geophysics.
- Dr. A.K. Dubey, Scientist 'G' received an award “Uttarakhand Gaurav Award” bestowed by Bimal Herbal Heritage & Education Society, Dehradun.
- Dr. Sushil Kumar was appointed as Associate Editor of the academic International Journal of Geology and Mining Research.
- Dr. S.K. Ghosh was nominated as Visiting Fellow of HNB Garhwal University, Srinagar, Garhwal.

Ph.D. THESES

Name	Supervisor	Title of the Theses	University	Awarded/ Submitted
S.K. Rai	Prof. S. Krishnaswami Prof. L.S. Chamyal	Geochemical and isotopic studies of ancient and modern sediments	MSU, Baroda	Awarded
Vivek Retwij Bhardwaj	Dr. R. Islam Prof. M. Raza	Geochemistry of Mesoproterozoic metasediments of Khetri Copper Belt, NE Rajasthan and its implication on provenance characteristics and tectonic setting.	AMU, Aligarh	Awarded
Upasana Devrani	Dr. A.K. Dubey Dr P. C. Bahukhandi	Structural evolution of the Garhwal Synform: Field and anisotropy of magnetic susceptibility studies.	HNB Garhwal University, Srinagar, Garhwal	Awarded
Vivekananda Pathak	Prof. C.C. Pant Dr. Ajay Paul	Seismotectonics of the Dwarahat-Dhaulchhina area with special reference to neotectonics	Kumaun University, Nainital	Awarded
Gopal Singh Darmwal	Prof. C.C. Pant Dr. Ajay Paul	Seismotectonics of the Dharchula, Munsiari and Berinag area with special reference to neotectonics	Kumaun University, Nainital	Awarded
Anusuya Bhandari	Dr. B.N. Tiwari	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	Submitted
R.K. Bridramaditya 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	Submitted
P.R.K. Gautam	Dr. M.N. Viladkar Dr. Sri Niwas Pandey Dr. Rambhatla G. Sastry	Geotechnical mile characterization through geotechnical imaging.	IIT, Roorkee	Submitted

PARTICIPATION IN SEMINAR/SYMPOSIA/ WORKSHOP/ TRAINING COURSES

Seminar/Symopsia/Workshop

- International Seminar (causes and mitigation of Environmental degradation of planet Earth with special reference to Uttarakhand at MKP (P.G.) College, Dehradun, April 6-7, 2009.
  Participants: M.P. Sah, A.K. Mahajan and A.K.L. Asthana

- Meeting of the Expert Committee on Fast Track Scheme for Young Scientists (DST) at NGRI, Hyderabad, April 10-11, 2009.
  Participant: A.K. Dubey

- 40th IETA Mid Term Symposium on Information and Communication Technology for Disaster Management (ICTDM-2009), at CSIO, Chandigarh, April 17-18, 2009.
  Participant: Vikram Gupta

- EGU General Assembly 2009, Vienna Austria, on April 19-24, 2009.
  Participant: B.R. Arora

- Training on Concept of Quaternary Climate Studies with Emphasis on Dendrochronology and Palaeobotany, Lucknow, May 12-18, 2009.
  Participant: P.S. Negi

- Meeting of the Expert Committee on Women Scientist Scheme (DST) at CEPT University, Ahmedabad, May 20, 2009.
  Participant: A.K. Dubey

- Seminar on Environmental Pollution and Climate Change, at Doon University, Dehradun, June 5-6, 2009.
  Participant: R.K. Mazari

- National Workshop on Environmental Hazards at HNB Garhwal University, Srinagar, June 6-7, 2009.
  Participant: Vikram Gupta

- Workshop on Rehabilation of Upper catchment of River Tons, Organised by National Institute of Ecology, New Delhi at Uttarakhand Forest Deptt, Rajpur Road, Dehradun, July 9, 2009
  Participant: S.K. Bartarya

- National Workshop to Discuss the Findings of Climate Change Studies carried out under MoWR Action Plan on Climate Change, at National Institute of Hydrology, New Delhi, July 21, 2009.
  Participant: R.K. Mazari

- Environmental Threats in Cold Deserts – Challenges and the Way Ahead, organized by Pragya, an NGO, New Delhi, July 22-23, 2009.
  Participant: R.K. Mazari

- Regional Seminar on Climate Change organised by Navduniya, Dehradun, September 6, 2009.
  Participant: D.P. Dobhal

- National Conference on Earth System Processes and Disaster Management**,** at National Centre for Antarctic and Ocean Research Goa, September 15- 17 , 2009.
  Participant: V.C. Tewari

- Indo-German Workshop on Source, Treatment and Distribution of Drinking Water, organized by Uttarakhand State Council for Science and Technology, Dehradun, September 14-15, 2009.
  *Participant**:** R.K. Mazari and P.K. Mukherjee*

- National Workshop on Landslide Mitigation, at Amrita University, Kollam, Kerala, September 18-19, 2009.
  Participant: Vikram Gupta

- Energy Efficiency Programme for Government Buildings in Uttarakhand, at Uttarakhand Renewable energy Development Agency (UREDA), Urja Park Campus, Patelnagar, Dehradun, September 25, 2009.
  Participant: N.K. Saini

- Forty Sixth Annual Convention and meeting on 'Evolution of Himalayan Foreland Basin and Emerging Exploration Challenges, at Wadia Institute of Himalayan Geology, Dehradun, India, October 5-7, 2009.
  Participants: V.C. Tewari, Rohtash Kumar, P.P. Khanna, S.K. Ghosh, N.K. Saini, K.K. Purohit, Kishor Kumar, N.Siva Siddaiah, R. Islam, Rajesh Sharma, R.S. Rawat, S.K. Paul, H.K. Sachan, A.K. Mahajan, Pradeep Srivastava, S. Rajesh, , A.K. Mundepi, Santosh K. Rai, K. Lokho and Barun K. Mukherjee

- National Workshop on Seismogenesis to prediction of earthquakes: Himalaya and Indian Shield Perspective (SPRED – 2009), at Wadia Institute of Himalayan Geology, Dehradun, October 22-24, 2009.
  Participants: B.R. Arora, V.M. Choubey, S.K. Paul, R.S. Rawat, Sushil Kumar, Pradeep Srivastava, R.J. Perumal, A.K. Mahajan, A.K. Mumdepi, D. Hazarika, Naresh Kumar, G. Rawat, V. Sriram and D.K. Yadav,

- Workshop on "Renovation and Rejuvenation of Higher Education" organized at CSSTE-AP, Indian Institute of Remote Sensing, Dehradun, October 26, 2009.
  Participant: G. Philip

- Himalayan Chief Ministers Conclave on "Indian Himalaya: Glacier, Climate Change and Livelihood", organized by Department of Environment, Science and Technology, Govt. of Himachal Pradesh and Leadership for Environment and Development (LEAD)-India, at Hotel Peterhof Shimla, Oct.29-30, 2009.
  Participant: M.P. Sah

- International Training Program on "Seismic Design of Structure and Hazard Mitigation", National Center for Research on Earthquake Engineering (NCREE), Taipei, Taiwan, October 25 – November 1, 2009.
  Participant: D. Hazarika and D.K. Yadav

- EPMA Application Training organized by M/s Gannon and Dunkerly, Mumbia and held at Wadia Institute of Himalayan Geology, Dehradun, November 9-13, 2009.
  Participants : D.R. Rao, H.K. Sachan, B.K. Mukherjee, S.S. Thakur, P. Nandini and Megha Daga

- Second Asia Pacific Conference on Luminescence and Electron Spin Resonance dating, at Physical Research Laboratory, Ahmedabad, November 12-15, 2009.
  Participants: Pradeep Srivastava and N. Suresh

- National Seminar on "Geodynamics, Sedimentation and Biotic response in the context of India – Asia collision", Mizoram University, Aizawl, November 26 – 28, 2009.
  Participants: B.R. Arora, V.C. Tewari, D.R. Rao, S.K. Paul and Megha Daga

- International Conference on "Environment and Energy Conservation" organised at Graphic Era University, Dehradun, on November 27-28, 2009.
  Participant: G. Philip

- Short course on "New Developments in Magmatic Ni-Cu and PGE Deposits" conducted by Prof. Tony Naldrett and Prof. Edward M. Ripley at Institute of Minerals and Materials Technology (IMMT), Bhubaneswar, December 1, 2009.
  Participant: A.K. Singh

- Conference on Environment, organized by CII at ICFRE Auditorium, FRI Campus, Dehradun, December 2-3, 2009.
  Participant: S.K. Bartarya

- International Symposium on Magmatic Ore Deposits (ISMO 2009) at IMMT, Bhubaneswar December 2-4, 2009.
  Participant: A.K. Singh

- XXII Indian Colloquium on Micropalaeontology and Stratigraphy, at National College, Tiruchirapalli (Tamil Nadu), December 16-18, 2009.
  Participant: B.N. Tiwari, S.K. Parcha, Shivani Pandey and Anusuya Bhandari

- International Field Workshop on Vindhyan Supergroup, Central India, organized by PSI, BSIP and CAS at Lucknow University, Lucknow, January 20-31, 2010.
  Participant: B.N. Tiwari

- Workshop on"Application of satellite geodetic techniques for scientific studies in India at Indian Institute of Surveying & Mapping (IISM), Hyderabad, Feb. 3-4, 2010.
  Participant: Param K. Gautam

- International Conference and Field Meeting on Precambrian Life, Time and Environment: Evolutionary concepts and modern analogues, at Centre of Advanced study in Geology, Lucknow University, Lucknow, February 5-7, 2010.
  Participants: V.C. Tewari and Meera Tiwari

- Workshop on Climate – Change adaption practices organized by World Food Programme, Uttarakhand at Hotel Maduban, Dehradun, February 4-5, 2010.
  Participant: S.K. Bartarya

- ILTP Workshop on Modelling of Geological Structures at North East Institute of Science and Technology (NEIST), under CSIR Jorhat, Assam, February 5-13, 2010.
  Participant: D. Hazarika

- Seminar on "Science, Technology and Education Development Policy", organized by Indian Science Association at Uttarakhand State Forest Department, Rajpur Road, Dehradun, February 14, 2010.
  Participant: P.S. Negi

- Brain Storming/workshop on climate change and glacier, held at IIT. Delhi, sponsored by DST New Delhi, February 15-16, 2010.
  Participant: D.P. Dobhal

- Chapman Conference on Complexity and Extreme Events in Geosciences, at National Geophysical Research Institute , Hyderabad, February 15- 19, 2010.
  Participant: V.C. Tewari.

- Regional Workshop on Water Management and Hydrochemistry in Uttarakhand, organized by CGWB, Dehradun, at WIHG, Dehradun, February18-19, 2010.
  Participant: S.K. Bartarya and P.K. Mukherjee

- National Seminar on Sedimentation, tectonics and hydrocarbon potential in Himalayan foreland basin, University of Jammu, Jammu Tawi, February 22-23, 2010.
  Participants: Kishor Kumar, N. Siva Siddaiah, A.K. Mahajan, A.K. Mundepi, Anusuya Bhandari and M.K. Shukla

- Conference on Recent Trend in Conservation, Technology and Utilization of Bio-resources, at Advance Institute of Science and Technology, Dehradun, February 23, 2010.
  Participant: P.S. Negi

- Workshop on Slope stability and Landslides at CRRI, New Delhi, March 3,2010.
  Participant: A.K. Mahajan

- National Workshop on Water Resources of Uttarakhand and their Management for Sustainable use, at IIRS, Dehradun, March 3-4, 2010.
  Participants: P.K. Mukherjee and S.K. Bartarya

- 2nd Group Monitoring Workshop on Fast Track Proposals for Young Scientists in Earth and Atmospheric Sciences, at SRM University, Kattankulathur, Chennai, March 15-16, 2010.
  Participant: A.K. Singh

- International conference on Radium and Radon. Jerusalem, Israel, March, 14-19, 2010
  Participant: V.M. Choubey

LECTURES BY VISITING SCIENTISTS

Name and address	Date	Topic
Prof. G. N. Goswami, Director, Physical Research Laboratory, Ahmadabad	11.05.09	Chandrayan -I
Prof. Matthew J. Kohn, Boise State University, USA	01.05.09	Evidence for a Palaeoproterozoic Arc in the Lower Lesser Himalayan Sequence
Prof. S. K. Tandon, Pro-Vice chancellor, Delhi University, Delhi	15.05.09	Climate change and impact on large River System
Dr. Jennifer Chambers, Boise State University, USA	18.05.09	Meta-sedimentary rocks in the hanging wall of the South Tibetan Detachment and their implications for tectonic models of the Himalaya
Prof. Delores Robinson, University of Alabama, USA	18.05.09	Integrating Forward Modeling and unroofing data from the Central Himalayan thrust belt, western Nepal
Prof. A. N. Purohit, Former Director GBPIHED, Almora, Uttarakhand	29.06.09	Carbon dioxide & Global Warming: An overlooked Paradigm
Prof. S.G. Wesnousky, University of Nevada, Reno, USA	17.07.09	Paleoseismology along the Himalayan Frontal Thrust
Dr. Jerome Lave, Prof. CNRS, LGCA University, Joseph Fourier, Grenoble	30.10.09	Life and Death of Mountain Ranges
Dr. Tabata H. Gifu Academy of Forest Science & Culture, Japan	18.12.09	Why a plant ecologist organized geological and paleoecological research team in Nepal Himalayas; and has been interested in Himalayan geology?
Dr. Sakai, T. Associate Professor, Shimane University	18.12.09	A geological sketch of the Kathmandu valley especially from sedimentological view points.
Dr. V. K. Jha IIRS Dehradun	28.02.10	Indian Space programme

LECTURES BY INSTITUTE SCIENTISTS

Name of Scientist	Venue	Date	Topic
Sushil Kumar	WIHG, Dehradun	24.04.09	Seismological activities in the NW Himalaya and its contemporary scenario
N.Siva Siddaiah	WIHG, Dehradun	22.05.09	Volcanic signatures at the base of Subathu Formation, NW Himalaya
D.P. Dobhal	ICIMOD, Nepal	28.05.09	Mass balance measurement, methodologies and techniques in Himalayan perspective
Kapesa Lokho	WIHG, Dehradun	29.05.09	Fossil foraminifera and Pteropods from the Cenozoic sediments of Assam-Arakan basin, Northeast India
D.P. Dobhal	ICIMOD, Nepal	29.05.09	Mass balance studies of Himalayan glaciers: A study of Dokriani, Chorabari and Chotta Shigri glaciers
S.K.Ghosh	WIHG, Dehradun	05.06.09	Fossilized Seismographs in the 1.8Ga sediments of Garhwal Lesser Himalaya
B.N. Tiwari	WIHG, Dehradun	03.07.09	Geological milieu of Miocene replenishing of nutrients vis-à-vis afresh beginning of terrestrial life in Himalayan forelands
A.K. Mahajan	WIHG, Dehradun	24.07.09	Characterization of the sedimentary cover at the Himalayan foothills: A comparative study of active and passive Remote MASW and F-K techniques
P.K. Mukherjee	Archeological Survey of India, Dehradun	06.08.09	Weathering of building stones
R.K. Mazari	IIRS, Dehra Dun	12.08.09	Remote Sensing for Geo-Resources and Natural Hazard Assessment
Kishor Kumar	WIHG, Dehradun	11.09.09	Eocene terrestrial mammal faunas of India: palaeobiogeographic implications
A.K. Singh	WIHG, Dehradun	16.10.09	Chromite mineralization in Manipur Ophiolitic complex, Indo-Myanmar Orogenic Belt: A petrological and geochemical study

LECTURES BY INSTITUTE SCIENTISTS

Name of Scientist	Venue	Date	Topic
S.K. Bartarya	SSJ Campus, Almora	07.11.09	i. Groundwater targeting in hilly and mountainous terrain using remote sensing data ii.Introduction to Hydrogeology
S.K. Paul	WIHG, Dehradun	Nov. 09	Geology of Higher NW Himalaya
A.K. Dubey	IFA, Dehradun	11.11.09	Environment and development: In perspective of Himalayan states
S. Rajesh	WIHG, Dehradun	04.12.09	From space to deep into the earth: Satellite geodesy and dynamics of the density anomaly field in the Indian Plate.
R.S. Rawat	IRDE, Dehradun	04.12.09	Mineral Resources of Uttarakhand,
Pradeep Srivastava	PRL, Ahmedabad	12.11.09	Himalayan Rivers: Responses to past climatic changes
Rajesh Sharma	Geology Dept. Kumaun University, Nainital	14.12.09	Ore Petrology
Rajesh Sharma	Geology Department, Kumaun University, Nainital	15.12.09	Ore Petrography
A.K. Mahajan	IIRS, Dehradun	16.12.09	i.Seismic microzonation and Probabilistic hazard assessment ii.Case studies on Seismic hazard assessments
G. Philip	IIRS, Dehradun	18.12.09	i.Glacier mapping and monitoring using remote sensing ii.GLOF assessment
A.K. Dubey	IIT, Kharagpur	01.01.10	Faults and faulting
V.C. Tewari	Kerala University, Trivendram	05.01.10	Carbon and oxygen isotopes, paleomonsoon, paleoclimate and speleothemes from the NW and NE Himalaya
S.K. Bartarya	IIRS, Dehradun	12.02.10	Hydrogeology of mountainous terrain with special reference to Himalaya
V.M. Choubey	WIHG, Dehradun	12.02.10	Continuous radon measurements in Garhwal Himalaya

Name of Scientist	Venue	Date	Topic
D.P. Dobhal	School of Social Sciences, J.N.U, New Delhi	17.02.10	Long term monitoring of Dokriani glacier; (1991-2008), data acquisition and results
T.N. Jowhar	Department of Earth Scinces, Manipur University, Imphal	22.02.10	An insight into the estimation of Pressure-Temperature in rocks
H.K. Sachan	PRL, Ahmedabad	23.02.10	UHP metamorphism and its consequences on Himalayan orogeny
P.S. Negi	AIST, Dehra Dun	23.02.10	Climate Change Impact on the High Altitude Resources of Himalaya
Meera Tiwari	WIHG, Dehradun	12.03.10	Fossil Record in Himalaya: Early Evolution of life and global significance
Sushil Kumar	IIT, Roorkee	12.03.10	Improving local and regional earthquake locations using latest inversion technique namely particle swarm optimization.
V.C. Tewari	IIT, Roorkee	17.03.10	Origin of life , its evolution , diversification and search in the Universe
Pradeep Srivastava	Center for Earth Sciences IISc, Bangalore	21.03.10	Himalayan Rivers: Responses to past climatic changes.
Pradeep Srivastava	Center for Advance Studies in Geology, Lucknow University	30.03.10	Quaternary: Proxies and Archives.

TECHNICAL SERVICES

Analytical Services

Central Facility Laboratories

XRF, XRD, SEM, ICPMS and EPMA are the main instruments available in Central Facility Laboratories of the Institute. This group is fulfilling the analytical needs of not only the scientists and research scholars working in the institute but also of those working in different universities and organizations. Researchers of various projects running in the institute as well as many industries of the surrounding areas are also being benefited, using the facilities available. Three thousand two hundred ninety five samples were analyzed for major, trace, and rare earth elements during this period using the available tools. Break up is as follows.

There was a major break down in ICPMS. It took nearly six months to put it back to function. Rest all the instruments remained functional throughout the year.

New Addition of Fully Automatic Sequential X-ray Fluorescence Spectrometer (XRF)

XRF - S8 Tiger

An advance X-ray Fluorescence Sequential Spectrometer (S8 Tiger from Bruker-AXS GmbH Germany) was installed in the Central Facility Laboratories replacing the old Siemens SRS3000 XRF system. The new spectrometer has the several advantageous features like high speed, more precise elemental analysis with enhanced sensitivity, accommodating 60 samples at a time and flexibility in terms of adopting several analytical modes including a special analytical program for analysis of rock/mineral samples. The built-in standardless analysis program is a useful tool for the qualitative analysis of completely unknown materials. The extended analytical range includes some of the very useful elements that can be analysed along with the usually analysed major and trace elements in geological samples. Special features include a High power X-ray tube of 4kW capacity providing more powerful excitation of elements, eight number of analyzing crystals and two x-ray detectors (Gas flow proportional and scintillation) with three optimized coarse and fine collimators.

Instrument	WIHG Users	Outside Users	Total
XRF	827	354	1181
XRD	282	230	572
SEM.EDX	419	73	792
ICPMS	340	410	750
EPMA	75	60	135

Practical training to the users

Under course module for the JRFs of the Institute training course for four research scholars were provided training on analytical techniques for a period of three months (January to March 2010). Users mainly students from various universities were trained in basic techniques of sample preparation and instrument operation. Five P.G. dissertations of Gurukul Kangri University, Haridwar were also supervised during the year.

Photography Section

During the reporting year around 4000 pictures were clicked using only digital cameras to cover various functions, including Foundation Day, Founders day, National Science Day, National Technology Day, New Year Day, Seminars/ Symposia, Inauguration of Glaciology Centre, and superannuation parties for Institute staff etc., organized in the Institute. Apart from this around 700 snaps were clicked for rock and fossil specimens. The colour printing of around 500 digital images was arranged from the market.

Drawing Section

The drawing section catered to the cartographic needs of the scientists of the Institute including the sponsored projects. During the 2009-10, the drawing section has provided 123 geological / structural / geo-morphological maps for the scientists of the Institute. The staff of the drawing section has also prepared line diagrams, Litho-logs, geological cross sections and addition/ alteration in maps.

***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 1597 thin and polished sections to various users for carrying out microscopic, fluid inclusion and EPMA studies. 1391 rock samples were powdered for carrying out mineral identification, major, trace and REE analysis by ICPMS, XRF and XRD.

S.P. NAUTIYAL MUSEUM

The Museum is the key affiliation of education; and continues to generate an axis of awareness to the students and public not only from the distant corners of India but also from abroad. As usual, it 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. More than 5000 people from different parts of country including foreign groups visited the Museum. On the National Science Day 28th February, 2010 more than 2500 students from various Universities, colleges, technical institutes, schools, paramedical as well as from the engineering colleges of the Doon valley visited the Museum.

The Museum observed Open Days during, National Technology Day (11th May, 2009), Foundation Day (29th June, 2009), Founder's Day (23rd Oct. 2009), and National Science Day (28th Feb., 2010). Students and public in large numbers visited the museum on these open days The print media gave wide coverage to these functions. Science quiz and Hindi essay competitions were organized on the eve of Science week celebrations. Various schools of Doon Valley and of the surrounding areas participated in the quiz competition and prizes were distributed to the students who stood, first, second and third in the merit of these competitions. Besides this consolation prizes were given for science quiz and for Hindi essay competitions.

A large number of students continue to visit the museum for their respective school projects. The activities of the museum are according to the needs and the interests of the students. The visitors from U.S.A., England, Israel, Belgium, West Indies, Columbia, Taiwan, U.K, France, Turkey, Nepal, Bangladesh, Vietnam, Malaysia, Afghanistan and Sri Lanka also visited the Museum.

LIBRARY

The Library of the Wadia Institute of Himalayan Geology is one of the advanced libraries in the field of earth sciences in terms of its collection and services. It 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 is 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 the National Knowledge Resource Consortium (formerly known as CSIR-DST e-journals consortium). WIHG Library has access to various science and Technology packages of 24 different major publishers. Some of them are American Institute of Physics, Cambridge and Oxford University Press, Springer, Wiley, Taylor and Francis, Sage and different databases like Sci-Finder, INSPEC, Indianjournals.com, Indian Standards etc. 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 will grow further in terms of number of publishers.

The Library subscribed to 81 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 1500 titles pertaining to various disciplines of thrust areas of the Institute. Since the Elsevier is presently not participating in the consortia, therefore, WIHG Library has subscribed to Elsevier's *Earth & Planetary Collection* consisting of 115 titles on science direct platform. The Library added three more Journals (Journal of Mass Spectrometry published by Elsevier, Journal of Geophysical research (Earth Surface) published by AGU and Geochemistry, Geophysics, Geosystems ***(G^3)*** published Online only by AGU) to its subscription list for the year 2010.

During the period of this report Library has acquired a total number of 1183 e-books and 179 books (printed). Out of these 28 books/reference books are purchased while 33 books are received as gratis. In addition to this 118 books in Hindi are purchased for Hindi collection. The Library has a good collection of Hindi books to promote the usage of Hindi Language in the staff of the Institute. Library acquired a total number of 750 reprints of publications of various scientists.

The Library purchased all the back volumes till 1996 for the following two journals:

a. Geophysical Journal International (GJI), published by Wiley-Blackwell.

b. Sedimentology, published by Wiley-Blackwell.

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.

PUBLICATION & DOCUMENTATION

The Publication and Documentation Section is involved in bringing out the 'Himalayan Geology' (Journal) and publishing Annual Report and Hindi magazine Ashmika etc. During this year, the Section published 'Himalayan Geology' volumes 30(2) 2009, 31(1) 2010, Hindi magazine 'Ashmika' volume 15, and 'Annual Report' of the Institute for the year 2008-09 in Hindi and English. It had also broughtout the 'Abstract volume' of the National workshop on “Seismogenesis to PREDiction of earthquakes: Himalaya and Indian Shield Perspective - [SPRED-2009]”, and the Golden Jubilee volume of Memoir Geological Society of India, volume 72 edited by Drs. B.R. Arora and Rajesh Sharma on “Collision Zone Geodynamics”. Apart from this, it also involved in printing of Lectures, Circulars, Invitation Cards, and Certificates etc. Additionally, it also provides central facility and technical support service on A0 size Scanner and Printer to Scientists, Research scholars and other staff of the Institute for scanning and colour printing of maps, diagrams and figures.

Himalayan Geology (Journal) website http://www.himgeology.com is maintaining and functioning with online enquiry, online prepaid subscription order and online Manuscript submission facility under this Section. This website is up-to-date with all information (i.e. all contents and abstracts from 1971 to 2010) of Himalayan Geology (Journal) Articles.

FOUNDATION DAY CELEBRATIONS

The 41st Foundation Day of the Institute was celebrated on June 29, 2009. Padmashree Prof. A. N. Purohit, Former Director, GBPIHED, Almora, Uttarakhand was the Chief Guest. He delivered the Foundation Day Lecture on "Carbon dioxide & Global Warming: An overlooked Paradigm". On this occasion, Himalayan Geology Volume 30 (1) and Hindi Magazine 'Ashmika' Volume 15 was also released by the Chief Guest. On this occasion, distribution of awards for best research paper published by the Scientists in their respective fields were also given by the Chief Guest. The awards were given to Dr. Pradeep Srivastava and Dr. R. Islam for their paper entitled “Fashion and phases of Late Pleistocene aggradation and incision in Alaknanda River, western Himalaya, India” published in Quaternary Research and to Dr. Ajay Paul, Dr. Naresh Kumar and Sh. Gautam Rawat for best scientific team award for their outstanding work during the year. Dr. V.C. Tewari was given best Hindi paper award for the paper published in Ashmika. Best worker awards were given to Sh. Dinesh Chandra, Registrar, Sh. Harish Chandra, Finance & Accounts Officer, Sh. M.K. Biswas, Store & Purchase Officer, Sh. Rambir Kaushik, Sr. Tech. Assistant, Sh. C.B. Sharma, Jr. Engineer, Sh. M.M. Barthwal, UDC and Sh. S.K. Chettri, UDC, for good work carried out by them during the year 2008-2009.

Chief Guest Padmashree Prof. A.N. Purohit, Former Director, GBPIHED, Almora lecturing in the Foundation Day Celebration.

Prof. A.N. Purohit along with Dr. A.K. Dubey and Dr. R.J. Azmi releasing the Himalayan Geology volume during the Foundation Day Celebration.

NATIONAL TECHNOLOGY DAY

The eleventh National Technology Day was observed on 11th May, 2009. Museum and other laboratories were kept open for public and for the school and college children. A large number of student and the people visited the institute museum and other laboratories. On this occasion, Prof. J.N. Goswami, Director, Physical Research Laboratory, Ahmedabad delivered Technology Day lecture on "Chandrayan -I". The lecture was well attended by students, general public and by the Institute staff.

Prof. J.N. Goswami, Director, PRL, Ahmedabad delivering the National Technology Day Lecture.

W.D. WEST LECTURE

The W.D. West lecture on *"Climate change and impact on large River System"* was delivered by Prof. S.K. Tandon, Pro-Vice Chancellor, Delhi University on 15.5.2009. On this occasion Dr. K.R. Gupta, Former Advisor, DST and Convener Northern Chapter Geological Society of India was the Guest of Honor. The lecture was well attended by scientists of the Institute as well as scientists from other organizations.

Prof. S.K. Tandon, Pro-Vice Chancellor, Delhi University sharing the dias with Dr. K.R. Gupta, Dr. B.R. Arora and Dr. A.K. Dubey during W.D. West Lecture.

FOUNDER'S DAY CELEBRATIONS

The Institute celebrated its Founder's Day on October 23, 2009 in the honour of Prof. D.N. Wadia. On this occasion Prof. S. Sinha Roy, Birla Institute of Scientific Research, Jaipur, delivered the D.N. Wadia Honour Lecture on *"Convergence strain partitioning in relation to seismicity and critical taper dynamics in the Himalaya"*.

Prof. S. Sinha Roy, Birla Institute of Scientific Research, Jaipur delivering the D.N. Wadia Honour Lecture on the Founder's Day Celebration.

NATIONAL SCIENCE DAY CELEBRATIONS

The National Science Day-2010 was organized in the Institute by a week long activities, beginning with a Science Quiz Competition. The various educational institutions of the Dehradun participated in the Science Quiz and Hindi Essay Competition. In total 54 educational institutions participated in the quiz competition (34) and Hindi Essay competition (20). In addition this year Science slogan competition was also organized for all the staff of the Institute and the prizes were distributed to those who stood first, second and third in each category in Hindi and English.

On 26th Feb. 2010, an open day was observed and all the laboratories were kept open to students and general public. In total 36 educational institutions with more than 3,500 school children and a large number of public visited the Institute Museum and laboratories. Scientists as well as the technical staff and research scholars explained to the students and public, the functioning of the various scientific instruments and their uses.

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

In the evening an invited National Science Day Lecture on "Indian Space programme" was delivered by Dr. V. K. Jha, a retired Scientist of Indian Institute of Remote Sensing, Dehradun. This was attendant by Scientists of the Institute and by a large number of public and students of different schools. On this occasion, former Uttarakhand Chief Minister Shri N.D. Tiwari also visited the Institute and encouraged the students to opt for science and research.

Students participating in Hindi Essay Competition and visiting the various laboratories during National Science Day Celebration.

Shri N.D. Tiwari, Former Chief Minister Uttarakhand visiting the Institute during the National Science Day Celebration.

Dr. V.K. Jha, Retired Scientist, IIRS delivering the Science Day Lecture.

DISTINGUISHED VISITORS TO THE INSTITUTE

- Shri Prithviraj Chavan, Hon'ble Minister of State (Independent Charge) Ministry of Science & Technology and Earth Sciences, Ministry of Personnel, Public Grievances & Pensions and Minister of State in the Prime Minister's Office, Ministry of Parliamentary Affairs, Govt. of India
- Dr. Ramesh Pokhriyal 'Nishank', Chief Minister, Uttarakhand
- Maj. General B.C. Khanduri, Former Chief Minister, Uttarakhand
- Shri N.D. Tiwari, Former Chief Minister, Uttarakhand
- Shri Harish Rawat, Hon'ble Minister for State, Labour & Employment, Govt. of India
- Shri Harbans Kapoor, Hon'ble Speaker, Uttarakhand Vidhan Sabha
- Dr. Shailesh Nayak, Secretary, MoES, Govt. of India
- Prof. S.K. Tandon, Pro-Vice chancellor, Delhi University, Delhi
- Padmshree Prof. A.N. Purohit Former Director, GBPIHED, Almora, Uttarakhand
- Dr. H.K. Gupta, Raja Ramana Fellow
- Dr. Jitender Nath Goswami, Director, PRL, Ahmedabad
- Prof. S.G. Wesnousky, University of Nevada, Reno, USA

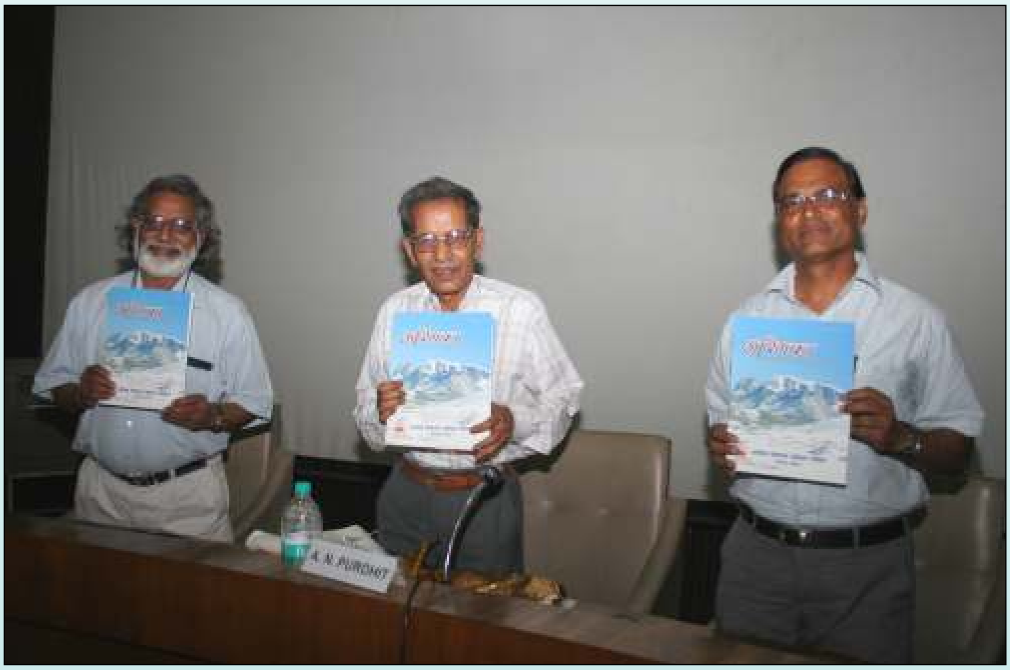
Hon'ble Minister Shri Prithviraj Chavan, Ministry of Science & Technology and Earth Sciences, Govt. of India along with Dr. T. Ramasami, Secretary, DST During one of their visit to Institute.

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, 2009, during which essay competition and debate for school children and Institute employees was organized on topics "*Yadi mein vaigyanik hota*", "*Paryavaran mein parivartan*", "*sansthan ke prati kartavya aur apke adhikar*", *and "paryavaran mein parivartan ke liye vikasshil desh nahin viksit rashtra jimmedar hein*" respectively. A nara competition was also organized for Institute employees on this occasion. During Hindi pakhwara also one day Hindi workshop was organized, wherein Dr M.N. Joshi, gave an invited talk on the topic "Pracheen Sagar" followed by a swarachit Kavita path.

On the occasion of the Foundation Day of the Institute on June 29, 2009, the Hindi Magazine *'Ashmika'* volume 15 was released. The Annual Report of the Institute for the year 2008-09 was published in bilingual form.



Padmashree Prof. A.N. Purohit, Former Director, GBPIHED, Almora along with Dr. A.K. Dubey and Dr. R.J. Azmi releasing the hindi magazine 'Ashmika' during the Foundation Day Celebration.

MISCELLANEOUS ITEMS

1. **Reservation/Concessions for SC/ST employees**

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

2. **Monitoring of personnel matters**

   Monitoring of personnel matters relating to employees of the Institute 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 Senior Scientists/Officers for redressal of employee's grievances. No request regarding grievance of any of the employee was received during the year by the Grievance Committee.

4. **Welfare measures**

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

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

   To inquire into the complaints of sexual harassment of women employees at work places in the Institute, a separate Committee has been constituted. The Committee consists of six members. The Chairman and two other members of the Committee are female officers, which includes a female officer from the Geological Survey of India. No complaint of sexual harassment of women employees at work places was received by the Committee during the year 2009-10.

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 2009-10.

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 2008-09.

   The details of information on the RTI cases during the year 2009-10 are as under:-

Details	Opening balance as on 01.04.2009	Received during the year 2009-2010	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	13	Nil	Nil	13
First appeals	Nil	Nil	Nil	Nil	Nil

No application or appeal under the Right to Information Act, 2005 was carried forward to the next financial year 2010-11.

8. **Sanctioned Staff strength (category wise)**

Group/Category	Scientific	Technical	Administrative	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 2008-2009**

Plan : Rs. 2,562.50 lakhs

Non-Plan : Rs. 100.00 lakhs

Total : Rs. 2,562.50+100.00 = 2,662.50 lakhs

10. **XIth Plan approved outlay**

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

INSTITUTE EMPLOYEES DONATING BLOOD DURING THE BLOOD DONATION CAMP ORGANIZED BY INDIAN MEDICAL ASSOCIATION AT WIHG, DEHRADUN

STAFF OF THE INSTITUTE
(AS ON 31.03.2010)

A) SCIENTIFIC STAFF

1.	Prof. B.R. Arora	Ex-Director (retd. 31.10.2009)
2.	Dr.A.K. Dubey	Acting Director
3.	Dr. R.K. Mazari	Scientist 'G'
4.	Dr. R.J. Azmi	Scientist 'G'(retd. 31.10.2009)
5.	Dr. V.C. Tewari	Scientist 'F'
6.	Dr. B.K. Choudhary	Scientist 'F'
7.	Dr. V.M. Choubey	Scientist 'F
8.	Dr. Rohtash Kumar	Scientist'F'
9.	Dr. P.P. Khanna	Scientist F'
10.	Dr.(Mrs) Meera Tiwari	Scientist 'F'
11.	Dr. S.K. Ghosh	Scientist 'F'
12.	Dr. N.R. Phadtare	Scientist 'F'
13.	Dr. D.K. Misra	Scientist 'F'
14.	Dr. N.K. Saini	Scientist 'F'
15.	Dr. K.K. Purohit	Scientist 'F'
16.	Dr. Kishor Kumar	Scientist 'F'
17.	Dr. M.P. Sah	Scientist 'F'
18.	Dr. N.Siva Siddaiah	Scientist 'F'
19.	Dr. Rajesh Sharma	Scientist 'F'
20.	Dr. G. Philip	Scientist 'F'
21.	Dr. Rafikul Islam	Scientist 'F'
22.	Dr. B.N. Tiwari	Scientist 'F'
23.	Dr. D. Rameshwar Rao	Scientist 'F'
24.	Dr. R.S. Rawat	Scientist 'E'
25.	Dr. R.K. Choujar	Scientist 'E'
26.	Dr. Keser Singh	Scientist 'E'
27.	Dr. S.K. Paul	Scientist 'E'
28.	Dr. T.N. Jowhar	Scientist 'E'
29.	Dr. S.K. Bartarya	Scientist 'E'
30.	Dr. P.K. Mukharjee	Scientist 'E'
31.	Dr. P. Banerjee	Scientist 'E'
32.	Dr. S.K. Parcha	Scientist 'E'
33.	Dr. H.K. Sachan	Scientist 'E'
34.	Dr. Sushil Kumar	Scientist 'D'
35.	Dr. A.K. Mahajan	Scientist 'D
36.	Dr. D.P. Dobhal	Scientist 'D'
37.	Dr. Vikram Gupta	Scientist 'D'
38.	Shri B.S. Rawat	Scientist 'C' (on deputation)
39.	Dr. S.S. Bhakuni	Scientist 'C'
40.	Dr. Suresh N.	Scientist 'C'
41.	Dr. Pradeep Srivastava	Scientist 'C'
42.	Dr. Ajay Paul	Scientist 'C'
43.	Dr. A.K. Mundepi	Scientist 'C'
44.	Shri V. Sriram	Scientist 'C'
45.	Dr. P.S. Negi	Scientist 'C'
46.	Dr. A.K.L Asthana	Scientist 'C'
47.	Dr. (Mrs) Kapesa Lokho	Scientist 'C'
48.	Dr. A.K. Singh	Scientist 'C'
49.	Dr. R. Jayangondaperumal	Scientist 'C'
50.	Dr. B.P. Sharma	Scientist 'B'
51.	Dr. Khaying Shing Luirei	Scientist 'B'
52.	Dr. Rajesh S.	Scientist 'B'
53.	Shri Gautam Rawat	Scientist 'B'
54.	Dr. B.K. Mukherjee	Scientist 'B'
55.	Shri Naresh Kumar	Scientist 'B'
56.	Dr.(Mrs) Swapnamita	Scientist 'B'
57.	Dr. Devajit Hazarika	Scientist 'B'
58.	Dr. Santosh Kumar Rai	Scientist 'B'
59.	Shri N.K. Meena	Scientist 'B'
60.	Dr. Dilip Kumar Yadav	Scientist 'B'
61.	Shri P.K.R. Gautam	Scientist 'B'
62.	Dr. Kaushik Sen	Scientist 'B'
63.	Dr. S.S. Thakur	Scientist 'B'(lien vacancy)

(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(4)
4.	Shri B.B. Sharma	Sr.Tech.Officer Gr.III(4)
5.	Shri A.K.Pandit	Artist-cum-Modellor Gr.III(4)
6.	Shri Sanjeev Kumar Dabral	Tech.Officer Gr.III(4)
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.Asstt.(EDP) Gr.III(2)
21.	Shri Bharat Singh Rana	Technical Asstt.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	Draftsman Gr.II(3)
27.	Shri Chandra Pal	Section Cutter Gr. II(5)
28.	Shri Shekhranandan	Section Cutter Gr.II(5)
29.	Shri Pushkar Singh	Section Cutter Gr.II(5)
30.	Shri Satya Prakash	Section Cutter Gr.II(5)

31.	Shri Santu Das	Section Cutter Gr.II(3)
32.	Shri Nand Ram	Elect.cum-Pump.Optr.Gr. II(5)
33.	Shri Lokeshwar Vashistha	S.L.T. Gr.II(3)
34.	Dr. S.K. Chabak	S.L.T. Gr.II(3)
35.	Shri R.M. Sharma	S.L.T. Gr.II(3)
36.	Shri C.P. Dabral	S.L.T. Gr.II(3)
37.	Shri Satish Pd.Bahuguna	Sr.Lab.Assistant Gr.II(5)
38.	Shri S.K. Thapliyal	Sr.Lab.Assistant Gr.II(5)
39.	Shri Shiv Pd. Bahuguna	Sr.Lab.Assistant Gr.II(5)
40.	Shri Sashidhar Pd.Balodi	Sr.Lab.Assistant Gr.II(5)
41.	Shri Rajendra Prakash	Lab. Assistant Gr.II(3)
42.	Shri A.K. Gupta	Lab.Asstt.Gr.II(3)
43.	Shri Tirath Raj	Lab.Asstt.(Photography)Gr.II(3)
44.	Shri Balram Singh	Elect-cum-Pump Opt.Gr.II(3)
45.	Shri Pratap Singh	F.C.L.A.Gr.I(4)
46.	Shri Ram Kishor	F.C.L.A.Gr.I(4)
47.	Shri Ansuya Prasad	F.C.L.A.Gr I(4)
48.	Shri Puran Singh	F.C.L.A.Gr.I(4)
49.	Shri Ram Khilawan	F.C.L.A.Gr.I(4)
50.	Shri Madhu Sudan	F.C.L.A.Gr.I(4)
51.	Shri Hari Singh	F.C.L.A.Gr.I(3)
52.	Shri Ravi Lal	F.C.L.A.Gr.I(3)
53.	Shri Preetam Singh	F.C.L.A.Gr.I(3)
54.	Shri Vivekanand Khanduri	F.C.L.A.Gr.I(1)
55.	Shri S.K. Barthwal	Lab.Assistant
56.	Shri Nain Das	Lab.Assistant
57.	Mrs.Rama Pant	Field Attendant Gr.I(3)
58.	Shri R.S.Negi	Field Attendant Gr.I(3)
59.	Shri Ramesh Chandra	Field Attendant Gr.I(3)
60.	Shri Khusi Ram	Field Attendant Gr.I(3)
61.	Shri Tikam Singh	Field Attendant Gr.I(3)
62.	Shri Bharosa Nand	Field Attendant Gr.I(3)
63.	Shri B.B.Panthri	Field Attendant Gr.I (3)
64.	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 Manas Kumar Biswas	Store and Purchase Officer
5.	Shri Tapan Banerjee	Sr.Personal Assistant
6.	Shri U.S. Tikkha	Accountant
7.	Mrs. Manju Pant	Office Superintendent
8.	Mrs. Shamlata Kaushik	Assistant (Hindi)
9.	Shri O.P.Anand	Assistant
10.	Shri N.B.Tiwari	Assistant
11.	Shri B.K.Juyal	Assistant
12.	Shri Hukam Singh	Assistant
13.	Shri D.P.Chaudary	Stenographer Grade - II
14.	Shri P.P.Dhasmana	Stenographer Grade - II
15	Smt. Rajvinder Kaur Nagpal	Stenographer Grade -III
16.	Shri D.S.Rawat	Assistant
17.	Shri S.S.Bisht	Assistant (lien vacancy)

List for Annual Report 2009-10

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. B.R. Arora (Upto 31.10.2009) Dr. A.K. Dubey Acting Director (w.e.f. 01.11.2009 onwards)	Director, Wadia Institute of Himalayan Geology, Dehra Dun - 248 001	Member Secretary
10.	Shri Dinesh Chandra	Registrar, Wadia Institute of Himalayan Geology, Dehra Dun - 248 001	Non-Member Asstt. Secretary

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

Sl.	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. B.R. Arora (Upto 31.10.2009)	Director, Wadia Institute of Himalayan Geology, Dehra Dun - 248 001	Member
11.	Dr. A.K. Dubey	Scientist 'G', Wadia Institute of Himalayan Geology, Dehra Dun - 248 001	Member Secretary

Finance Committee
(w.e.f. 01.12.2006)

Sl.	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. B.R. Arora (Upto 31.10.2009) Dr. A.K. Dubey Acting Director (w.e.f. 01.11.2009 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. 1.12.2006)

Sl.	Name	Address	Status
1.	Dr. B.R. Arora (Upto 31.10.2009)	Director, Wadia Institute of Himalayan Geology, Dehra Dun - 248 001	Chairman
2.	Dr. A.K. Dubey	Scientist 'G', Wadia Institute of Himalayan Geology, Dehra Dun - 248 001	Member
3.	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	Member Secretary

STATEMENT OF ACCOUNTS

Goyal Bhanot & Co.
Chartered Accountants

1, Turner Road, Clement Town,
Dehra Dun - 248 002 Uttarakhand
Phone : 0135-6543358 (O)
Mobile : 9837383358, 9219606467
E-mail : goyalbhanotco@rediffmail.com

AUDITOR'S REPORT

The Director,
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, 2010 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, 2010.
  - 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 7, 2010
Place: Dehradun

Goyal Bhanot & Co.
Chartered Accountants

1, Turner Road, Clement Town,
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E-mail : goyalbhanotco@rediffmail.com

Annexure 1 to the Main Audit Report

The following observations were noted during the course of audit for the financial year 2009-10. 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, 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 31.03.2010 could not be bifurcated into Plan and Non-Plan funds as the books of accounts and bank account is one only, and, 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 4,87,03,485 that means, 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.

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.

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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:

   a) Full year depreciation is charged instead of six months, on assets purchased for the half year ending 31st March, 2010. As per the management the same policy had been adopted in the previous financial years also. But if the same has been depreciated as per the rule prescribed by the Income Tax Act 1961, then surplus would have been overstated by Rs. 1373380.00.

   b) The Computer System and peripherals are depreciated @ 15% p.a. instead of 60% p.a. on W.D.V basis. Depreciation amounting to Rs.3,31,953/- has been charged by the institute on additions made during the F.Y.2009-10 but if the same has been depreciated as per the rate prescribed by the Income Tax Act 1961, then surplus would have been understated by Rs.3,31,923/- (6,63,906-3,31,953)

   c) 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.16,12,712/- has been charged by the institute on additions made during the F.Y.2009-10 but if the same has been depreciated as per the rate prescribed by the Income Tax Act 1961, then surplus would have been understated by Rs.17,87,665/- (34,00,377-16,12,712)

   d) 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. 1,42,779/- and Staff Debtors amounting to Rs 30,339/- are outstanding since more than 3 years. The advance which could not be realized in due course should be written off with the approval of the competent authority.

9. The internal control regarding Tax Deducted at Source needed to be strengthened. The observations are as follows:

   a) It was observed that only one challan was used to deposit the income tax deducted at source which falls under the category of different sections like 194C, 194I, 194J etc. As per the Income Tax provisions a separate challan should be used for deposit of TDS under different sections and for corporate and non-corporate deductees.

   b) The challansare not being deposited electronically.

   c) The Challans for TDS deducted have not been deposited in time as per the provisions of Income Tax Act; 1961.

10. The Institute has transferred fixed assets of 9 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 about 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

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WIHG.

11. The balances in the earmarked funds of IAS-2005 Workshop, Expert Committee, NSOA & FSZ and ULF/VLF Equipments have been shown negatively by Rs. 3, 65,096.00 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

[Partner, FCA]

Date : 7th July, 2007

Place: Dehradun.

WADIA INSTITUTE OF HIMALAYAN GEOLOGY, DEHRADUN

BALANCE SHEET
(AS AT 31ST MARCH 2010)

(Amt in Rs…)

Particulars	Schedule	Current Year	Previous Year
LIABILITIES			
Corpus/ Capital Fund	1	359970780	303988088
Reserves and Surplus	2	-	-
Earmaked/ Endowment Fund	3	1463326	954366
Secured Loans & Borrowings	4	-	-
Unsecured Loans & Borrowings	5	-	-
Deferred Credit Liabilities	6	-	-
Current Liabilities & Provisions	7	3125835	1958721
TOTAL		**364559941**	**306901175**
ASSETS			
Fixed Assets	8	276253872	269449589
Investments from Earmaked/ Endowment Funds	9	26809	24759
Investment- Others	10	-	-
Current Assets, Loans & Advances	11	88279260	37426827
TOTAL		**364559941**	**306901175**
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/-	
CA RAJNISH BHANOT	**HARISH CHANDRA**	**DINESH CHANDRA**	**A.K. DUBEY**
(PARTNER, F.C.A)	(Finance & Accounts Officer)	(Registrar)	(Acting Director)

Date : 07-07-2010
Place : Dehradun

WADIA INSTITUTE OF HIMALAYAN GEOLOGY, DEHRA DUN

INCOME & EXPENDITURE ACCOUNT
FOR THE PERIOD ENDED 31ST MARCH 2010

(Amt in Rs…)

Particulars	Schedule	Current Year	Previous Year
A INCOME			
Income from sales/ services	12	-	-
Grants/ Subsidies	13	214966364	120670000
Fees/Subscription	14	20000	33435
Income from Investments (Income on Invest from Earmarked/ Endowment - Fund)	15	801972	548238
Income from Royalty, Publication etc.	16	93499	55055
Interest earned	17	4045154	2825539
Other Income	18	1481952	1757809
Adjustment for Rounding Off		-	1
TOTAL (A)		**221408941**	**125890077**
B EXPENDITURE			
Establishment Expenses	20	144312747	106628784
Other Research & Administrative Expenses	21	29361294	33249995
Expenditure on Grant/ Subsidies etc.	22	-	-
Interest/ Bank Charges	23	2198	5929
Depreciation Account	8	43242978	44319323
Increase/ Decrease in stock of Finished goods, WIP& Stock of Publication		96105	16616
TOTAL (B)		**217015322**	**184220647**
Surplus/ (Deficit) being excess of Income over Expenditure (A - B)		4393619	-58330570
Transfer to Special Reserve (Specify each)		-	-
Transfer to / from General Reserve		-	-
BALANCE BEING SURPLUS /(DEFICIT) CARRIED TO CORPUS FUND		**4393619**	**58330570**
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**	**A.K. DUBEY**
(PARTNER, F.C.A)	(Finance & Accounts Officer)	(Registrar)	(Acting Director)

Date : 07-07-2010
Place : Dehradun

WADIA INSTITUTE OF HIMALAYAN GEOLOGY, DEHRA DUN

RECEIPTS & PAYMENTS ACCOUNT
(FOR THE YEAR ENDED 31st MARCH 2010)

(Amt in Rs…)

Particulars	Schedule	Current Year	Previous Year
RECEIPTS			
Opening Balance	24	6499487	6838252
Grants - in - Aids	26	265750000	156200000
Grants - in - Aids/Other Receipts (Ear Marked)	27	1398860	713080
Loan & Advances	28	75689250	50153527
Loan & Advances (Ear Marked)	31	-	52560
Fees/Subscription	14	20000	33435
Income from Investments	15	801972	548238
Income from Royalty, Publication etc.	16	93499	55055
Interest earned on Loan to Staff	17	4045154	2825539
Other Income	18	1481952	1757809
Investment (L/C Margin Money)	34	17500000	27500000
		373280174	**246677495**
PAYMENTS			
Establishment Expenses	20	144312747	106628784
Other Administrative Expenses	21	29361294	33249995
Expenditure on Grant/Subsidies Etc.	22	-	-
Interest/ Bank Charges	23	2198	5929
Loans & Advances	29	68024498	47419325
Loans & Advances (Ear Marked)	32	394070	52570
Investment (L/C Margin Money)	35	53100000	17500000
Fixed Assets	36	49241824	34623411
Ear Marked Fund Expenses	33	497880	697994
Grant - in - Aid (Ear Marked) Refunded	30	-	-
Closing Balance	25	28345663	6499487
		373280174	**246677495**
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**	**A.K. DUBEY**
(PARTNER, F.C.A)	(Finance & Accounts Officer)	(Registrar)	(Acting Director)

Date : 07-07-2010
Place : Dehradun

AUDITOR'S REPORT

WADIA INSTITUTE OF HIMALAYAN GEOLOGY, 33, GMS ROAD DEHRADUN

SCHEDULE FORMING PART OF ACCOUNTS FOR THE YEAR ENDED 31ST MARCH 2010
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.

Sd/-	Sd/-	Sd/-
HARISH CHANDRA	**DINESH CHANDRA**	**A.K. DUBEY**
(Finance & Accounts Officer)	(Registrar)	(Acting Director)

Date : 7th July, 2010
Place : Dehradun

WADIA INSTITUTE OF HIMALAYAN GEOLOGY, 33, GMS ROAD DEHRADUN

SCHEDULE FORMING PART OF ACCOUNTS FOR THE YEAR ENDED 31ST MARCH 2010
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	531,00,000
	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 n on-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	1,60,79,102.00
	iv)	Stores, Spares and Consumables	- Nil -
b)	Expenditure in foreign currency		
	i)	Travel (for attending Seminar/Conference abroad)	2,94,476.00
	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. 2009-10 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 507,83,636.00 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. 5,30,000.00, however, the overhead charges accounted in the books of the Institute are Rs. 4,70,000.00. The difference of Rs. 60,000.00 is due to cheques in transit as on 31st March 2010.

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	ONGC PROJECT	14712	13471	28183
2	PBBD PROJECT	45812	41948	87760
3	LHZ (GP) PROJECT	31485	28830	60315
4	CSIR (VRV) PROJECT	26518	24282	50800
5	PBEKS PROJECT	86902	79576	166478
6	SEISIMICITY PROJECT	13050	11950	25000
7	EGMS PROJECT	441329	404119	845448
8	PGC PROJECT	36928	32663	69591
9	CSIR (KNK)	108701	99536	208237
	TOTAL	**805437**	**736375**	**1541812**

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.

13. 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, 2010 and the Income and Expenditure Account for the year ended on 31st March, 2010.

Sd/-	Sd/-	Sd/-
HARISH CHANDRA	**DINESH CHANDRA**	**A.K. DUBEY**
(Finance & Accounts Officer)	(Registrar)	(Acting Director)

Date : 7th July, 2010
Place : Dehradun

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